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EPRI

ALWR Policy and Summary of Top-Tier Requirements

Volume I Revision 2

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LIGHT WATER REACTOR

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Introduction

The U.S. utilities have completed an industry wide effort to establish the technical foundation for the design of the Advanced Light Water Reactor (ALWR). This effort, the ALWR Program, was managed for the U.S. electric utility industry by the Electric Power Research Institute (EPRI) and included participation and sponsorship of several international utility companies and close cooperation with the U.S. Department of Energy (DOE). The cornerstone of the ALWR Program is a set of utility design requirements which are contained in the ALWR Utility Requirements Document.

Purpose of the Utility Requirements Document

The purpose of the Utility Requirements Document is to present a clear, complete statement of utility desires for their next generation of nuclear plants. The Utility Requirements Document consists of a comprehensive set of design requirements for future LWRs. The requirements are grounded in proven technology of 40 years of commercial U.S. and international LWR experience. Furthermore, the utility design requirements build on this LWR experience base, correcting problems which existed in operating plants and incorporating features which assure a simple, robust, more forgiving design.

The anticipated uses of the Utility Requirements Document are threefold:

- Establish a stabilized regulatory basis for future LWRs which includes the NRC's agreement on resolution of outstanding licensing issues and severe accident issues, and which provides high assurance of licensability;

- Provide a set of utility design requirements for a standardized plant which are reflected in individual reactor and plant supplier certification designs;

- Provide a set of utility technical requirements which are suitable for use in an ALWR investor bid package for eventual detailed design, licensing and construction, and which provide a basis for strong investor confidence that the risks associated with the initial investment to complete and operate the first ALWR are minimal.

Scope of Requirements Document

The Utility Requirements Document covers the entire plant up to the grid interface. It therefore is the basis for an integrated plant design, i.e., nuclear steam supply system and balance of plant, and it emphasizes those areas which are most important to the objective of achieving an ALWR which is excellent with respect to safety, performance, constructibility, and economics. The document applies to both Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs).

The Utility Requirements Document is organized in three volumes. Volume I summarizes ALWR Program policy statements and top-tier utility requirements.

Volumes II and III present the complete set of top-tier and detailed utility requirements for specific ALWR design concepts. Volume II covers Evolutionary ALWRs. These are simpler, much improved versions of existing LWRs, up to 1350 MWe, employing conventional but significantly improved, active safety systems. Volume III covers Passive ALWRs, greatly simplified, smaller (i.e., reference size 600 MWe) plants which employ primarily passive means (i.e., natural circulation, gravity drain, stored energy) for essential safety functions. Two passive design concepts are addressed in Volume III, the Passive BWR with pressure suppression containment and the loop-type Passive PWR with dry containment. These Volume III concepts extensively utilize existing LWR experience and Evolutionary ALWR utility requirements and are expected to offer substantial advantages in constructibility and operability, as well as the potential to surpass the very high ALWR safety standards.

In addition to the above Volume II and III ALWR concepts, there may be other design concepts which could be developed to meet ALWR Program objectives. Such design concepts are, however, not explicitly addressed in the Utility Requirements Document.

ALWR Policies

The ALWR Program formulated policies in a number of key areas in order to provide guidance for overall Utility Requirements Document development, and to provide guidance to the Plant Designer in applying the requirements. While not design requirements themselves, the policies cover fundamental ALWR principles which had a broad influence on the development of the design requirements. A summary of key policy statements is as follows:

Simplification - Simplification is fundamental to ALWR success. Simplification opportunities are to be pursued with very high priority and assigned greater importance in design decisions than has been done in recent, operating plants; simplification is to be assessed primarily from the standpoint of the plant operator.

Design Margin - Like simplicity, design margin is considered to be of fundamental importance and is to be pursued with very high priority. It will be assigned greater importance in design decisions than has been done in recent, operating plants. Design margins which go beyond regulatory requirements are not to be traded off or eroded for regulatory purposes.

Human Factors - Human factors considerations will be incorporated into every step of the ALWR design process. Significant improvements will be made in the main control room design.

Safety - The ALWR design will achieve excellence in safety for protection of the public, on-site personnel safety, and investment protection. It places primary emphasis on accident prevention as well as significant additional emphasis on mitigation. Containment performance during severe accidents will be evaluated to assure that adequate containment margin exists.

Design Basis Versus Safety Margin - The ALWR design will include both safety design and safety margin requirements. Safety design requirements (referred to as the Licensing Design Basis [LDB]) are necessary to meet the NRC's regulations with conservative, licensing-based methods. Safety margin requirements (referred to as the Safety Margin Basis [SMB]) are Plant Owner-initiated features which address investment protection and severe accident prevention and mitigation on a best estimate basis.

Regulatory Stabilization - ALWR licensability is to be assured by resolving open licensing issues, appropriately updating regulatory requirements, establishing acceptable severe accident provisions, and achieving a design consistent with regulatory requirements.

Standardization - The ALWR utility requirements will form the technical foundation which leads the way to standardized, certified ALWR plant designs.

Proven Technology - Proven technology will be employed throughout the ALWR design in order to minimize investment risk to the plant owner, control costs, take advantage of existing LWR operating experience, and assure that a plant prototype is not required; proven technology is that which has been successfully and clearly demonstrated in LWRs or other applicable industries such as fossil power and process industries.

Maintainability - The ALWR will be designed for ease of maintenance to reduce operations and maintenance costs, reduce occupational exposure, and to facilitate repair and replacement of equipment.

Constructibility - The ALWR construction schedule will be substantially improved over existing plants and must provide a basis for investor confidence through use of a design-for-construction approach, and completed engineering prior to initiation of construction.

Quality Assurance - The responsibility for high quality design and construction work rests with the line management and personnel of the Plant Designer and Plant Constructor organizations.

Economics - The ALWR plant will be designed to have projected busbar costs that provide a sufficient cost advantage over the competing baseload electricity generation technologies to offset higher capital investment risk associated with nuclear plant utilization.

Sabotage Protection - The design will provide inherent resistance to sabotage and additional sabotage protection through plant security and through integration of plant arrangements and system configuration with plant security design.

Good Neighbor - The ALWR plant will be designed to be a good neighbor to its surrounding environment and population by minimizing radioactive and chemical releases.

ALWR Top-Tier Design Requirements

A brief summary of top-tier utility design requirements is provided in Table 1 for the ALWR. The top-tier utility design requirements are categorized by major functions, including safety and investment protection, performance, and design process and constructibility. There is also a set of general utility design requirements, such as simplification and proven technology, which apply broadly to the ALWR design, and a set of economic goals for the ALWR program. The top-tier utility design requirements are described further in Volume I and are formally invoked as utility requirements in Volumes II and III. These requirements reflect the ALWR Program policies described above and form the basis for developing the detailed system design requirements for specific ALWR concepts in Volumes II and III. Figure 1 shows the relationship of Volumes I, II, and III.

ALWR Implementation

Assuring that the role of the Utility Requirements Document is understood and is successfully carried out depends on an understanding of the relationship between the various activities which comprise ALWR implementation. Accordingly, implementation scenarios for the Evolutionary and Passive ALWRs have been developed. Though uncertainties remain, these scenarios are plausible enough to provide reasonable understanding of the relationships noted above. A key assumption in the implementation scenarios is that increasing demand for electricity in combination with concerns over the environment and greenhouse gas effects associated with fossil fuel burning will result in significant improvements in political and public acceptance of nuclear power in the U.S. The implementation scenarios are also based on the ALWR policy that a prototype plant is not required. Figure 2 shows the major milestones in the Evolutionary and Passive ALWR implementation scenarios.

Table 1. Summary of Top-Tier ALWR Plant Design Requirements

GENERAL UTILITY DESIGN REQUIREMENTS

Plant type and size	PWR or BWR, applicable to a range of sizes up to 1350 MWe • Reference size for Evolutionary ALWR: 1200-1300 MWe per unit; • Reference size for Passive ALWR: 600 MWe per unit.
Safety system concept	Simplified safety system concepts: • Evolutionary ALWR - simplified, improved active systems; • Passive ALWR - primarily passive systems; safety-related ac electric power shall not be required.
Plant design life	60 years
Design philosophy	Simple, rugged, high design margin, based on proven technology; no power plant prototype required.
Plant siting envelope	Must be acceptable for most available sites in U.S.; 0.3g Safe Shutdown Earthquake (SSE).

SAFETY AND INVESTMENT PROTECTION

Accident resistance	Design features that minimize the occurrence and severity of initiating events, such as: • Fuel thermal margin $\geq$ 15%; • Slower plant response to upset conditions through features such as increased coolant inventory; • Use of best available materials.
Core damage prevention	Design Features that prevent initiating events from progressing to the point of core damage.
Core damage frequency	Demonstrate by PRA that core damage frequency is less than 10^{-5} per reactor year.

Table 1. Summary of Top-Tier ALWR Plant Design Requirements (Continued)

SAFETY AND INVESTMENT PROTECTION (Continued)

• LOCA protection	No fuel damage for up to a 6-inch break
• Station blackout coping	8 hours minimum (indefinite for Passive ALWR) time for core cooling
• Operator action	For passive ALWR, no core protection regulatory limits exceeded for at least 72 hours assuming no operator action for LDB events including loss of all power.
Mitigation	
• Severe accident frequency and consequence	Demonstrate by PRA that the whole body dose is less than 25 rem at the site boundary for severe accidents with cumulative frequency greater than 10^{-6} per year.
• Containment Design	Large, rugged containment building with design pressure based on Licensing Design Basis pipe break.
• Containment Margin	Margin in containment design is sufficient to maintain containment integrity and low leakage during severe accident.
• Licensing source term	Similar in concept to existing Regulatory Guide, TID 14844 approach, but with more technically correct release fractions release timing, and chemical form.
• Hydrogen control to ensure containment integrity under hydrogen burn	Control concentration to less than 10% in PWR containment for 100% active clad oxidation
• Emergency planning	For Passive ALWR, provide technical basis for simplification of off-site emergency plan.

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Table 1. Summary of Top-Tier ALWR Plant Design Requirements (Continued)

PERFORMANCE

Design availability	87%
Refueling interval	24-month capability
Unplanned automatic scrams	Less than 1/year
Maneuvering	Daily load follow
Load rejection	Loss of load without reactor trip or turbine trip for PWR (from 100% power) and for BWR (from 40% power).
Low level radio active waste	Based on best current plants
Site spent fuel wet storage	10 years of operation plus one core off load
Occupational radiation	Less than 100 person rem per year
Operability and Maintainability	
• Design for operation	Operability features designed into plant, such as: forgiving plant response for operators, design margin, and operator environment.
• Design for Maintenance	Ready access to equipment.
• Equipment Access	Facilitate replacement of components, including steam generators.
Man-Machine Interface	
• Instrumentation and Control Systems	Advanced technology, including software based systems, control systems alarm prioritization, fault tolerance, automatic testing, multiplexing, and computer driven displays.
• Operation Simplicity	A single operator able to control plans during normal power operation.
• Control Stations	Human engineered to enhance operator effectiveness, utilizing mockups, dynamic simulation, and operator input to design.

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Table 1. Summary of Top-Tier ALWR Plant Design Requirements (Continued)

DESIGN PROCESS AND CONSTRUCTIBILITY

Total time from owner commitment to construct to commercial operation	1300 MWe evolutionary plant designed for less than or equal to 72 months 600 MWe passive plant designed for less than or equal to 60 months
Construction time from first structural concrete to commercial operation	1300 MWe evolutionary plant designed for less than or equal to 54 months 600 MWe passive plant designed for less than or equal to 42 months
Design status at time of initiation of construction	90% complete
Design and plan for construction	Design for simplicity and modularization to facilitate construction; develop an integrated construction plan through Plant Owner acceptance.
Design Process	
• Design integration	Manage and execute design as a single, integrated process.
• Configuration management	Comprehensive system to control plant design basis and installed equipment and structures.
• Information management	Computerized system to generate and utilize an integrated plant information management system during design, construction and operation.

Table 1. Summary of Top-Tier ALWR Plant Design Requirements (Continued)

ECONOMICS

Cost goal	ALWR plant will have a sufficient cost advantage over competing baseload electricity generation technologies to offset a higher capital investment risk associated with nuclear plant utilization.
Resulting quantified cost goals	Levelized January 1994 constant dollars for a 30-year capital amortization period, plant startup in 2005, and a mid-range-cost, and a U.S. location (Kenosha, Wisconsin).
• Median busbar cost	Sufficiently less than 43 mills/KWh to offset the higher capital investment risk associated with nuclear plant utilization.
• Uncertainty	Projected 95th percentile non-exceedence cost substantially less than 53 mills/KWh both to offset a higher capital investment risk associated with nuclear plant construction and to recognize that cost uncertainties with alternative generating technologies will decrease with time.

Figure 1. RELATIONSHIP OF THE THREE VOLUMES OF THE ALWR REQUIREMENTS DOCUMENT

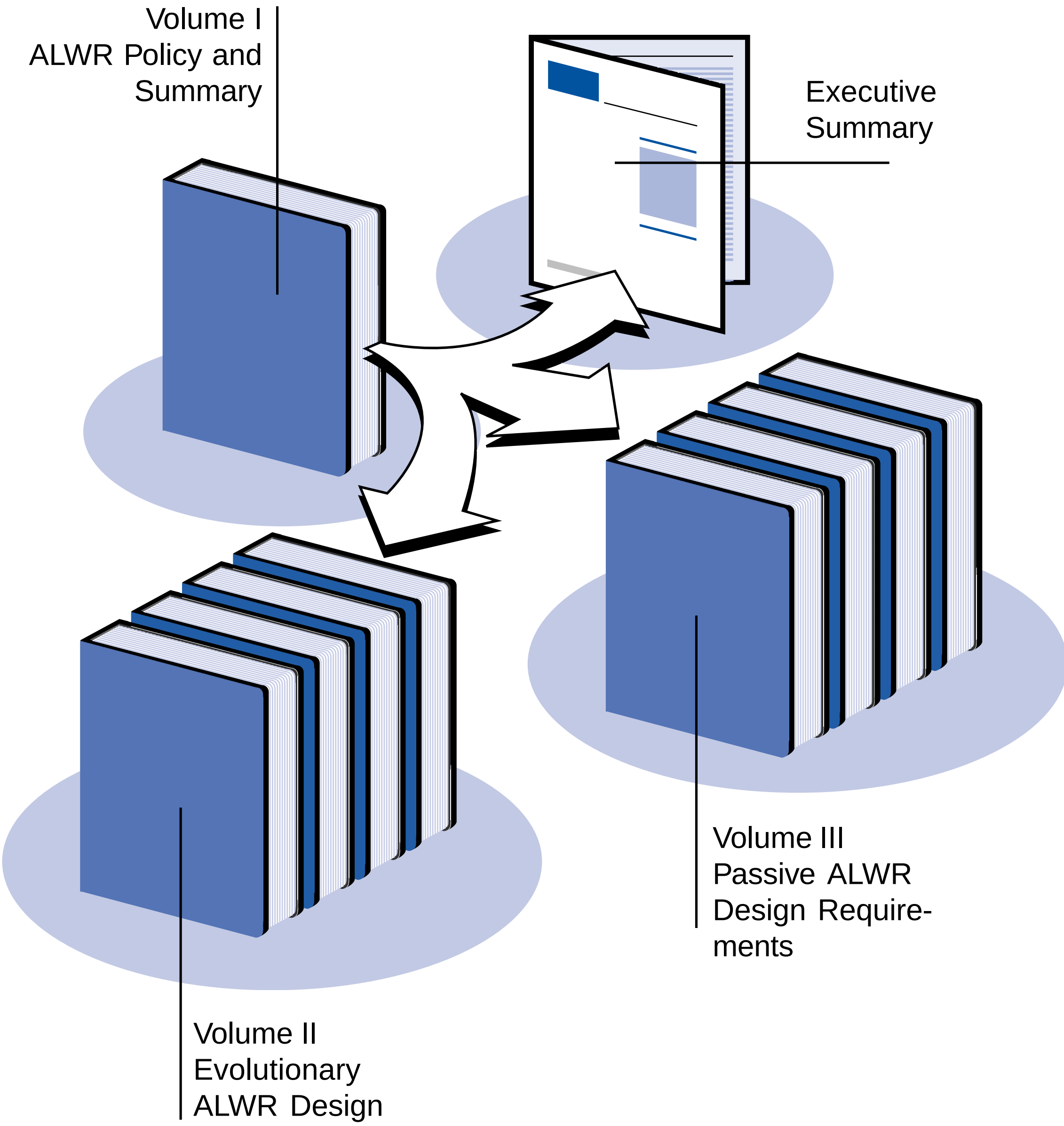
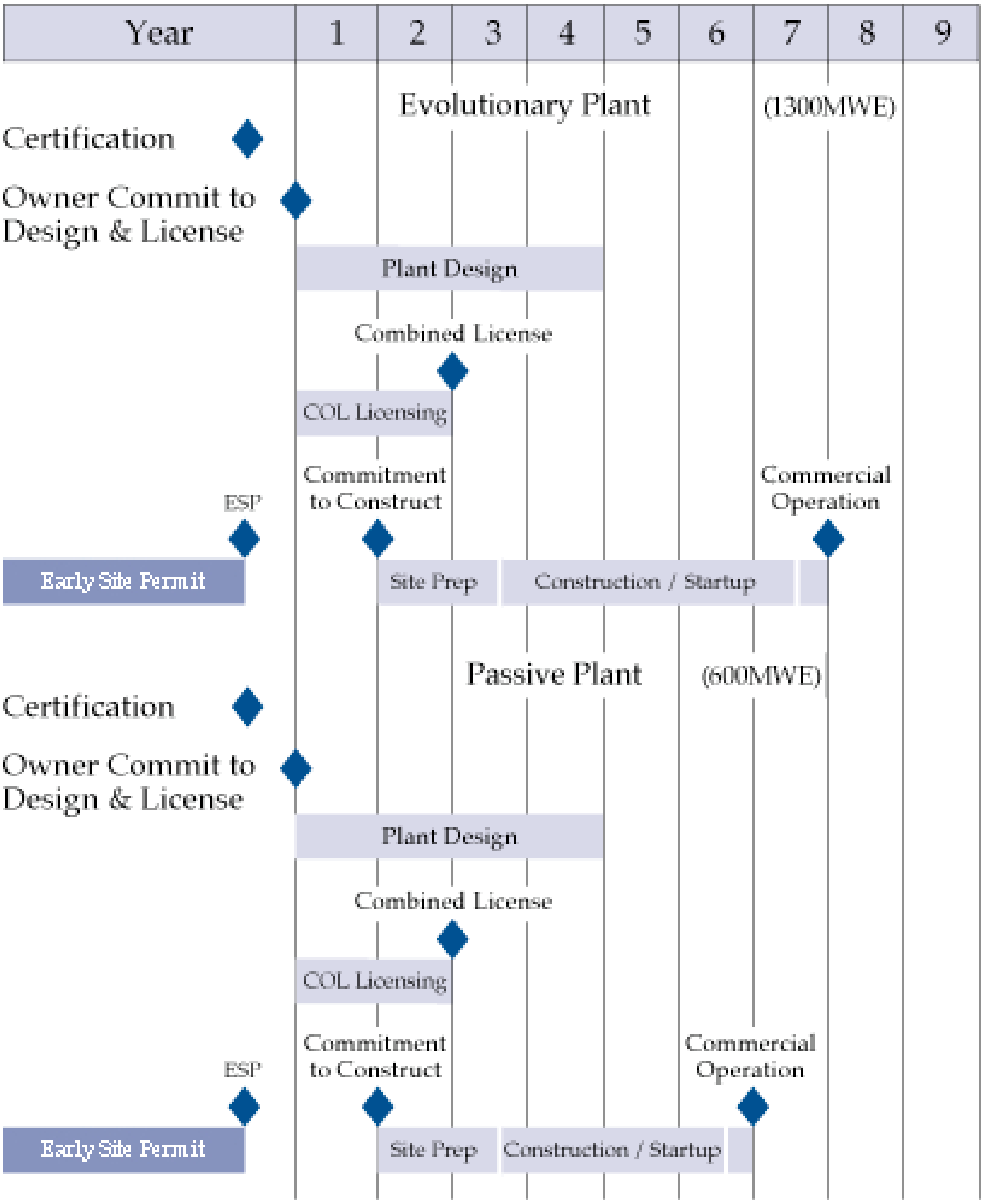


Figure 2. PLAUSIBLE ALWR IMPLEMENTATION SCENARIO



Targets:

Nuclear Power Group Full Purchase

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1 INTRODUCTION

1.1 ALWR PROGRAM

During the last two decades, the U.S. utilities have been leading an industry-wide effort to establish a technical foundation for the design of the next generation of light water reactors in the United States. Since 1985, this utility initiative has been affected through a major technical program managed by the Electric Power Research Institute (EPRI): the U.S. Advanced Light Water Reactor (ALWR) Program.

In addition to the U.S. utility leadership and sponsorship, the ALWR Program also had the participation and sponsorship of several international utility companies and close cooperation with the U.S. Department of Energy (DOE).

The main purpose of the ALWR Program was to develop a comprehensive set of design requirements for the advanced LWR. These design requirements are in the form of a Requirements Document which defines the technical basis for improved and standardized future LWR designs. This effort was necessary so that when new electricity generating plants are needed, the nuclear option will be fully viable and able to meet its share of the nation’s energy demands.

The ALWR Program was organized to make extensive use of the extraordinary data base of information and lessons learned from 40 years of experience in operating over 100 light water reactor power plants in the U.S. and many more overseas. This operating experience comprises over 1700 reactor years in the U.S. and over 5000 reactor years world wide. The light water reactor is the design technology used for every operating U.S. commercial power reactor and for over 70 percent of nuclear power plants in the world.

The overall direction of the Program was provided by a Utility Steering Committee, consisting of senior executives from about 20 U.S. and foreign utilities. EPRI organized an ALWR Program Office which acted as staff to this committee. The Program Office, in turn, established contracts with U.S. nuclear steam supply system vendors, as well as engineering service, consulting, architect-engineer, and construction companies. As a result, the ALWR requirements are driven by utilities, but have also had the benefit of participation of a broad range of industry participants. Thus the requirements are essentially a consensus of the industry as to those features which should be sought in the next generation of plants.

In addition, the ALWR Program had important interfaces in the following key areas:

- The U.S. Nuclear Regulatory Commission (NRC) was directly involved in the ALWR Program. The Utility Steering Committee and its EPRI staff worked with the NRC to identify and resolve outstanding licensing issues. This effort was closely linked to the preparation of the ALWR Requirements Document, and the results were incorporated therein. Further, the NRC formally reviewed the Requirements Document and prepared an SER on the requirements for each type of ALWR.

- The DOE sponsored plant design certification efforts for advanced LWRs. The certification efforts and their supporting technology programs were closely coordinated with the ALWR Program to assure that vendor submittals to the NRC were consistent with the ALWR Requirements Document. Further, an agreement was established between DOE, EPRI, and the certification applicants to facilitate the interface between the individual vendor certification designs and the utility design requirements for the Passive ALWR. DOE also sponsored the Advanced Reactor Severe Accident Program (ARSAP) which provided technical support to the ALWR Program in resolving severe accident issues.

These interfaces assured that the regulators, designers, constructors, U.S. and international utilities, and DOE sponsors worked together to obtain a fully integrated design which met the ALWR requirements for improved safety, performance, constructibility, and economics.

1.2 OBJECTIVES AND SCOPE OF ALWR REQUIREMENTS DOCUMENT

1.2.1 Objectives of the ALWR Program

The objectives of the ALWR Program were as follows:

- Provide a comprehensive set of design requirements for future LWRs which is based upon proven technology from 30 years of commercial LWR experience. At the same time, these requirements will provide improved versions of the LWR that eliminate existing design, construction, and operational problems, and assure a simpler, more forgiving plant design which is excellent in all respects, including safety, performance, constructibility, and economics.

- Provide a stabilized regulatory basis for future LWRs by resolving outstanding licensing issues, defining changes to regulatory requirements which will make the regulations more appropriate for the ALWR, and specifying design requirements which provide acceptable severe accident prevention and mitigation.

- Support the development of ALWR plant concepts which have high potential for successful application in the U.S. and around the world, and which meet the fundamental policies of the ALWR Program.

1.2.2 Applicability and Scope of the Utility Requirements Document

The ALWR Requirements Document addresses the entire plant, including nuclear steam supply system and balance of plant, up to the interface with the utility grid at the distribution side of the circuit breakers which connect the switchyard to the transmission lines. Addressing the entire plant is considered necessary based on utility experience with existing plants. The main focus of the requirements and commensurate level of detail is on those areas where improvements were necessary to achieve an excellent power plant.

Two ALWR types are currently addressed in the Requirements Document: the Evolutionary ALWR and the Passive ALWR. The Evolutionary ALWR is viewed as the next step in evolving LWR technology. Two specific Evolutionary ALWR plant concepts are included in the Requirements Document: the Evolutionary BWR with pressure suppression containment and the Evolutionary PWR with dry containment. The Evolutionary ALWR is a simpler, substantially improved version of existing LWRs, which employs active safety systems and incorporates lessons learned from 40 years of design, construction, and operational experience. Consistent with the existing regulatory framework, the Evolutionary ALWR is intended to be available for commercial operation prior to year 2005, utilizing proven designs from several U.S. vendors which are well along in efforts to certify designs with the NRC.

The Passive ALWR is a further advancement in LWR technology. Two specific Passive ALWR plant concepts are included in the Requirements Document: the Passive BWR with pressure suppression containment and the loop-type Passive PWR with dry containment. While not as mature as the Evolutionary ALWR, these concepts build heavily on existing LWR experience, and the Evolutionary ALWR design requirements provide a technical foundation for these passive designs. The plants employ passive safety systems for core and containment cooling, relying on phenomena such as gravity drain and natural circulation. These systems are expected to be simpler to operate and maintain than active systems since the passive systems have fewer active components and supporting systems. This simplicity, together with smaller size and advanced construction techniques, provide the potential for great improvements in construction and operation compared to current plants. From a safety standpoint, these passive concepts have the potential to surpass the very high ALWR Program safety standards as well as those established by the NRC for advanced reactor designs. Furthermore, the smaller size expected to be optimum for these passive concepts appears to fit well with the longer term needs of many U.S. and international utilities.

In addition to the above ALWR plants, there are other design concepts which could be developed in a way which might meet the ALWR Program objectives. Such designs might include hybrid designs (i.e., plants licensed on the basis of a combination of active and passive safety systems) and integral reactors. Detailed requirements were not developed for these other concepts.

As noted above, the Requirements Document applies to ALWRs with either Boiling Water Reactor (BWR) or Pressurized Water Reactor (PWR) designs. Based on the successful experience of both BWR and PWR systems worldwide together with the fact that there is significant commonality between them, it was considered reasonable and appropriate to cover both with the same document. Certain individual requirements apply only to one type or the other. These are clearly identified. Unless an individual item is identified as applicable to only one of these two types, it is applicable to both.

The ALWR requirements specify a complete single unit (i.e., stand alone) regardless of whether there are other units on the same site. The Requirements Document generally does not allow sharing of common facilities inside the standard plant envelope.

Requirements on processing of low level radioactive waste at the plant site and spent fuel storage requirements are included in the Requirements Document. Off-site waste disposal is not covered since it is beyond the scope of the ALWR Program.

Finally, since it is a top-tier design requirement that the ALWR will not require a power plant prototype, it follows that any plant design concepts which would require a prototype are outside the scope of the Requirements Document.

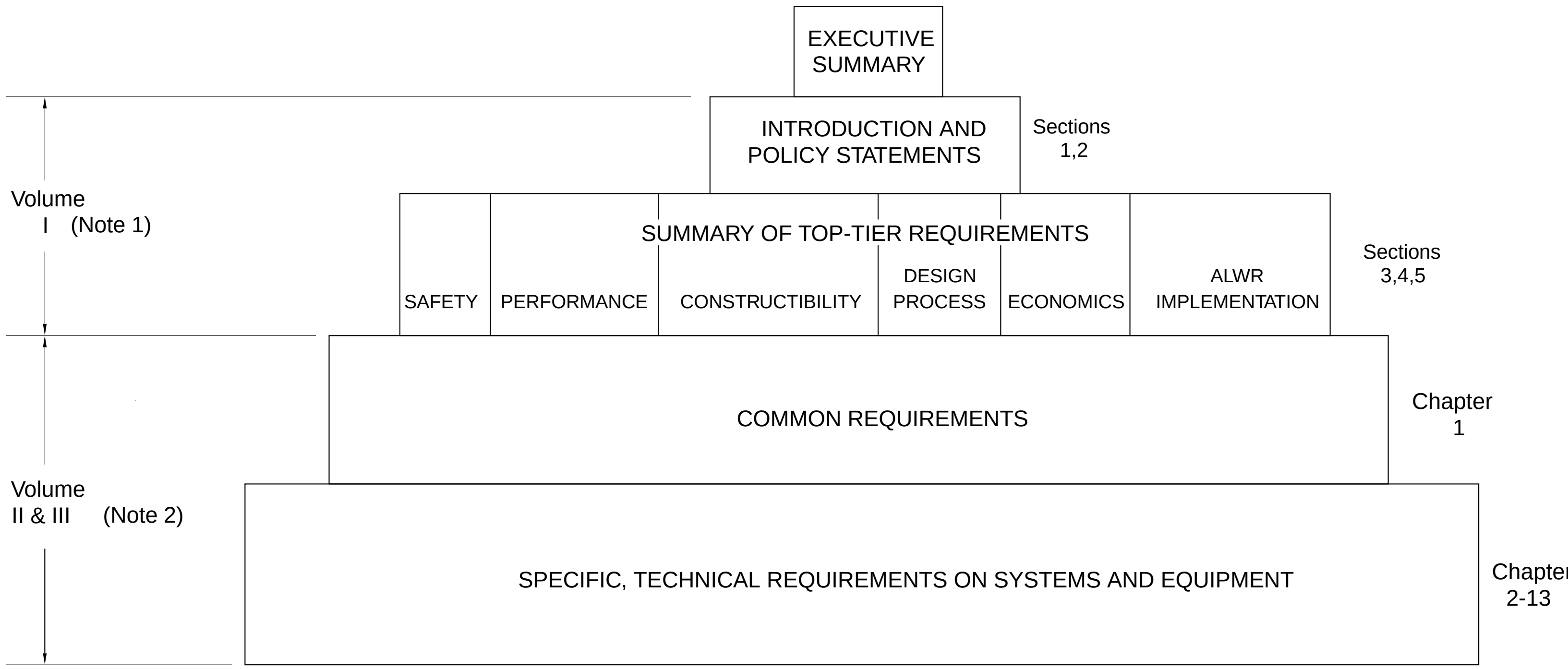
1.2.3 Structure of the Utility Requirements Document

This section describes the organization of the ALWR Requirements Document and the general approach which was taken in preparing the document.

1.2.3.1 Organization of the Requirements Document

A systematic approach was taken in developing and organizing the requirements. An overall illustration of the structure of the document is provided in Figure 1.

FIGURE 1 ALWR UTILITY REQUIREMENTS DOCUMENT ORGANIZATION



Note 1: Policy Statements and Summary of Top-Tier Requirements for all ALWRs

Note 2: Technical Requirements (Volume II - Evolutionary ALWR, Volume III - Passive ALWR)

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

Volume I of the document defines ALWR Program policy and summarizes top-tier design requirements. The policy statements provide utility positions on key aspects of design, development, and ALWR Program implementation. The top-tier design requirements were the key elements in meeting ALWR Program objectives to make available a viable nuclear power generation option for the 1990’s and beyond. They are also the requirements which have the greatest impact on the overall design. The top-tier design requirements form the basis for developing the detailed requirements in subsequent volumes for specific plant concepts.

Volume I is written in a narrative format (versus the requirements—rationale format used in Volumes II and III as described below) in order to present the policies and top-tier requirements in a more compact manner. Also included in Volume I is a section which defines ALWR cost goals to assure that the ALWR is economically competitive with other generation alternatives. Finally, a section is included on ALWR implementation, including certification, design, and construction. This section is not a requirement but rather provides plausible scenarios for ALWR implementation. A list of acronyms is in Appendix A and a glossary of commonly used terms is in Appendix B of Volume I.

The second and third volumes of the Requirements Document contain the complete set (top-tier and detailed) of design requirements for the Evolutionary and Passive ALWRs, respectively. Each of these volumes contains 13 chapters. Chapter 1 of each volume defines common requirements applicable to a number of plant systems. These requirements have been organized into one chapter to avoid repetition in the subsequent chapters.

Chapters 2 through 13 of Volumes II and III have been organized by groups of systems to cover the entire nuclear plant. Each chapter covers a number of related systems.

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

The titles of each of the 13 chapters in Volumes II and III are as follows:

Chapter	Title
1	Overall Requirements
2	Power Generation Systems
3	Reactor Coolant System and Reactor Non-safety Auxiliary Systems
4	Reactor Systems
5	Engineered Safety Systems
6	Building Design and Arrangement
7	Fueling and Refueling
8	Plant Cooling Water Systems
9	Site Support Systems
10	Man-Machine Interface Systems
11	Electric Power Systems
12	Radioactive Waste Processing Systems
13	Turbine Generator Systems

1.2.3.2 Requirement/Engineering Rationale Approach

The design requirements specified in the ALWR Requirements Document are organized in a side-by-side format which provides an engineering rationale for each requirement. The requirements define utility positions on the means for resolving problems in design, construction, and operation of current plants and for meeting the ALWR Program objectives. The rationale presents the basis for the requirement and provides later users of the document a better understanding of the requirement and its intent.

Volume I and the introductions to various sections of Volumes II and III include narrative text which is not in the side-by-side format. This narrative text typically states ALWR policy or necessary background. Although not strictly considered to be plant design requirements in the same sense as the side-by-side format, the narrative text should also be carefully reviewed by the users of the Requirements Document to assure understanding of ALWR policy and to provide perspective on program background or section scope.

1.2.3.3 Explanation of Requirement Terminology

This document establishes utility design requirements. These requirements are mandatory features and attributes of the ALWR design which are necessary to satisfy the Plant Owner that the plant will be excellent in all respects. By definition then, requirements are directed at the plant design team, i.e., the Plant Designer, and compliance with them should be demonstrable at the time that the detailed ALWR design is completed. Requirements are intended to be challenging, yet achievable.

It was the intent of the ALWR Program to provide a set of compatible requirements which result in an integrated design which meets overall ALWR program objectives. The Requirements Document should not be considered as a set of requirements to be selected and chosen from. Rather it is meant to be invoked as an integrated set of requirements which establish the plant design basis for the Plant Designer.

There are a number of very desirable plant characteristics which are established as design requirements but are in areas which pertain to factors beyond the Plant Designer's complete control, such as volume of radioactive waste produced, plant construction schedule, and plant availability. In these cases, the intent was to require the Plant Designer to develop a plant design for which the stated characteristic can be achieved by a competent and professional constructor and owner/operator organization. The ability of the design to support achievement of the stated characteristic should be demonstrable by the Plant Designer.

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

2 ALWR PROGRAM POLICY STATEMENTS

The ALWR Program Utility Steering Committee set policy in key areas which are central to achievement of program objectives and which have broad, fundamental influence on plant design requirements. These policy areas tend to be pervasive ones which the utility sponsors consider important to correcting problems (e.g., plant simplification) in existing plants or to be ones which explain fundamental ALWR guiding principles (e.g., use of proven technology). The policy statements are not considered design requirements by themselves, but rather influence or form the foundation for a set of requirements. The policy statements included in Section 2 are as follows:

- Simplification
- Design Margin
- Human Factors
- ALWR Safety
- ALWR Design Basis Versus Safety Margin
- Regulatory Stabilization
- Plant Standardization
- Use of Proven Technology
- Maintainability
- Constructibility
- Quality Assurance
- ALWR Economics
- ALWR Sabotage Protection
- ALWR Good Neighbor

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

2.1 ALWR SIMPLIFICATION POLICY

It was ALWR Program policy to emphasize simplicity in all aspects of plant design, construction, and operation. Unnecessary complexity was considered to be a root cause of a wide range of problems in existing plants. Because of the fundamental importance of simplicity and the difficulty of accurately quantifying this importance, ALWR designs pursued simplification opportunities with very high priority and assigned greater importance to simplification in design decisions than had traditionally been done in recent, operating plants. Cost-benefit trade-offs reflect this greater importance.

Simplicity was incorporated in the ALWR design in many ways, particularly from the viewpoint of plant operations. ALWR simplification requirements include:

- Use a minimum number of systems, valves, pumps, instruments, and other mechanical and electrical equipment, consistent with essential functional requirements;
- Provide a man-machine interface which will simplify plant operation and reflect operator needs and capabilities.
- Provide system and component designs which assure that plant evolutions minimize demands on the operator during normal operation as well as transient and emergency conditions (e.g., minimizing system realignments to accomplish safety functions, segregation of safety and non-safety functions unless otherwise justified);
- Design equipment and arrangements which simplify and facilitate maintenance;
- Provide protective logic and actuation systems which are simplified compared to those in existing plants;
- Use standardized components to facilitate operations and maintenance;
- Design for ease and simplification of construction.

Because of the importance of simplicity in achieving an excellent power plant and the need for careful design trade-off decisions to maximize overall simplicity in the face of sometimes competing objectives, plant simplification was specified as an integral part of the design process.

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

2.2 ALWR DESIGN MARGIN POLICY

It was ALWR Program policy that significant margin be designed into the ALWR so as to make it a forgiving, rugged plant. Like simplicity, significant design margin was considered to be of fundamental importance to nuclear plant safety and economics, and it was ALWR policy to treat it accordingly in design trade-off decisions. Significant design margins will benefit the ALWR in the following ways:

- Provide designed-in capability to accommodate transients without causing initiation of engineered safety systems;
- Provide the operator significant time to assess and deal with upset conditions with minimum potential for damage;
- Provide margin to enhance system and component reliability and to minimize the potential of exceeding limits (e.g., technical specifications) which might require derating or shutdown;
- Provide additional assurance that the longer plant life requirement of 60 years can be met.

Areas in which design margin is emphasized in the ALWR design include fuel thermal margin, RCS hot leg temperature, coolant inventory, provisions for assuring availability of ac power, and requirements to assure high plant availability.

It is noted that the design margins resulted in designs which have the capability beyond regulatory requirements in various respects. It was ALWR policy that these margins be maintained and be available to the plant operator and not be eroded by regulatory requirements since this would result in unnecessarily stringent operating envelopes.

2.3 ALWR HUMAN FACTORS POLICY

The ALWR Program policy was to include human factors considerations in the design of ALWR systems, facilities, and equipment in a systematic manner. All aspects of plant design for which there is an interface with plant personnel incorporate human factors considerations. Human factors driven design features were applied consistently plant-wide. This includes those aspects of the design which affect:

- Monitoring, controlling, and protection functions assigned to plant operators;
- Monitoring and diagnostic functions performed by plant engineers and managers during normal, upset, and emergency conditions;
- Inspection, on-line and off-line surveillance testing, preventive maintenance, and corrective maintenance functions assigned to maintenance personnel.

To implement this policy, it was essential that there be early design participation by qualified, experienced operators and maintenance personnel and interaction of these personnel with human factors experts. The design process included techniques, such as mock-ups and simulators, to provide an environment in which experienced operators and maintenance personnel contributed to the design. Also, operating experience from existing LWRs were reviewed and considered in order to minimize human performance problems. Man-machine interface systems employ modern digital technology. In particular, the main control room utilizes an advanced control concept in which integrated displays, alarms, procedures, and controls are available to the operators at a compact workstation.

2.4 ALWR SAFETY POLICY

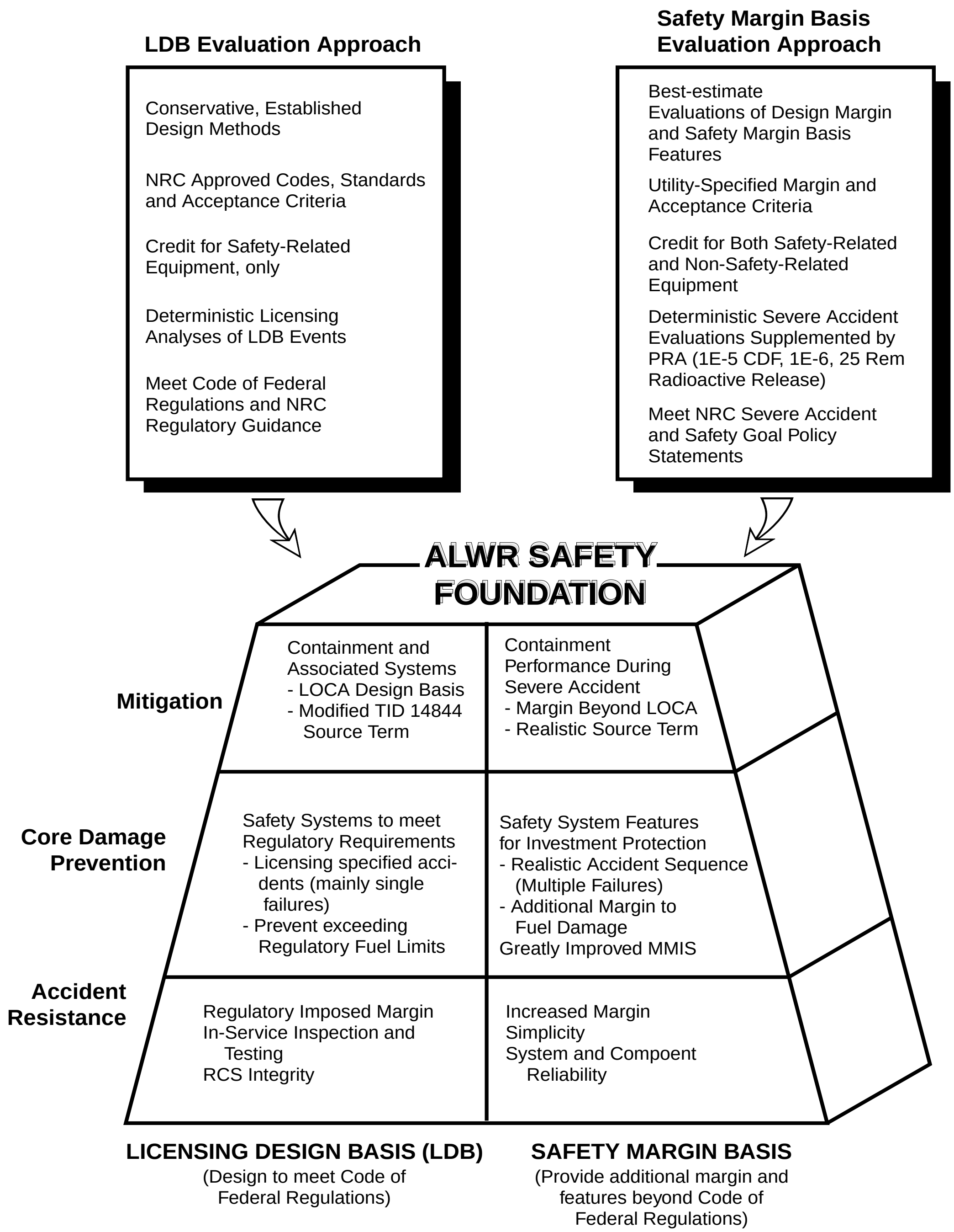
The ALWR safety policy was that there will be excellence in safety both to protect the general public and to assure personnel safety and plant investment protection. The primary emphasis was on accident prevention (which includes accident resistance and core damage prevention); this approach is the best way to achieve plant owner investment protection and is also considered to be the best way to achieve improved overall safety. Emphasis was also placed on mitigation of the consequence of potential accidents so that a balanced approach to safety was achieved.

This policy of excellence in safety was implemented through an integrated design approach to safety which included three overlapping levels of safety protection, i.e., accident resistance, core damage prevention, and mitigation, and which utilized a deterministic analysis framework supplemented by probabilistic risk assessment (PRA). These levels of safety protection incorporate the philosophy of defense-in-depth. Figure 2 illustrates the three levels of safety protection and important example design requirements for each. The ALWR Safety Foundation, depicted in Figure 2, is discussed further in Section 2.5.

The first level of protection, and the cornerstone of ALWR safety as shown in Figure 2, is accident resistance. Accident resistance was designed into the ALWR in order to minimize the frequency and severity of initiating events which could challenge safety.

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

FIGURE 2 - ALWR SAFETY FOUNDATION



The second level of protection is provided by core damage prevention. Core damage prevention includes systems and features which provide high confidence that initiating events which do occur will not progress to the point of core damage. ALWR policy on core damage prevention was to establish a challenging, quantitative requirement (core damage frequency [CDF] < 10^{-5} per reactor year) in order to provide investment protection for the Plant Owner. It was also ALWR policy to provide dedicated safety systems which, together with accident resistance, assure that this core damage frequency requirement and regulatory requirements can be met. The policy also requires that a PRA be carried out to confirm that the 10^{-5} requirement is achieved and to provide feedback to the Plant Designer.

ALWR policy on accident mitigation was to establish a challenging, quantitative requirement on mitigation (whole body dose less than 25 rem at the site boundary [about 0.5 miles from the reactor] for accident sequences with cumulative frequency greater than 10^{-6} per year) and to provide conservative, rugged containment systems to meet this requirement and regulatory requirements. This 10^{-6}, 25 rem requirement provides considerable margin to the NRC safety goal. The PRA was also used to confirm that the 10^{-6}, 25 rem requirement is met.

With regard to severe accidents, ALWR policy was to assure that adequate severe accident protection exists through the integrated safety approach described above. This approach assures that the NRC Severe Accident Policy and Safety Goal Policy are met. This was accomplished by providing plant features and processes which assure that severe accident sequences which could lead to containment failure are prevented through engineered means and thus are very remote in probability. Further, containment performance requirements were defined and best-estimate evaluations of those severe accident sequences which survive a sequence screening process were performed to assure that adequate containment margin exists.

2.5 ALWR POLICY ON DESIGN BASIS VERSUS SAFETY MARGIN

The ALWR Safety Policy above describes the integrated approach to safety with the three overlapping levels of safety protection. Each of these levels of safety protection is divided into a Safety Design Basis and a Safety Margin Basis, as depicted in Figure 2. The Safety Design Basis, henceforth referred to as the Licensing Design Basis (LDB), is the set of ALWR safety design requirements which are necessary to satisfy the NRC's requirements, including LDB transient and accident events, in the Code of Federal Regulations and associated regulatory guidance. The required analyses were done with the strict, conservative, NRC approved calculation methods and assumptions and met NRC-mandated acceptance criteria. Only safety-related equipment was assumed to be available for purposes of meeting regulatory limits for LDB transients and accident events with the exception of a limited number of multiple failure events such as ATWS and station blackout where credit for non-safety-related equipment is allowed.

The Safety Margin Basis (SMB) contains ALWR design requirements which provide margin beyond the minimum required by the Code of Federal Regulations, thereby providing additional safety assurance. The SMB requirements have been defined at the initiative of the Plant Owner in order to increase investment protection and severe accident protection. The increased investment protection addresses the utility desire to minimize financial risk and also improves safety by improving accident prevention. The severe accident protection incorporates the NRC's policy level guidance and provides increased assurance of containment integrity and low leakage of radioactivity during a severe accident.

The LDB Evaluation Approach and the SMB Evaluation Approach (see Figure 2) are the methods, criteria and assumptions which were used by the Plant Designer in analyzing those portions of the ALWR design which are required to meet the LDB and SMB, respectively. The main distinction between the LDB Evaluation Approach and the SMB Evaluation Approach is the fact that the former requires conservative, NRC-specified design methods and acceptance criteria. The methods and criteria generally are subject to rigorous demonstration through peer review and testing. The SMB Evaluation Approach, on the other hand, is a best-estimate evaluation which, in the case of containment performance, for example, confirms the adequacy of the margin for severe accidents.

Although defined at the initiative of the Plant Owner, the SMB is the means for satisfying the NRC's policy level guidance for severe accidents and safety goals. Thus, the NRC's review of portions of the SMB and its associated Evaluation Approach allowed confirmation that the Commission policies were met. These portions of the SMB, which the NRC reviewed, include containment performance during a severe accident, the realistic source term to be used for severe accident dose evaluations, and the PRA and its risk results.

2.6 ALWR REGULATORY STABILIZATION POLICY

The ALWR Regulatory Stabilization Policy was to achieve high assurance of licensability, including having no unresolved licensing issues. The policy was implemented by the process illustrated in Table 1 and described below.

- The ALWR Program worked directly with the NRC to resolve outstanding licensing issues and to incorporate the issue resolutions into the Requirements Document. The NRC Safety Evaluation Report (SER) on the ALWR Requirements Document documents the NRC's agreement with these resolutions.

- Where considered necessary, the ALWR program proposed changes to existing NRC regulations or guidance in order to make them more appropriate for the ALWR. These changes are explicitly incorporated into the Requirements as "Optimization Issues." The SER serves as a record of the NRC staff's agreement to make such changes. The changes may have resulted in rulemaking activity, e.g., as part of the certification rulemaking, or the SER itself may represent new staff guidance where rule changes were not necessary.

- The ALWR Program took specific positions in areas for which regulatory guidance was unclear or still developing. For example, provisions were included in the Requirements Document to assure that the ALWR is acceptable from a severe accident prevention and mitigation standpoint.

- The ALWR design requirements were defined with the intent of meeting or exceeding applicable NRC regulations. Further, the Plant Designer was required to produce a design which was consistent with applicable NRC regulations and regulatory guidance, or with documented, acceptable alternatives to this guidance. Applicable NRC regulations are identified in Chapter 1, Appendix B, of Volumes II and III of the Requirements Document. The SERs establish the NRC's agreement that the ALWR requirements result in no actual or potential conflicts with NRC requirements.

Table 1. ALWR PROGRAM PROCESS TO ASSURE REGULATORY STABILIZATION

	ALWR PROGRAM ACTIONS	ASSOCIATED NRC ACTIONS IN SER	ASSOCIATED NRC ACTIONS IN CERTIFICATION RULE
1.	Resolution of outstanding licensing issues for ALWR.	Staff agreement of issue resolutions and to make changes to regulations as applied to ALWR	Non required
2.	Optimized Regulatory Requirements for ALWR.		
3.	Design requirements to address areas without regulatory guidance, including assuring adequate severe accident prevention and mitigation.	Clearly stated agreement that ALWR designs meeting these requirements are acceptable from a regulatory policy standpoint, including severe accidents.	Certify that ALWR designs which meet these requirements are acceptable from a regulatory policy standpoint, including severe accidents.
4.	Make design requirements consistent with applicable NRC regulations and regulatory guidance, or with documented alternatives to this guidance. Require Plant Designer to be consistent with applicable regulations.	Clearly stated agreement that ALWR requirements do not result in any actual or potential conflicts with NRC requirements.	Certify that ALWR designs which meet the requirements also meet regulations.

2.7 ALWR PLANT STANDARDIZATION POLICY

The ALWR Program recognized the importance of standard designs and the historic problems associated with customized designs. Accordingly, the program developed design requirements intended to form the technical foundation which will lead the way to one or more standardized detailed designs. Key plant features were specified in sufficient detail in the Requirements Document to permit meaningful standardization.

An important step in achieving real, lasting standardization was to develop technical requirements which are industry and NRC consensus positions. This is an important supplement to standardization by regulation since it provides a commitment of plant designers, prospective owners, and the NRC to standardization design decisions. The ALWR Program was the means of achieving this industry and NRC consensus.

Although the ALWR does not address major institutional improvements in support of standardization, e.g., one-step licensing, the ALWR policy was to be fully supportive of and to maintain close linkage with efforts to implement 10CFR52 so no inconsistencies occur. Furthermore, plausible ALWR implementation scenarios discussed in Volume I, Section 5, utilize a one-step construction permit/operating license process. Finally, the ALWR program was closely coordinated with the DOE sponsored ALWR design certification effort.

2.8 ALWR PROVEN TECHNOLOGY POLICY

ALWR Program policy was that successful, proven technology be employed throughout the plant, including system and component designs, maintainability and operability features, and construction techniques. The intent was to utilize the large experience base from existing LWRs in order to minimize the risk to the plant owner, assure credibility and control of ALWR schedules and costs, and ensure that a power plant prototype is not required.

Proven technology was defined as structures, systems, components, and design and analysis techniques with the same characteristics and materials, working conditions, and environments as those which had been successfully demonstrated, preferably through several years of operation in existing LWRs. Many such requirements are stated explicitly in the Requirements Document, e.g., use of best available materials and water chemistry. In other areas the Plant Designer was to review existing data bases of LWR operating experience to identify both positive experience as well as causes of significant events and unplanned outages, and to incorporate appropriate features in the plant design. In this way the latest information was factored in and the design will reflect hard-won lessons.

The ALWR proven technology policy encouraged the use of advanced technology, e.g., digital man-machine interface systems, where there was a need to solve known LWR problems or an opportunity for simplification, and where the advanced technology was proven. Assuring that advanced technologies were sufficiently proven typically required testing and/or proven successful use in other applicable industries, e.g., fossil-fired power plants, process industries, etc.

2.9 ALWR POLICY ON PLANT MAINTAINABILITY

It was ALWR Program policy that the ALWR be designed from the outset to make the plant readily maintainable over its life. This included providing standardization of components, designing equipment to minimize maintenance needs, designing to reduce occupational exposure, and designing to facilitate those maintenance needs which existed. Such needs included activities to support inspection, test, repair, and replacement of equipment and systems over the plant life and assuring that adequate access, laydown space, tooling, and services were provided as part of the basic plant design. It also included consideration of the environment in which the maintenance activities are to be performed. It anticipated that the ALWR maintainability needs along with other requirements, such as constructibility and design margin, would require providing more space per kw than current LWRs.

2.10 ALWR CONSTRUCTIBILITY POLICY

The ALWR constructibility policy was to achieve a substantially improved construction schedule compared to experience with existing plants. Specifically, the Evolutionary ALWR was designed to be constructed in no more than 54 months from the start of structural concrete placement through completion of the full power warranty run. The Passive ALWR was designed to be constructed in no more than 42 months for the same schedule milestones. The shorter passive plant schedule results from significantly smaller quantities due to greatly simplified systems and a lower plant rating, and from more extensive use of modular.

Achievement of an improved construction schedule is an essential element in meeting the ALWR cost requirements. The Requirements Document includes specific, enforceable technical requirements in this area to provide high assurance of success. Several such requirements are:

- Ninety percent design completion is required before construction begins, i.e., 90 percent of design drawings must be 100 percent complete.

- Constructibility is to be explicitly considered in the design to enhance productivity and assure known problems are addressed e.g., provide space and arrangement for construction work and eliminate features which have caused major construction problems such as use of unrealistic construction tolerances.
- Construction planning, erection, and installation activities shall maximize the use of advanced techniques, including modularization. For the Evolutionary ALWR, this will involve designing to permit "out of hole" craft work which helps to reduce critical path in-place fabrication. For the Passive ALWR, this will involve more extensive use of modularization in order to assure meeting the ambitious 36-month schedule. Provisions for modular construction shall be incorporated in the Passive ALWR designs at an early stage of design development. Modularization shall be accomplished in the ALWR design while still preserving needed access space.
- The overall schedule is to be developed jointly by the Constructor, Plant Designer, and Startup Test organizations utilizing inputs from the principal suppliers and subcontractors.

2.11 ALWR QUALITY ASSURANCE POLICY

It was ALWR Program policy that the responsibility for high quality design and construction work rests with the personnel and management of the Plant Designer and Constructor organizations actually performing the work. Further, an effective Quality Assurance (QA) Program was implemented to independently verify that the line organizations are performing high quality work and that defined QA requirements were met. The QA Program emphasis in audits and other QA activities was on performance (vs. being strictly compliance oriented).

2.12 ALWR ECONOMICS POLICY

The ALWRs were designed to have projected busbar costs that:

- are as low as practicable while conforming to the operational and safety policies of this Utility Requirements Document
- provide a sufficient cost advantage over the competing baseload electricity generation technologies to offset the higher capital investment risk associated with nuclear plant deployment
- have quantified uncertainties (and therefore quantified cost risks) that provide a similar cost advantage over the competing baseload electricity generation technologies

Implementing this policy necessitated that design requirements be specified which assured control of construction and operating costs. Therefore, great emphasis was placed on constructibility, simplicity, design margin and other requirements which provided confidence that the construction schedule can be met, that licensing approval will be obtained, that operating costs will be controlled, and that the plant design availability can be achieved.

Implementing this policy also necessitated projecting electricity generation costs for the baseload technologies anticipated to be in competition with early ALWRs. These projections are provided in Section 4, Economic Goals, of this volume of the Utility Requirements Document. Section 4 also quantifies the uncertainties in the projections, and defines ALWR goals based on the projections. Cost assessments were carried out as part of the ALWR program, to confirm that the ALWRs designed in accordance with this Utility Requirements Document met the cost goals. The cost assessments were performed in accordance with cost estimating groundrules provided in Appendix C of Volumes II and III of this document.

2.13 ALWR SABOTAGE PROTECTION

The ALWR sabotage protection policy was to provide the following from inception of the design:

- An overall ALWR design which integrates consideration of sabotage protection along with safety, operability, and cost;
- A plant with built in resistance to sabotage and reasonable capability to mitigate acts of sabotage;
- Additional sabotage resistance through the plant security system.

Inherent sabotage resistance was achieved at little or no additional cost by developing ALWR plant layouts which take advantage of other design requirements (e.g., hardening for missiles, separation of safety system divisions, backup capabilities to accomplish safety functions, etc.).

The plant security system included access control and intrusion detection, a plant security organization, and plant operating procedures and personnel practices which consider sabotage protection needs. An improved ALWR design was achieved by requiring that the design of the plant security system be integrated with finalization of plant arrangement, safety system separation, and building structural design.

2.14 ALWR GOOD NEIGHBOR POLICY

It was ALWR Program policy that the plant be a good neighbor to its surrounding environment and population. To implement this policy, specific requirements to limit radioactive releases from normal operation were defined. The radioactive release limitations apply to solid waste shipment quantities and radioactive liquid and radioactive gaseous release quantities to the environment. Further, releases of hazardous and toxic chemical wastes, which are inherently minor in a nuclear plant, will be in accordance with prevailing Environmental Protection Agency standards.

It is also part of the ALWR Good Neighbor Policy that the ALWR be designed to be an asset to the community in which it is located. This is to be provided through requirements which provide a technical basis for safe and secure operation, favorable economics and resulting cost of service compared to competing alternatives, non-intrusive emergency planning, good architectural design to aid the visual appearance of the site, and the above-mentioned normal operation release limits on waste.

Finally, it is ALWR Good Neighbor Policy that the design address the environmental consequences of leakage of radioactivity during an accident.

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

3 TOP LEVEL ALWR DESIGN REQUIREMENTS

This section contains a summary of the top level ALWR design requirements in a narrative format. The requirements are broken down by function: safety, performance, constructibility, and design process.

3.1 ALWR TOP-LEVEL SAFETY DESIGN REQUIREMENTS

ALWR safety design requirements are consistent with the three levels of safety protection for the ALWR defined in the safety policy statement above and illustrated in Figure 2. The top level safety design requirements in Section 3.1 are broken down by these three levels of protection.

3.1.1 Requirements Common to All ALWRs

The following top-level safety design requirements apply to all ALWRs.

3.1.1.1 Accident Resistance

Design characteristics are required for the ALWR which reduce the dependence on engineered safety systems to achieve safety and protect the utility's investment. The design shall minimize the occurrence and propagation of initiating events which could lead to larger events and resulting challenges to safety systems. Accident resistance requirements include Licensing Design Basis requirements as well as Safety Margin Basis requirements initiated by the utility to further increase accident resistance. The top level accident resistance requirements are as follows:

- Simplification shall be emphasized as described in the policy statement in Section 2 above.
- Ample margin shall be designed into the ALWR plant so as to provide a more forgiving and resilient plant including:
  - Fuel design margin of 15 percent over and above regulatory fuel design requirements;
  - PWR pressurizer inventory and steam generator secondary side inventory larger than existing plants; and
  - PWR maximum vessel exit temperature of 600oF.
- The Safe Shutdown Earthquake (SSE) shall be 0.3g.
- The reactor shall be designed so that the power reactivity coefficient is negative under all conditions.
- Use of best available materials and water chemistry shall be specified, based on the extensive LWR operating experience.
- A greatly improved man-machine interface system shall be provided which will promote error-free normal operations and quick, accurate diagnosis of off-normal conditions.

- Proven diagnostic monitoring techniques shall be used in the ALWR for leak detection, vibration, and other potential problems to minimize failure of critical rotating equipment and high pressure systems.
- For investment protection purposes, the operator shall have adequate time (30 minutes or more after indication of the need for action) to act to prevent damage to equipment or to prevent plant conditions which could result in significant outages.

3.1.1.2 Core Damage Prevention

Requirements for core damage prevention apply primarily to engineered safety systems and include Licensing Design Basis requirements as well as Safety Margin Basis investment protection requirements. Top-tier core damage prevention requirements are as follows:

- The ALWR shall meet applicable NRC requirements with regard to engineered safety system design and analysis of plant and engineered safety system response to the regulatory specified transients and accidents.
- For investment protection purposes, the ALWR design shall be such that no fuel damage (i.e., the core can be used for further power operation) is predicted to occur for a postulated near instantaneous RCS break of up to six inches. Consistent with Safety Margin Basis evaluation, this analysis shall use best-estimate methodology to calculate core temperature and resulting effects.
- The role of the operator in the ALWR shall be that of an intelligent overseer in the event of off-normal conditions. The plant shall be designed to allow the operator significant time to evaluate the plant condition and decide what, if any, manual action is needed. The plant shall not be designed to lock out the operator at any time. The plant shall, however, be designed so as to prevent operator override of safety system functions as long as a valid safety system actuation signal exists.
- The mean annual core damage frequency for the design shall be evaluated using PRA and it shall be confirmed by the Plant Designer that this frequency is less than 1x10-5 events per reactor year, including both internal and external events. The PRA shall be performed as part of the detailed design and shall be used by the Plant Designer as a tool to identify and resolve any potential core damage and risk vulnerabilities, as an input to the Plant Technical Specifications, and as an input to emergency procedure guidelines and maintenance priorities.

- As part of performing the PRA, the Plant Designer shall define the technical basis to allow the Plant Owner to assure that risk-significant system, structure, and component design reliability is maintained and key PRA assumptions continue to be met throughout plant life.
- The technical basis for severe accident management to help assure core damage prevention and mitigation shall be provided by the Plant Designer.

3.1.1.3 Mitigation

Design requirements for accident mitigation include those necessary for Licensing Design Basis as well as Safety Margin Basis requirements to assure protection against severe accidents. These design requirements are as follows:

- A large, rugged containment building and associated containment systems shall be provided for heat removal and retention of fission products for Licensing Design Basis events. Containment design pressure shall be based on the most limiting loss of coolant or steam line break accident.
- Licensing Design Basis source term analyses shall be more realistic than the TID 14844, Regulatory Guide approach for current LWRs. Fission product release timing from the fuel shall recognize the physical delays relative to the time of the initiating event; fuel release magnitudes shall consider radionuclides in addition to noble gases and iodine; iodine chemical form shall be assumed to be primarily aerosol; and aerosol removal assumptions shall be more realistic.
- The ALWR design shall allow siting at most sites available in the United States.
- The ALWR Licensing Design Basis shall provide control of hydrogen for a degraded core in-vessel so that the concentration of combustible hydrogen in containment does not exceed 10 percent under dry conditions for an amount of hydrogen equivalent to that generated by oxidation of 100 percent of the active fuel clad. The Safety Margin Basis shall address best-estimate hydrogen generation from both in-vessel and ex-vessel sources and shall demonstrate that ALWR severe accident mitigation requirements are met.
- Safety Margin Basis features shall be provided such that, when combined with the ALWR design requirements for the LDB, core damage sequences which are coincident with or could cause containment failure (such as containment bypass sequences and direct containment heating sequences) are prevented through engineered means and thus are very remote in probability.

- Containment system components for which a change of state is necessary to assure an intact containment (e.g., containment isolation valves, cavity/lower drywell flooder valves) shall be redundant and shall be sufficiently independent from the systems whose failure could lead to core damage so as to avoid significant vulnerability to common cause failure.
- Severe accident risk shall be evaluated using PRA, and it shall be confirmed by the Plant Designer that the whole body dose at the site boundary (approximately 0.5 miles from any individual reactor) is less than 25 rem for releases from severe accidents, the cumulative frequency of which exceeds $1x10^{-6}$ per reactor year.

3.1.2 Requirements for Evolutionary Plants

The following additional top-level safety design requirements apply only to Evolutionary ALWRs:

- Active engineered safety systems shall be provided. The systems shall be simplified relative to current LWRs so as to make them less complex, to minimize or eliminate realignments to accomplish safety functions, and to minimize the number of active components, consistent with other needs. The systems shall reflect lessons learned from current LWRs.
- At least two separate and independent ac power connections to the grid shall be provided to decrease the likelihood of a loss of off-site power;
- The Evolutionary ALWR design shall permit increased operator response time over existing LWRs. For transients and accidents analyzed under the initiating event plus single failure Licensing Design Basis assumptions, no credit for manual operator action shall be necessary to meet core protection regulatory limits until at least 30 minutes following initial indication of the need for action.
- For investment protection there shall be no fuel damage in the PWR for at least two hours after sustained loss of all feedwater with no operator action.
- For investment protection, the plant shall be capable of withstanding a loss of off-site and on-site ac power for up to eight hours without fuel damage.
- In addition to an independent, safety-related, on-site ac power generation source provided for each division, the Evolutionary ALWR shall further reduce the risk from station blackout by providing a non-safety-related, alternate ac on-site power source.

- Containment systems shall be designed so that applicable exposure limits can be met, assuming a containment building design leak rate no less than 0.5 weight percent per day and a BWR main steam isolation valve design leak rate no less than 35 standard cubic feet per hour per steam line.

3.1.3 Requirements for Passive Plants

The following additional top-level safety design requirements apply only to passive plant designs:

- Engineered safety systems necessary for the Licensing Design Basis shall utilize passive means for water injection, cooling, and other functions. Passive means are natural forces such as gravity and natural circulation, stored energy such as batteries and compressed fluids, check valves, and non-cycling powered valves. The design shall not rely on features such as multiple acting valves, and ac powered divisions and continuously rotating machinery, other than inverter supplied components, to prevent or mitigate LDB events.

- The passive plant design shall not require safety-related ac electric power other than inverter supplied ac power for instrumentation and control functions.

- For investment protection, the Passive ALWR shall have a low likelihood of loss of all ac power. In addition to power from the main generator and from the normal tie line to the plant switchyard, the plant shall have at least two non-safety-related ac power sources (not including inverter supplies). At least one of these sources shall be an on-site power generator.

- The Passive ALWR design shall provide a greatly increased time for operator response. For transients and accidents analyzed under the initiating event plus single failure Licensing Design Basis assumptions (which include loss of all ac power), no credit for manual operator action shall be necessary to meet core protection regulatory limits for at least 72 hours following initial indication of the need for action (i.e., approximately the time of the initiating event).

- Only simple operator actions (e.g., few in number, unhurried, dependent on straightforward diagnostics, requiring common operator skills) and minimal off-site assistance (e.g., commercial supplies and components which are readily available, easily transported, and easily installed, such as a portable ac generator with its fuel and connection cables) shall be necessary beyond 72 hours to prevent core damage for the transients and accidents noted above.

- The Passive ALWR Safety Margin Basis shall address containment performance during severe accidents. A severe accident selection process shall be defined and, for the sequences surviving this selection process, evaluations shall be performed to assure that margin in the containment design is sufficient to meet the containment performance requirement specified below.

- Containment performance for the sequences surviving the severe accident selection process shall assure containment leaktightness sufficient to meet off-site dose limits, including dose limits associated with simplified emergency planning, for at least 72 hours without the need for off-site assistance. Beyond 72 hours, only minimal off-site assistance shall be necessary to maintain required containment leaktightness.

- Permanent features shall be designed into the plant to facilitate connection and use of any portable equipment (e.g., ac generator) required for the off-site assistance referred to above, and to minimize radiation exposure from this connection and use.

- The plant shall be designed to provide a technical basis for simplification of plume exposure pathway-related off-site emergency planning. The intent is to retain an on-site emergency plan and certain elements of the off-site plan, but demonstrate that doses are low enough that early notification, evacuation planning of the public, and provisions for exercising the off-site plan are not necessary.

3.2 ALWR TOP-LEVEL PERFORMANCE DESIGN REQUIREMENTS

The top level performance requirements presented in this section have been grouped into five major categories. The first category presents required plant characteristics, such as rating and design life. The second presents maneuvering and transient response requirements, such as startup and shutdown and load following requirements. The third category is reliability and availability requirements. The fourth is operability, maintainability, and surveillance testing. The fifth is top tier requirements for the man-machine interface.

3.2.1 Plant Characteristics

The top-tier requirements for plant characteristics are as follows:

- The ALWR requirements shall apply to a wide range of plant sizes extending up to 1350 MWe. Cost and design trade-off studies for the Evolutionary ALWR in Volume II have been based on the larger ratings (1200-1300 MWe per unit). For the passive plant concepts in Volume III, these studies are done for a 600 MWe unit.

- The plant shall be designed to operate for 60 years. Over this life span, components will need to be replaced, and special attention will need to be paid to material issues such as fatigue, corrosion, thermal aging, and radiation embrittlement effects. Therefore, the design shall include features to permit necessary component replacement within the design availability requirements and shall include analyses and data necessary to support the design life of materials.

- The plant should be capable of operating on a fuel cycle, from post-refueling startup to the subsequent post-refueling startup, with a refueling interval of 24 months.

- BWR fuel mechanical designs shall be capable of a peak bundle-average burnup of at least 50,000 MWD/MTU. For PWRs, fuel mechanical design shall be capable of assembly-average burnups of at least 60,000 MWD/MTU.

- The premature fuel failure rate due to manufacturing defects shall be less than one in 50,000 fuel rods.

- The radioactive waste and water treatment systems and plant shielding design basis shall use a failed fuel rate consistent with regulatory requirements. For purposes of normal operation performance evaluation, .025% failed fuel for PWRs and a noble gas release rate of 15,000 μCi/second at 30 minutes BWRs shall be utilized.

- The ALWR shall be designed and constructed so that the amount of radioactive gaseous, liquid, and solid waste released from the plant shall be equal to or better than comparable values for the 10 percent best plants of the same type (i.e., BWR or PWR) currently operating in the U.S. Furthermore, the ALWR shall provide on-site storage capacity for a minimum of six months radioactive solid waste accumulated during a period of maximum generation rate.
- Wet storage capacity for spent fuel resulting from ten years of operation plus one core off-load of fuel shall be provided. In addition, on-site land shall be reserved to permit the construction of a dry storage system with capacity to store all of the fuel discharged over the plant design life.
- The ALWR shall be designed and constructed so that occupational radiation exposure can be less than 100 person-rem/year averaged over the operating life of the plant.

3.2.2 Maneuvering and Transient Response Requirements

The top-tier requirements for ALWR maneuvering and non-accident transient response are as follows:

- The plant shall be designed to be capable of startup from cold shutdown to hot standby at full pressure and temperature in 24 hours. Similarly, it shall be capable of cooling down from reactor critical at full temperature and pressure to start of refueling operations in 24 hours.
- The plant shall be designed for a 24-hour load cycle with the following profile: starting at 100 percent power, power ramps down to 50 percent in two hours, power remains at 50 percent for two to ten hours, and then ramps up to 100 percent in two hours. Power remains at 100 percent for the remainder of the 24-hour cycle. The plant shall be designed to permit this cyclic load following for 90 percent of the days of each fuel cycle for the life of the plant.
- The plant shall be designed so that it may be remotely dispatched for load following.
- The plant shall be designed to permit it to be used for normal frequency control of the grid.
- The plant shall accept a generator load rejection from 40 percent power or less in a BWR and from 100 percent power or less in a PWR, without reactor or turbine trip and without lifting the main steam safety valves, and be able to continue stable operation with minimum house electrical loads.

Additional requirements of this type and their associated specifics are contained in Chapter 1 of Volumes II and III.

3.2.3 Reliability and Availability Requirements

The following top-tier reliability and availability requirements apply:

- The plant shall be designed for an annual average availability of greater than 87 percent over the life of the plant.
- The plant shall be designed to achieve the following outage durations:
  - Planned Outages: less than 25 days/year
  - Forced Outages: less than 5 days/year
  - Major Outages: less than 180 days/10 years
- The plant shall be designed so that a refueling outage free from major problems can be conducted in 17 days or less (breaker to breaker) assuming 24-hour productive days.
- The plant shall be designed to limit the number of unplanned automatic trips to be less than one per year. In response to this requirement, the plant shall utilize a minimum number of plant variables for reactor trip signals consistent with plant safety and shall provide increased margin between the normal operating range and the trip set point of safety variables so that the number of plant trips resulting from normal operation activities is minimized.
- Non-safety-related active RCS makeup capability and any other necessary measures shall be provided in the Passive ALWR such that RCS depressurization is not required for RCS breaks up to a size equivalent to 3/8-inch diameter.
- The reliability of actuation systems shall be such that the chance of inadvertent RCS depressurization in the Passive ALWR can be demonstrated by reliability analysis to be less than 10 percent over the entire 60-year life of the plant.
- Recovery from inadvertent RCS depressurization in the Passive ALWR shall be rapid enough that lifetime-average design availability requirements can still be met assuming one inadvertent RCS depressurization during the 60-year plant life. Specifically, design features shall be provided to permit recovery from an inadvertent RCS depressurization within 30 days and this outage shall be included in the lifetime-average availability.
- Where feasible, Passive ALWR systems and equipment shall be designed to withstand a complete loss of ac power (other than inverter supplied power) for at least two hours without exceeding equipment design limits. Where it is not feasible to provide this protection, the design shall be such as to allow repair or replacement of the damaged equipment within 24 hours after power restoration.

3.2.4 Operability, Maintainability, and Testing Requirements

The following top-tier requirements for operability, maintainability, and testing apply:

- Ease of operation shall be designed into the ALWR through such features as use of modern digital technology for monitoring, control, and protection functions, a forgiving plant response to upset conditions, design margins, and consideration of the environment in which the operator must perform.
- The design shall incorporate the results of a systematic identification and resolution of operational and maintenance problems which exist in current plants.
- Consistent with overall simplification, the number of different types of equipment which must be specified and maintained, i.e., valves, pumps, instruments, and electrical equipment, shall be minimized by standardization except in those limited applications where diversification is adopted by the designer as an appropriate means to protect against common cause failure.
- The plant shall be designed to facilitate replacement of equipment, including major components such as steam generators, within design availability limits.
- Equipment shall be designed to have minimal, simple maintenance needs, and be designed to facilitate needed maintenance.
- The layout of systems shall consider the maintenance needs for access, pull space, laydown space, and heavy lifts.
- The plant shall be designed so that the environment under which the maintenance and testing of equipment must be performed provides satisfactory working conditions, including temperature, dose, ventilation, and illumination.
- The plant design shall include features to facilitate the use of robots for plant maintenance activities. Such features shall address arrangements to accommodate movement, necessary access ports in equipment, robot communication needs, and robot storage and decontamination.

- The surveillance tests shall be designed to measure simply and directly the systems design basis performance parameters, preferably with the plant at power in order to avoid adding tasks to the planned outage time. Mechanical and electrical systems shall be designed to avoid plant trips, and plant equipment and layout shall be designed to facilitate and simplify surveillance testing. The allowable interval between tasks should be increased where justified. Where surveillance tasks must be performed during an outage, the design should assure that the tests will not be critical path for the outage.

- The protection system and control systems for the engineered safety systems shall be designed so that: (a) the plant can be safely operated indefinitely at full power with one protection channel in test or bypassed (because of failure or other reasons), (b) one subsequent single failure will not cause a plant trip.

- The M-MIS shall be such that testing and maintenance is greatly simplified with respect to current plants. For example, self-testing shall be included and the testing automated to the degree practical.

3.2.5 Man-Machine Interface System Requirements

The top-level requirements for the man-machine interface system (M-MIS) include the following:

- The M-MIS shall employ modern digital technology, including multiplexing and fiber optics, for monitoring, control, and protection functions. Multiplexing is to be used for any function, including safety functions, where it is appropriate and reduces the cost and complexity of cable runs throughout the plant.

- Existing regulatory requirements enforce segmentation and separation on safety and protection systems. In addition, for the major plant control and monitoring functions, the M-MIS shall incorporate segmentation of major functions, separation of redundant equipment within a segment, and fault tolerant equipment to achieve high reliability and prevent propagation of a fault between redundant equipment and from one segment to another. The M-MIS shall assure "graceful" failure which allows continued plant operation to the extent practical.

- The M-MIS design process shall be fully integrated with the remainder of the ALWR plant design. The design process shall provide for iteration among the M-MIS and plant designers and shall use mock-ups, dynamic simulation, and operations and maintenance personnel input in the M-MIS design.

- The main control room shall be designed on the basis of a specified number of operators (two or three) being available for operation of the plant in all modes of operation. Adequate space and layout shall be available for up to 10 occupants on a temporary basis. The design is to be such that a single operator can adequately control the plant during normal power operations.
- The main control room shall contain compact, redundant, operator work stations with multiple display and control devices that provide organized, hierarchical access to alarms, displays, and controls. Each work station shall have the full capability to perform main control room functions as well as support division of operator responsibilities. A supervisor's work station shall also be located in the main control room.
- The main control room shall incorporate modern, computer-driven displays to provide enhanced trending information, validated data, and alarm prioritization and supervision, as well as diagrammatic normal, abnormal, and emergency operating procedures with embedded dynamic indication and alarm information. In addition, extensive use of data management and computer-aided design (CAD) techniques shall be made to display plant information at appropriate levels of detail with updated equipment status indication.
- The main control room shall include large, upright, spatially dedicated panels which provide an integrated plant mimic, indicating equipment status, plant parameters, and high level alarms.
- The main control room and control station environments, e.g., lighting levels, HVAC, sound levels, colors, etc., shall provide a comfortable, professional atmosphere that enhances operator effectiveness and alertness.
- Local and stand-alone control systems shall be designed in the same rigorous way as the main control stations and will use consistent labeling, nomenclature, etc. Particular attention is to be paid to visibility, color coding, use of mimics, access, lighting, and communication.
- An integrated, plant wide communications system shall be provided for construction and operations.
- The Passive ALWR design shall be such that the main control room shall be available for post-accident monitoring for all Licensing Design Basis accidents and transients (except for events requiring main control room evacuation, e.g., control room fire), including loss of all ac power, for 72 hours without the need for off-site assistance. Beyond 72 hours, reasonable off-site assistance as defined in Section 3.1.3 may be utilized.

VOLUME I: POLICY AND TOP-TIER REQUIREMENTS

3.3 ALWR TOP-LEVEL CONSTRUCTIBILITY REQUIREMENTS

The key top-level requirements for constructibility of the ALWR can be separated into five general areas: quantitative requirements on construction duration and design completeness, construction and design coordination requirements, advanced technology requirements, planning and scheduling requirements, and inspection tests, and analyses for assuring construction adequacy. All requirements in these areas are oriented toward implementing the ALWR constructibility policy of achieving a substantially improved construction schedule over existing plants and of providing confidence that this improved schedule is achievable.

3.3.1 Construction Duration and Design Completion Requirements

There are several key quantitative requirements on construction duration and design completion. The most important of these is that the design shall be 90 percent complete before placement of structural concrete. The 90 percent complete figure means 90 percent of all plant engineering design documents, including site specific design documents but not counting vendor drawings, shall be 100 percent ready to issue for construction, procurement, or other future use. Vendor drawings, that provide the necessary technical information to enable completion of detailed plant engineering documents, also must be completed in order to qualify the plant engineering documents as 90 percent complete.

- The evolutionary plant (1200MWe) shall be designed for construction in 48 months from the first structural concrete placement milestone to fuel load. Allowing 6 months for plant startup and low power testing and 18 months as representative of the duration necessary to prepare the site and complete major excavation work, the planning base is for an overall duration of 72 months from owner commitment to construct to commercial operation.

- The passive plant (600MWe) shall be designed for construction in 36 months from the first structural concrete placement milestone to fuel load. Allowing 6 months for plant startup and low power testing and 18 months as representative of the duration necessary to prepare the site and complete major excavation work, the planning base is for an overall duration of 60 months from owner commitment to construct to commercial operation.

Figures 5 and 6 (Section 5) show implementation scenarios for the Evolutionary and Passive ALWRs, respectively, which reflect these schedule requirements.

3.3.2 Construction and Design Coordination

The key requirements to obtain the needed coordination of design and construction activity are as follows:

- Plant Constructor personnel shall participate in the ALWR design process to assure that constructibility requirements are adequately implemented.
- Design provisions to simplify and facilitate construction and startup shall be explicitly considered in the design process. Such provisions include good crane and material handling access, adequate space and access for construction activities, and provision for temporary construction buildings and equipment.
- Standardized component sizes, types, and installation details shall be provided to improve productivity and reduce material inventories.
- Reasonable construction tolerances shall be specified to minimize unnecessary re-work and improve productivity.
- An experience review of previous LWR construction problems shall be performed to assure lessons learned are addressed in ALWR design and construction.

3.3.3 Advanced Construction Technology

Provisions for advanced construction techniques were included in the ALWR design to support improved constructibility which leads to a predictable construction schedule and actual construction durations which meet the ALWR objectives. Such provisions were incorporated into the design at an early stage of design development in order to be fully effective. Examples of some of the provisions which were included are:

- Extensive use of multiplexing for the instrument and control systems to reduce electrical raceways and cable pulling.
- Designs which permit construction craft work to be performed at “out of hole” locations so that large fabrications of material and equipment are assembled and installed in the final location using heavy load capacity cranes, thereby reducing congestion in the installation locations.
- Modularization of equipment packages and structural elements to take advantage of improved productivity by reducing congestion and reduced costs of field versus shop labor. Modularization shall be accomplished while preserving space needed for maintainability, testing, and other access related requirements. More extensive use of modularization of structural and equipment packages was expected to be necessary in the Passive ALWR in order to achieve the very ambitious 36-month construction schedule.

3.3.4 Integrated Construction Planning and Scheduling

Experience with existing LWR construction projects has shown the importance of effective construction planning, scheduling, and monitoring. The ALWR key top-level requirements in this regard are:

- A detailed living construction plan shall be jointly developed prior to start of construction by the Plant Designer, Constructor, and Startup Test organizations, utilizing input from principal suppliers and subcontractors. The plan shall establish the overall approach and provide a basis for developing and assessing schedules.
- Detailed schedules shall also be jointly developed prior to start of construction to integrate the design, procurement, construction, and startup testing activities up to Plant Owner acceptance. The startup testing requirements shall establish the logic for system turnover sequence and schedule including requirements necessary for defining system boundaries, establishing system numbering, and assuring timely turnover.
- Monitoring of the construction progress shall be accomplished using quantitative methods appropriate to the particular activity, e.g., number of welds, feet of cable pulls, to make up-to-date assessments of progress and to anticipate where deviations from schedules may occur in time to take appropriate action to resolve problems and maintain schedule milestones. The schedules shall be updated as work progresses to realistically reflect the actual work status.

3.3.5 Inspections, Tests, and Analyses for Assuring Construction Adequacy

The NRC Standardization Rule, 10CFR52, requires that the tests, inspections, and analyses, performed to provide reasonable assurance that the plant is properly constructed, shall be identified in the combined license. Accordingly, the Plant Designer shall prepare a set of tests, inspections, and analyses and associated acceptance criteria which will demonstrate that the plant has been constructed and will be operated in conformity with Commission regulations, the combined license, and the Atomic Energy Act. The technical basis for the completeness of the set of inspections, tests, and analyses and for the specified acceptance criteria shall be provided. The nature and level of detail of acceptance criteria shall be such as to allow third party (i.e., the NRC staff) verification that the acceptance criteria have been met.

3.4 ALWR TOP-LEVEL DESIGN PROCESS REQUIREMENTS

This section provides top tier requirements for the process to be carried out in the design of the ALWR, including hardware and computer software. The design process includes activities such as development, testing, analyses, preparation of specifications and drawings, models, reports and support of others as required to complete the licensing, construction, and startup of the ALWR plant and turnover to the operator. The top-level design process requirements are divided into four areas: design integration, configuration management, information management, and engineering verification.

3.4.1 Design Integration

Complete and early integration of all factors important to the plant design has been demonstrated to improve life cycle costs by minimizing the need for redesign and backfit, helping to assure adequate design interfaces, and minimizing operational difficulties. The following top-tier requirements apply:

- The design process is to be managed and executed as a single integrated process. Therefore, the requirements have been addressed to the "Plant Designer" even though the effort may involve more than one organization (e.g., an Architect Engineer, an NSSS supplier, and a constructor).

- The Plant Designer shall prepare design basis documents for each plant system or element which describe specific design criteria, the design features, and how these features satisfy the criteria. The documents shall be sufficiently complete that an acceptable design can be developed and that the potential acceptability and conformance to ALWR requirements can be judged.

- Interdisciplinary design reviews shall be conducted throughout the design and construction process. These reviews shall include confirmation that the utility simplification policy is being emphasized in the design and that all simplification requirements are being addressed.

- The Plant Designer shall utilize verified and validated computer models, physical models of the plant, and a control room simulator as design tools in studying plant response, defining human-engineering aspects of the plant controls and control room design, and developing plant operating procedures. The verification and validation should be documented.

3.4.2 Configuration Management

The Plant Designer shall develop a comprehensive configuration management program to ensure that plant structures, systems, components, and computer software conform to approved design requirements. In addition, the plant's as-built physical and functional characteristics shall be properly reflected in selected plant documents, including those for design, procurement, construction, operation, testing, and training. The configuration management program shall be applicable for use throughout all phases of the plant life, including the design phase, and shall provide for turnover of the program to the Plant Owner for use during startup and operation. The configuration management program shall include the following features:

- Methods for controlling and providing accessibility to design basis documents.
- Verification methods to insure compliance of the hardware and software design at all levels with the design basis documents.
- Change control methods to assure that all changes from the original designs are approved at the appropriate level of authority in the design and plant owner organization and documented for the life of the plant.
- A process to assure verification and auditing of program data gathering, updating, revising, dissemination and security.
- Auditing and checking of the configuration management programs and data on a regular basis.

3.4.3 Information Management System

The Plant Designer shall utilize appropriate computer hardware and software to establish, manage, and operate an information management system (IMS) during the design process and shall provide for turnover of the IMS to the Plant Owner for use during construction, startup and operation.

The main objectives of the IMS are as follows:

- To provide a logical breakdown of the ALWR into a number of systems and system groups and to use standard identification for all systems, components, facilities, and documentation which can be used for design, construction, and operation;
- To make effective utilization of computer aided design and engineering during design and construction, and after the plant is turned over to the operator;

- To provide for efficient implementation of a project information network which utilizes a methodology such as that described in EPRI NP-5159, Guidelines for Specifying Integrated Computer-Aided Engineering (CAE) Applications for Electric Power Plants;
- To provide an effective means to acquire, store, retrieve and manipulate the documents and data necessary to design, construct, startup, operate and maintain the plant; and
- To assure that information needed for construction and operations is available when the plant is turned over to the owner.

3.4.4 Engineering Verification of As-built Conditions

As part of the design process, the Plant Designer shall identify field verification activities necessary to confirm adequacy of the installation. Such engineering verifications will be in addition to the normal quality control verification of construction work. The following specific requirements apply:

- Engineering verification activities shall be identified early in the construction and scheduled so that completed walkdowns and evaluations, as well as any necessary rework, support project completion milestones.
- Engineering verification activities shall include a seismic walkdown to verify all key seismic PRA assumptions such as equipment anchorages and system interactions.
- To the extent practical, the design shall include provisions which minimize the complexity and scope of engineering verification walkdowns during construction. Where verification is necessary, the Plant Designer shall develop procedures, including walkdown objectives and scope, process for evaluation, and process for resolution of items which do not meet the design intent. Sampling techniques shall be used in preference to inspections of the total population in question.

4 ALWR PROGRAM ECONOMIC GOALS

It is the policy of this Utility Requirements Document that ALWR plants will have projected busbar costs that:

- are as low as practicable while conforming to the operational and safety policies of this Utility Requirements Document
- provide a sufficient cost advantage over the competing baseload electricity generation technologies to offset the higher capital investment risk associated with nuclear plant deployment
- have quantified uncertainties (and therefore quantified cost risks) that provide a similar cost advantage over the competing baseload electricity generation technologies

A U. S. market for new baseload generating capability is expected to re-emerge as the current excess capacity is overtaken by continuing load growth and as existing generating plants reach the end of their economic lives and require replacement. The future market for power is expected to be very competitive, placing a premium on the economic performance of the alternative generating technologies.

The competitiveness of any particular technology depends on many factors, including cost of plant construction and operation, plant performance, fuel availability and cost, and other external factors such as the cost of meeting environmental impact limits. While the ALWR designer was able to influence only some of these factors that will ultimately decide economic success in the market, it was important that the ALWR designs provide an economic advantage over a broad range of potential future conditions.

Accordingly, US electricity generation costs were projected for the baseload technologies currently anticipated to be in competition with early ALWRs. Four such competitors were anticipated, i.e. three alternative ways of burning coal (pulverized, fluidized or gasified) and natural gas. US electricity generation costs currently projected for each of these competitors to nuclear power are depicted in Figure 3, for 1200Mw multi-unit fossil-fuel plants, a 30-year capital amortization period, plant startup in 2005, and a mid-range-cost US location (Kenosha, Wisconsin). (Note that, because the projections escalate costs to the 2005-2035 time period, they are higher than generation costs for today's fossil plants.) Figure 3 also quantifies the uncertainties in the projections. The Figure 3 projection also includes a statistically derived composite of these competitors to nuclear power.

Figure 3 was derived using the levelized constant-dollar cost of electricity revenue requirement method specified in EPRI's Technical Assessment Guide. The derivation of the Figure 3 cost ranges involved 1) identifying the cost elements that have the most influence on the overall uncertainty in the projected levelized cost of electricity, 2) for each such separate cost element, quantifying its uncertainty in the form of a value/probability distribution, and 3) integrating these quantified uncertainties using a random sampling statistical analysis. The cost elements having most influence on the overall uncertainty in the projected levelized cost of electricity (and therefore treated as described above) were total plant cost, fixed O&M cost, fuel cost, fuel cost escalation rate, weighted cost of capital, plant construction time, net heat rate, and plant capacity factor. Parameters not addressed in the uncertainty analysis included the fixed parameters identified in the preceding paragraph, i.e. plant power rating, capital amortization period, plant startup date, and plant location. Details are recorded in EPRI ALWR Program Report, "Projected Cost of Electricity for Major Alternatives to Future Nuclear Power Plants," September 1995.

Based on the above, the following cost goals in terms of levelized constant 1994 dollars are defined for ALWR plants.

- Median busbar cost:
  - sufficiently less than 43 mills/kWh to offset the higher capital investment risk associated with nuclear plant deployment.
- Uncertainty:
  - While an exact quantitative goal for the upper bound of the uncertainty range cannot yet be established, the projected 95th percentile non-exceedance cost clearly must be substantially less than the 53 mills/kWh currently projected in Figure 3 for the alternative generating technologies, both to offset the higher capital investment risk associated with nuclear plant construction and to recognize that the cost uncertainties with alternative generating technologies will decrease with time.

At the time of deployment decisions, specific conditions may differ from those fixed for the Figure 3 projections. For example, a capital amortization period shorter than 30 years would constitute a disadvantage for the nuclear option. On the other hand, regulation requiring greater recognition of the costs of environmental impacts should constitute a disadvantage for the fossil-fuel options. The specific location could alter the nuclear/fossil comparison either way. Nonetheless, ALWRs that compare favorably with the competition for the conditions represented by Figure 3 should be economically competitive for a wide range of potential deployments.   The potential impacts of these considerations are discussed in EPRI report reference, above.

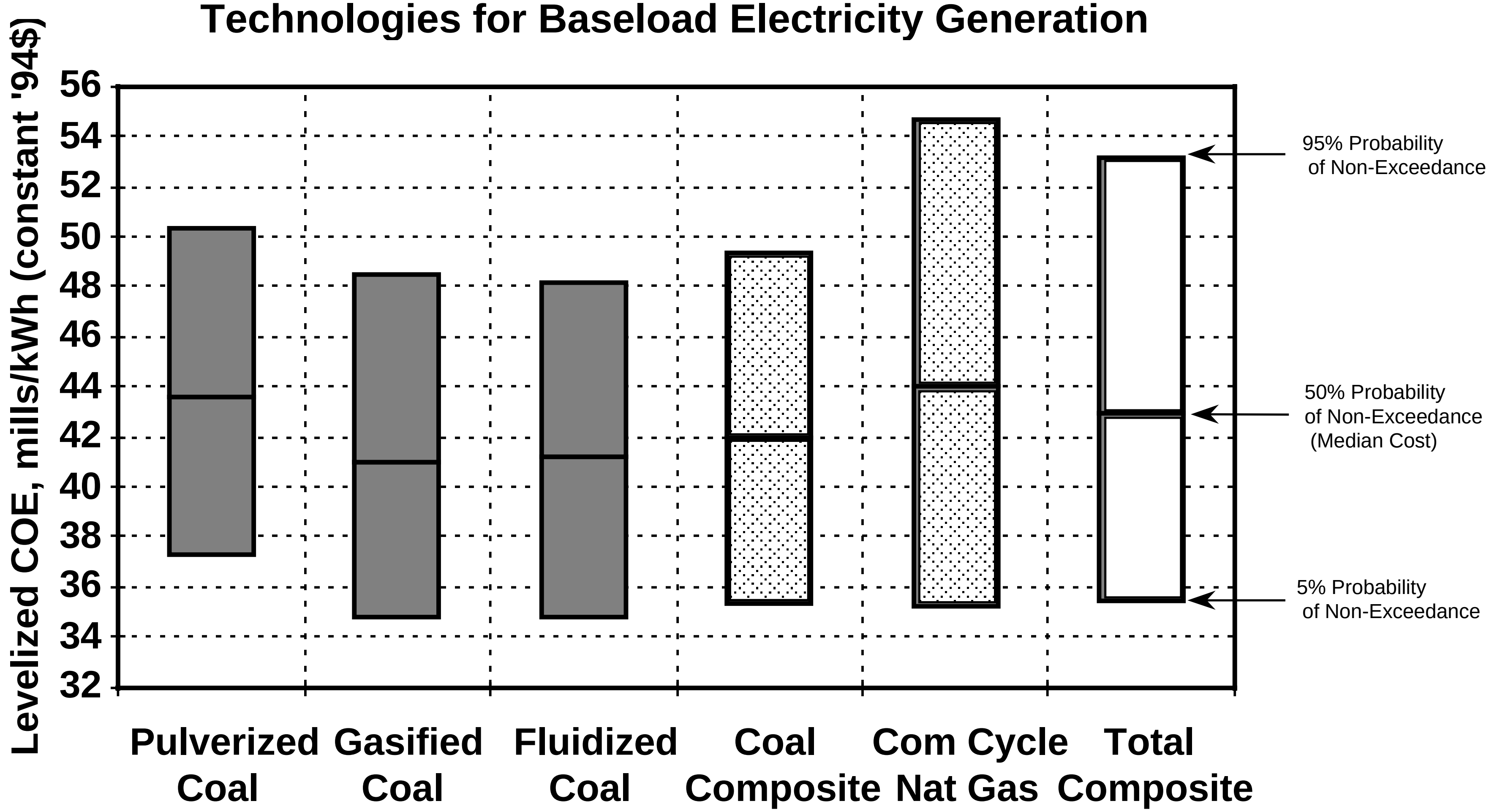
The ALWRs' projected costs should be derived in accordance with the cost estimating groundrules provided as Appendix C to Volumes II and III of the URD. These groundrules address cost estimating and uncertainty quantification for all four elements of the total electricity generating cost, i.e. plant capital costs, operation and maintenance costs, fuel cycle costs, and decommissioning costs (and the conversion of all four elements into levelized busbar cost).

The busbar cost is the sum of contributions from plant capital investment, operation and maintenance (O&M) costs, fuel cycle costs and plant decommissioning costs. Many combinations of these contributors could meet the above cost goal. For example, design simplification can lower plant capital investment, and a reduction in plant staffing requirements can lower the O&M cost. A nominal breakdown of the levelized median busbar cost goal is tabulated below. ALWR design, plant staffing, and cost estimate details will contain refinements of this nominal breakdown.

Busbar Cost Contributor	Median Cost Breakdown (mills/kWh Jan 94$)
Plant Capital Investment	28
O&M	7
Fuel Cycle	7
Plant Decommissioning	1
Total Levelized Cost	**43 ***

* As noted above, the total should be sufficiently less than this amount to offset the higher capital investment risk associated with nuclear plant utilization.

Figure 3. Projected Busbar Cost of the Competing Technologies for Baseload Electricity Generation



5 ALWR IMPLEMENTATION

5.1 INTRODUCTION

The objective of this section is to define the role of the ALWR requirements with regard to ALWR implementation and to define plausible scenarios for this implementation. Implementation refers to taking the ALWR from the design requirements established in the ALWR Program through detailed design, certification, licensing, and construction. Defining a scenario includes establishing assumptions regarding timing, need for the ALWR, the business entities involved, and the institutional factors such as the NRC and state regulators. Scenarios for both the Evolutionary ALWR and Passive ALWR are presented.

A discussion of plausible ALWR implementation scenarios is included in order to provide an understanding of the way in which the ALWR constructibility requirements, e.g., percent complete engineering, construction duration, relate to implementation.

As this document revesion is being released, no nuclear plants have been ordered in the U.S. for over 20 years, and there is substantial uncertainty surrounding many of the institutional aspects of new plant financing and regulation. Nevertheless, some trends are clear and reasonable inferences can be drawn. It is on this basis that the scenarios in Subsections 5.5 and 5.6 have been developed.

5.2 THE ROLE OF ALWR REQUIREMENTS IN IMPLEMENTATION OF THE ALWR

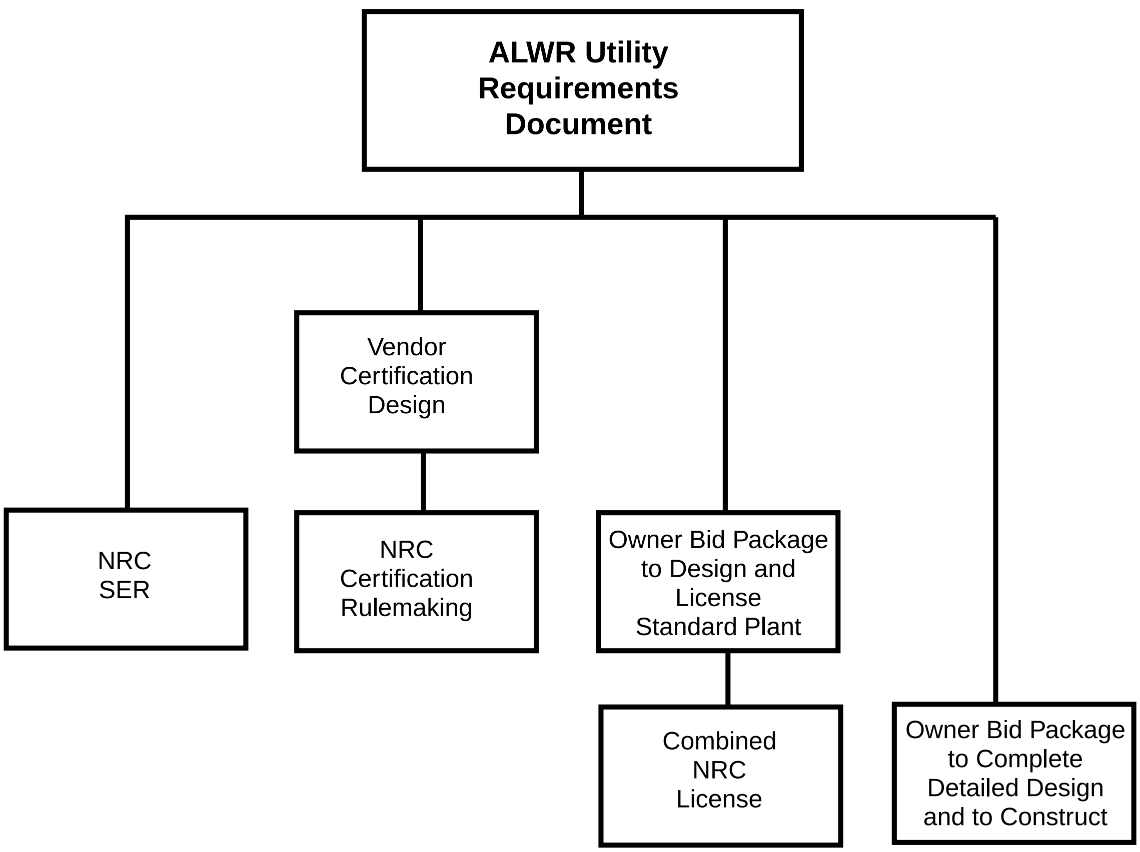
There are three primary roles of the ALWR design requirements which should be clearly evident in the ALWR implementation scenarios. These three roles are illustrated on Figure 4 and are discussed briefly below. From Figure 4 it is evident that the influence of the ALWR requirements is expected to pervade the entire ALWR implementation process from the early phase of regulatory stabilization to the late phases of plant investment, detailed design, licensing, and construction.

5.2.1 Establishing a Stabilized Regulatory Basis

The ALWR requirements establish a stabilized regulatory basis through actions in four areas: (1) licensing issue resolution, (2) regulatory requirement optimization, (3) establishing acceptable severe accident provisions, and (4) achieving a design consistent with regulatory criteria. These are discussed in the policy statement on regulatory stabilization (see Section 2.6). The key function of ALWR requirements was to obtain meaningful agreements with the NRC, reflected in the SER, in these four areas.

Figure 4.

ILLUSTRATION OF UTILITY REQUIREMENTS DOCUMENT ROLE IN ALWR IMPLEMENTATION



5.2.2 Providing Requirements for Certification Design

The second primary role of the ALWR requirements was to provide a set of standardized technical requirements to be met by the suppliers in their certification designs. It was in the suppliers' interest to meet the ALWR requirements because of the stabilized regulatory basis established by the requirements and because the requirements reflect the needs and desires of the electric utility industry which has the nuclear plant operating experience and which is likely to be a key participant in any ALWR investment group.

5.2.3 Providing Requirements for Owner Bid Packages

The third primary role of the ALWR requirements was to serve as the technical requirements for ALWR owner bid packages to design and license the standard plant. It is expected that any ALWR investor will insist on having an investment-ready design with high assurance of licensability. The ALWR requirements provide the foundation for this assurance, as shown on Figure 4 and discussed further in Subsection 5.3. Also, the ALWR requirements will be an input to the owner bid package to complete the detailed design and to construct.

5.3 THE FIRST ALWR ORDER

Although the ALWR requirements are intended to form the technical basis for a standardized plant design for which a number of units will ultimately be built, it is recognized that ordering the first ALWR unit in the U.S. will be a major step for any utility or investor group given the historical regulatory climate and public perception problems. The ALWR Requirements Document provisions which are considered essential to assure that this first ALWR order will be placed are discussed below.

First, there must be strong investor confidence that the risks associated with the investment to complete and operate the initial plant are minimal. To achieve this strong investor confidence, the ALWR requirements include the following:

- Requirements to provide high assurance of licensability. Such requirements include the four actions described above to achieve regulatory stability and a major emphasis on use of proven technology from the large LWR experience base which will be a significant factor in obtaining the NRC's authorization to operate.

- Requirements to provide efficient plant construction which is free of major problems and delays. This will be achieved by designing the ALWR for ease of construction and a short construction schedule, by requiring that engineering be 90 percent complete at the start of construction, and by specifying the latest, proven construction techniques such as modularization.

- Requirements to design the ALWR for high plant availability, based on careful incorporation of lessons learned from the operation of over 100 existing LWRs in the U.S.

Second, commercial and regulatory viability of the ALWR must be demonstrable without a prototype plant. The time and cost to design, construct, and gain significant operating experience for a prototype are considered prohibitive to the desire for a near-term (e.g., 5 to 10 years) commercial ALWR option. The ALWR Program philosophy of use of proven technology makes the no-prototype approach a feasible one for the ALWR.

5.4 ASSUMPTIONS FOR IMPLEMENTATION SCENARIOS

The following assumptions are made in defining the ALWR implementation scenarios.

5.4.1 Electricity Demand and Political Environment

It is assumed that there will be substantial demand for new base loaded generation in the U.S. Furthermore, it will become clear to government, to investors, and to the public that some significant fraction of our base load capacity expansion must be in the form of new nuclear power plants. Finally, this evident need for new nuclear generation will precipitate meaningful change in the political climate for nuclear power in the U.S.

The basis for these assumptions is straightforward and is largely derived from statistics and other well documented data. In the 1990's, electricity demand in the U.S. has been growing at a rate greater than that projected by most utilities. In this same period of time, nuclear has assumed a larger role in providing electricity, as a result of the number of nuclear plants which have recently come on line, and also because of the steadily improving capacity factor for operating nuclear plants. It is apparent to the public that the need for additional electricity, especially in some regions of the U.S. during periods of high demand, is more pressing than previously assumed and that the environmental consequences of fossil fuels is potentially severe. Finally, looking ahead, there is need to replace aging fossil-fired base loaded plants. (In 1995 nearly 50 percent of the nation's base loaded electrical plants were 30 years of age or older.)

5.4.2 Institutional Factors

The utility structure in the U.S. is changing, and there will be a significant transition from the traditional structure to that of separated generation and transmission companies. It is expected that the current trend toward independent power producers (IPP) will result in this type of organization taking on the role of building and operating electricity generating plants. This leads to the following ALWR implementation scenario assumptions:

- An entity other than a single utility (e.g., an investment consortium comprised of one or more utility companies, an NSSS vendor, and outside investors) will sponsor the detailed design, construction, and operation of the first series of ALWRs. It is anticipated that the utilities will play a key role in any investment consortium due to Public Utility Holding Company Act limitations on the fractions of project ownership which non-utility members can have.

- This consortium organization will be licensed by the NRC and will retain full measure of financial and legal accountability much like current utilities.

- The initial ALWR plants will be built in states where the financial risk to the Plant Owner from state regulatory rate actions is relatively low. Achieving this low risk will depend on the changed political climate noted above and efforts to provide information on ALWR improvements to these state regulatory bodies.

- Initial ALWR implementation will involve commitment for a single plant with potential for up to seven follow-on units, depending upon the financial success of the first unit. For all practical purposes, this means that the first ALWR will have to be commercially viable in its own right as noted in Section 5.3 above.

- This commercial viability is likely to result from the economic advantage of the ALWR compared to other central station alternatives. That is, in a given region where new generating capacity is required, the difference between the revenue to the ALWR-IPP (based on existing cost of power in that region) and the cost which the IPP must bear (based on ALWR cost goals) is assumed to result in an appropriate economic return on the ALWR investment.

5.4.3 Regulatory Structure

There has been progress towards a significantly streamlined, new plant regulatory structure. It is assumed that the first ALWR will be licensed via the process in 10CFR52 recently approved by the NRC. This process includes an early site approval, certification of a standardized nuclear plant design, and issuance of a combined construction-operation license for the first unit by the NRC. It is further assumed that any hearing that may arise from an amendment of the combined license or challenges that the combined license acceptance criteria have not been met, will not delay bringing the plant on line.

5.5 EVOLUTIONARY ALWR SCENARIO

The following is the Evolutionary ALWR implementation scenario based on the above set of assumptions. This scenario is shown schematically on Figure 5. Key schedule assumptions are listed in Table 2.

5.5.1 Timing

The Evolutionary ALWR scenario assumes in the near term the plant is on a schedule which is not constrained by political or extended licensing processes. That is, renewed demand for new base loaded nuclear plants will be contemporaneous with the certification of several vendor designs.

5.5.2 ALWR Requirements

The NRC has issued their Safety Evaluation Report for the Evolutionary ALWR Utility Requirements Document in NUREG-1242 that endorses URD requirements or provides a definitive NRC position on areas of regulatory concern that differ from URD positions. This indicates that the stable regulatory basis for design of ALWR evolutionary plants has been successfully achieved. The URD requirements together with the SER form the basis for the certification and detailed design of the first unit.

5.5.3 Certified Plant Designs

The scenario assumes that evolutionary plant designs have been certified by the NRC under 10CFR52 and that such designs, along with the requirements document provide a comprehensive licensing and technical basis for the detailed design of the plant. Note: As of the publication of this version of Volume I, this NRC design certification has been accomplished for two evolutionary ALWRs.

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FIGURE 5. PLAUSIBLE SCENARIO FOR FIRST EVOLUTIONARY ALWR IMPLEMENTATION

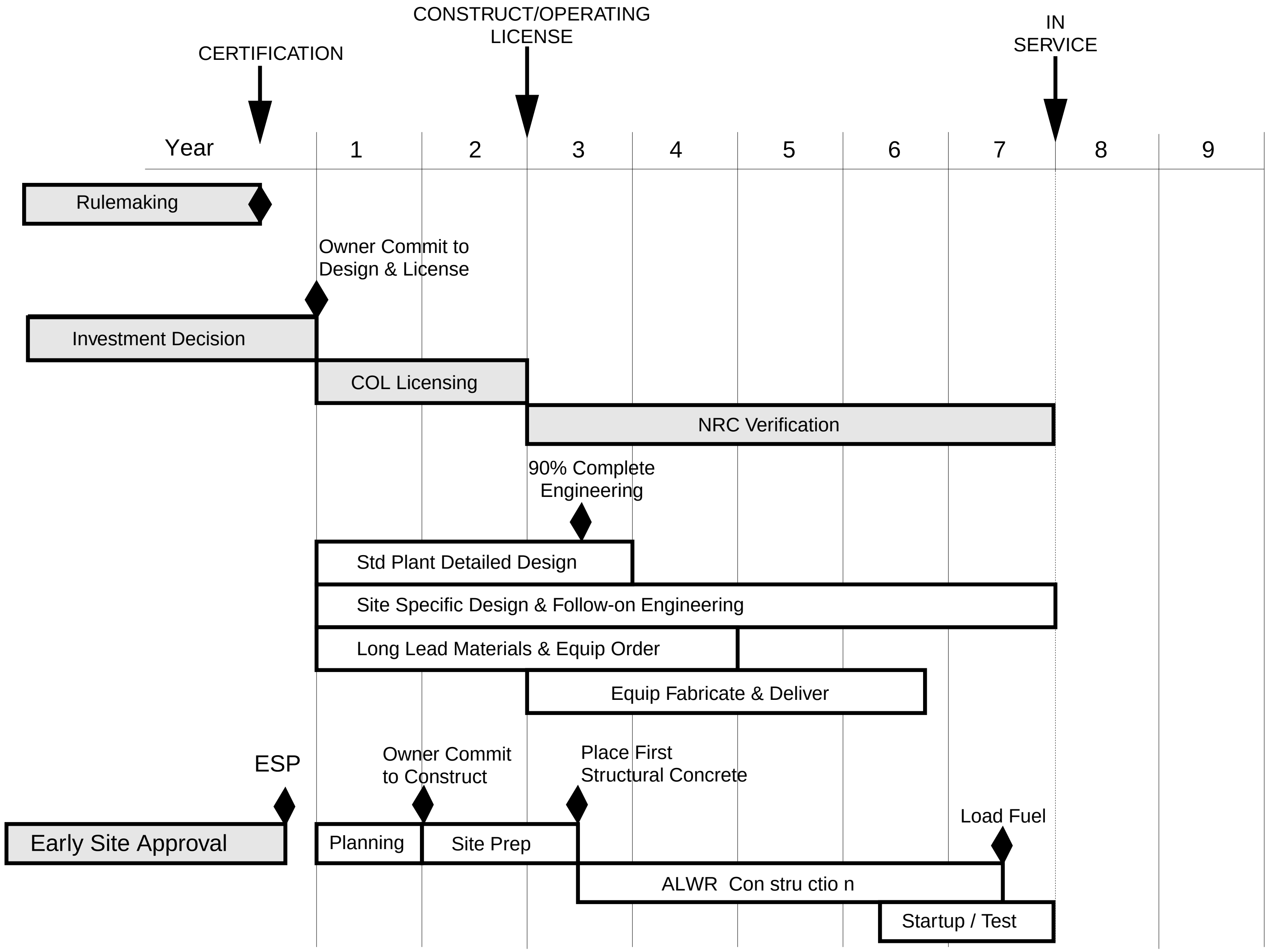

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Table 2. KEY ASSUMPTIONS FOR ALWR IMPLEMENTATION SCENARIOS

Implementation Activity	Evolutionary ALWR	Passive ALWR
Certification	Before C/OL initiation	Same as Evolutionary
Investment Decision to Design and License	Begin C/OL License	Same as Evolutionary
C/OL Licensing Duration	24 months	24 months
Detailed Design	- 30 months - Starts immediately after investment	Same as Evolutionary
Equipment Selection/Early Procurement	Start 30 months prior to first structural concrete milestone	Same as Evolutionary
Early Site Approval	Must be complete before initiating C/OL	Same as Evolutionary
Owner Commitment to Construct	12 months after C/OL initiation	Same as Evolutionary

5.5.4 Full Scope Standard Plant Designs

Under this scenario an ALWR consortium has been assembled and funds all work beyond Requirements Document completion, design certification, and First-of-a-Kind engineering. As shown on Figure 5, the investment is expected to occur in two phases: (1) site specific and standard plant design and combined licensing, and (2) construction. Important steps in the early standard plant design are as follows:

- The consortium selects from among the certified plant alternatives, one design for further development. It then sponsors detailed engineering to the level of completion which is specified in the ALWR requirements document and which is necessary to obtain the combined license. The detailed engineering is assumed to require 30 months on the basis that much of the detailed design of the evolutionary ALWR has already been completed. Although the bulk of initial capital cost comes in the second investment phase (equipment manufacture and construction) this first phase is nevertheless a significant phase. It involves expenditure not just for engineering but also for procurement of some plant equipment. The procurement action must proceed to the point where the equipment engineering can be completed and confidently employed in the plant design. In some cases this requires actual material ordering, particularly for long lead time materials that must be installed early in the construction schedule. Early procurement is assumed to start 30 months prior to the 'first structural concrete' milestone.

- Site selection and qualification. The site for the first ALWR is selected, qualified, and licensed under the early site approval provisions of 10CFR52. Issuance of the Early Site Permit facilitates the shortest overall schedule by allowing site preparation activities to proceed separately from COL proceedings; the duration from COL commitment to commercial operation could be reduced by about 12 months. Limited construction work that can proceed includes site preparation, erection of temporary facilities, and major excavation. Use of an existing site may allow the site selection process and qualification to proceed more quickly.

5.5.5 Licensing

The consortium is assumed to apply to the NRC for the combined construction-operation license in accordance with 10CFR52 at the time of the initial investment decision to 'design and license'. A period of 24 months has been derived from a sequence of events including applicant preparation of SSAR material to address the COL action items identified in each certified plant design, NRC review of the license application, owner response to NRC question generated related to COL action items, ACRS review, and public hearing prior to issuance of the combined license.

5.5.6 Construction

The owner commitment to construct is assumed to occur 12 months after initiation of design and COL licensing with an early site permit. At this point, the ALWR investment consortium must commit the balance of the initial capital investment for completion of the detailed design and construction. This is a very large commitment, but presumably one with manageable risk on the basis of the licensing process being well underway and the certification rulemaking having resolved all major regulatory issues that are not site unique. The construction period, that is the time from owner commitment to construct to commercial operation, is assumed to meet the 72 month ALWR top-tier requirement.

5.6 PASSIVE ALWR SCENARIO

The Passive scenario is conceptually similar to the Evolutionary ALWR scenario except as noted below. This scenario is shown schematically on Figure 6, and key schedule assumptions are listed in Table 2.

Although certification of the Passive ALWR will occur later than the evolutionary ALWR, it is expected to be in place before a consortium is ready to select a new design and so the certification is shown at about the same timeline as for the Evolutionary ALWR. The construction period, from owner commitment to construct to commercial operation, is assumed to meet the 60 month ALWR top-tier requirement.

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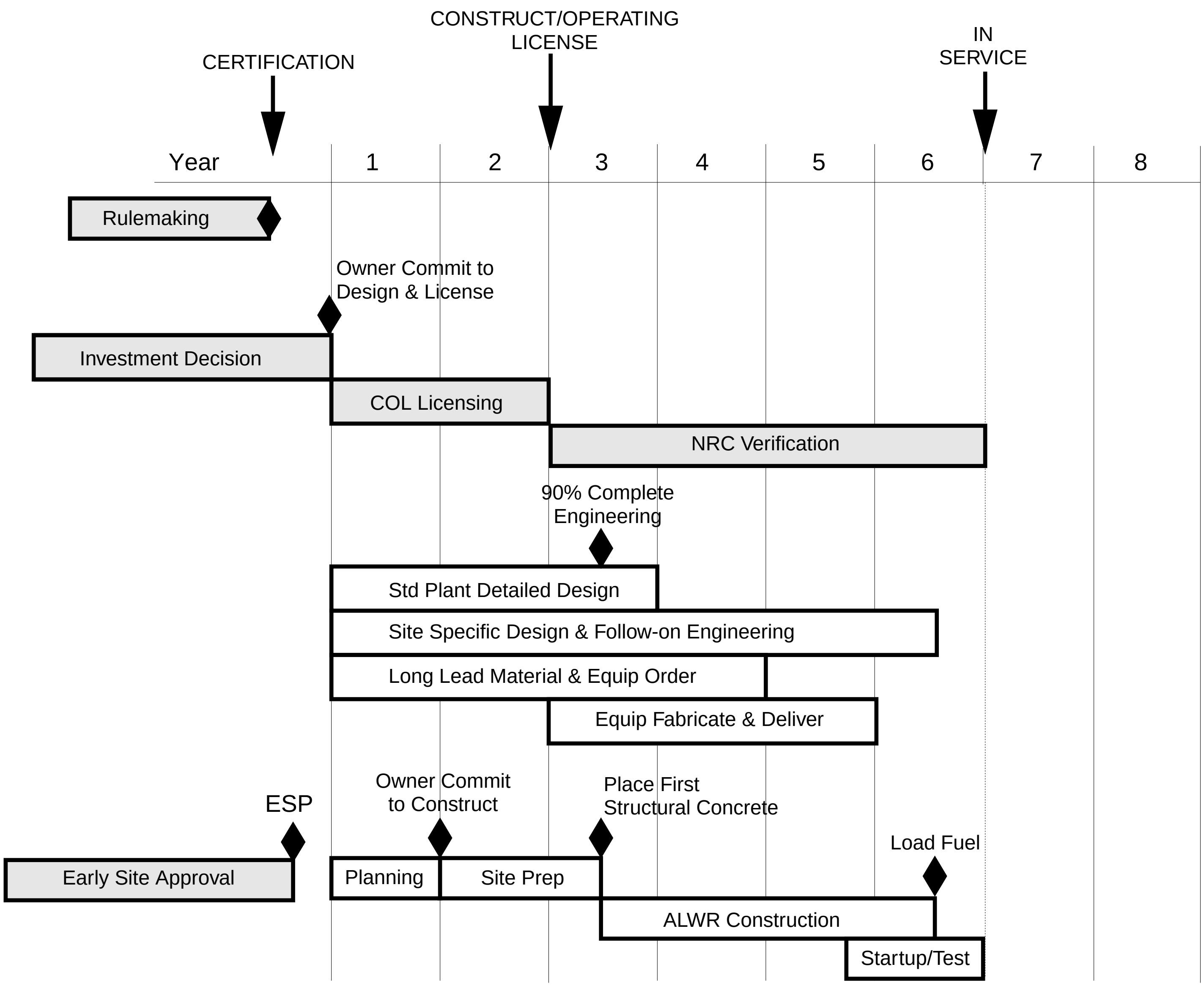
FIGURE 6. PLAUSIBLE SCENARIO FOR FIRST PASSIVE ALWR IMPLEMENTATION



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APPENDIX A DEFINITIONS OF ACRONYMS

The following list defines the acronyms used in Volume I, Policy and Top-Tier Design Requirements.

ABWR	Advanced Boiling Water Reactor
ac	alternating current
ALWR	Advanced Light Water Reactor
ARSAP	Advanced Reactor Severe Accident Program
ATWS	Anticipated Transient Without Scram
BWR	Boiling Water Reactor
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
Ci	Curies
C/OL	Construction/Operating License
dc	direct current
DOE	Department of Energy
DSER	Draft Safety Evaluation Report
EPG	Emergency Procedure Guidelines
EPRI	Electric Power Research Institute
g	gravity
HVAC	Heating, Ventilating, and Air Conditioning
IMS	Information Management System
IPP	Independent Power Producers
kwe	kilowatt electric
kWh	kilowatt hour
LDB	Licensing Design Basis
LOCA	Loss of Coolant Accident
LWR	Light Water Reactor

APPENDIX A DEFINITIONS OF ACRONYMS (CON'T)

M-MIS	Man-Machine Interface System
MWD/MTU	Megawatt Days/Metric Ton Uranium
MWe	Megawatts Electric
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NUREG	Nuclear Regulation
O&M	Operations and Maintenance
ORNL	Oak Ridge National Laboratory
QA	Quality Assurance
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor
RCS	Reactor Coolant System
SER	Safety Evaluation Report
SMB	Safety Margin Basis
SSE	Safe Shutdown Earthquake
TAG	Technical Assessment Guide

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

APPENDIX B GLOSSARY

AC (Alternating Current): Normal electric power, provided by ac power generators, contrasted with direct current (dc) which is supplied from batteries.

Accident Resistance*: Features and attributes designed into the ALWR to minimize the frequency and severity of initiating events which could challenge core damage prevention systems.

Active System*: A system that depends on major active components for operation. For example, active systems depend on pumps, large motors, ac power generators, etc.

Advanced Light Water Reactor (ALWR)*: A reactor, BWR or PWR, which meets the requirements of the ALWR Program.

ALWR Program*: A U.S. and international utility sponsored effort, managed by the Electric Power Research Institute (EPRI), to establish the technical foundation for the design of the next generation of nuclear power plants.

ALWR Safety Foundation*: The combination of Licensing Design Basis and Safety Margin Basis requirements, evaluations, and criteria.

Availability: The ratio of the time the unit or equipment is capable of operation to the total time in a given time period, usually a year. The ALWR is required to be designed for 87 percent availability.

Balance-of-Plant (BOP): All systems, structures, components, and facilities of the plant not a part of or included in the nuclear island.

Boiling Water Reactor (BWR): A nuclear power reactor cooled and moderated by ordinary water which is allowed to boil in the core to generate steam that passes directly to the turbine.

Boron: A chemical element that absorbs neutrons, thus controlling or stopping completely a nuclear chain reaction.

Capacity Factor: Ratio of energy actually produced to that which would have been produced in the same period (usually a year) had the unit operated continuously at full power (total energy output in kwh, divided by the product of the period in hours times the unit capacity).

Certification*: The legal process, defined in 10CFR52, for obtaining the Nuclear Regulatory Commission's approval of a standard design for a nuclear power plant.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.

APPENDIX B GLOSSARY (CONT'D)

CFR (Code of Federal Regulations): Written regulations of federal agencies. For example, Chapter I of Title 10 of the CFR (10CFR) contains the regulations of the NRC.

Combined License: The one-step construction/operating license issued by the NRC under 10CFR52. Today's operating plants were licensed with a two-step process, with issuance of a Construction Permit and an Operating License at different times.

Constant Dollar Analysis: Analysis made in a base year monetary value without including the effect of inflation (although real escalation is included in future years); economic goals in this document are based on a constant dollar analysis in the base year of 1994.

Constructibility*: Design attributes of the ALWR that provide a substantially improved construction schedule and a basis for investor confidence in this schedule.

Containment: Structures designed to prevent the escape of radionuclides from reactor to the outside environment in the event of an accident.

Containment Performance*: Ability of the containment to prevent the escape of radionuclides to the outside environment. Generally used in relation to mitigation after a severe accident.

Control Rods: Rods made of neutron-absorbing material, such as boron, that are used to regulate or halt nuclear fission in a reactor.

Coolant: A liquid or gas circulated through the core of a nuclear power reactor to transfer the heat of the fission process. Ordinary water is used in all operating U.S. commercial reactors and in the ALWR.

Core: The central portion of a nuclear reactor containing the fuel rods, moderator and control rods. Nuclear fission takes place and heat is generated within the core.

Core Damage: Damage to the fuel rods such that the core cannot be used for further power operation. Core damage is considered to start when the fuel rod cladding temperature exceeds a specified limit (2200^{o}F).

(Mean Annual) Core Damage Frequency (CDF): The calculated probability for core damage. For a reactor meeting ALWR requirements, the frequency would be less than one in 100,000 per reactor year.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

APPENDIX B GLOSSARY (CONT'D)

Cost of Electricity (also Busbar Cost or Revenue Requirement): Cost to the utility for electric power generated and delivered by a power plant. It is the total of all carrying charges and expenses.

* **Decontamination:** The removal of radionuclides from surfaces of pipes, components, etc. to reduce radiation levels to operating personnel.

Defense-in-Depth: The concept of designing nuclear power plants to avoid equipment failure, human error, and severe natural events, and to provide redundant and backup systems so that safety functions can be accomplished even in the event of the most unlikely malfunctions.

Design Margin: Capability beyond that required by design and regulation.

(Utility) Design Requirements: Mandatory features and attributes of the ALWR design which are specified in the Requirements Document and which are necessary to satisfy the Plant Owner that the plant will be excellent in all respects.

Deterministic Analysis: Methodology which assumes events progress in a completely determined manner-usually contrasted with probabilistic analysis.

Dose: Quantity of radiation absorbed, in units of Rem, by the body or by any portion of the body.

Emergency Core Cooling System (ECCS): A safety system that prevents core damage should a sudden loss of coolant occur.

Emergency Planning: A process in which the nuclear plant owner and surrounding community plan a response to protect the public in the event of a severe accident at the plant.

Engineered Safety System: A hardware system for preventing or mitigating the consequences of an accident.

Evolutionary ALWR*: Simpler, much improved versions of existing LWRs employing active safety systems.

Family of Plants: Group of plants that reference the same standard certified design and whose owners agree to construct, operate, maintain, and decommission the plants in a standardized manner.

Fission Product: A radioactive byproduct of nuclear fission.

Fuel Thermal Margin*: Fuel clad temperature or linear heat rate capability beyond regulatory limits.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.

VOLUME I: POLICY AND TOP-TIER DESIGN REQUIREMENTS

APPENDIX B GLOSSARY (CONT'D)

Grid: Utility electrical system transmitting and distributing power from power stations to consumers.

Human Factors: Elements affecting an individual's performance in a task.

Initiating Event: The first failure or action which could, in the absence of adequate operator action and/or engineered safety systems, lead to an accident.

Investment Protection*: Design features and margin in addition to that required by regulation which are intended to further reduce the possibility of a core damage accident.

Levelized Cost: A cost figure of merit derived from present-worth calculations, where a series of future costs varying over a specified period are converted to an equivalent present-day amount.

Licensing Design Basis* (LDB): Portion of the design which addresses NRC regulations and uses conservative, NRC-approved methods. Contrasted with Safety Margin Basis.

Light Water Reactor (LWR): A PWR or BWR in which ordinary water is the moderator and coolant. The ALWR is a light water reactor.

Loss-of-Coolant Accident (LOCA): A reactor accident that results in a loss of the water coolant from the reactor coolant system.

Man-Machine Interface System (M-MIS)*: All instrumentation and control systems which perform the monitoring, controlling, and protective functions associated with plant operation.

Megawatt: The unit by which the rate of production of electricity is usually measured: one megawatt equals one million watts or a thousand kilowatts.

Millirem: One one-thousandth of a rem, which is the unit that measures the effects of ionizing radiation on humans.

Mitigation: Action taken after an event such as core damage to lessen the severity of its consequences.

Moderator: A material used in a nuclear reactor to slow neutrons and thus increase the rate of nuclear fission.

Modularization*: A construction technique wherein portions of the equipment are assembled remote from their final location so as to speed up construction time.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.

APPENDIX B   GLOSSARY (CONT'D)

Nuclear Island: All systems, structures, and components that are a part of the reactor building, control building, and radwaste building of a BWR or a part of the primary containment, fuel facility, radwaste building, and auxiliary building of a PWR.

Operating Basis Earthquake (OBE): The level of earthquake ground motion severity above which plant shutdown is required.

Optimization Issue*: Regulation or regulatory guidance for which change is appropriate for the ALWR.

Passive ALWR*: Simpler, smaller and much improved LWRs employing primarily passive systems for essential safety functions.

Passive System*: Systems which employ primarily passive means (i.e., natural circulation, gravity, stored energy) for essential safety functions-contrasted with active systems. Use of active components is limited to valves, controls and instrumentation.

Plant Designer*: The organization responsible for implementing the utility design requirements and producing an NRC-certified plant design.

Plant Owner*: The organization which will purchase a certified design and hold the NRC Combined License.

Policy Statement*: Key ALWR Program principle which is central to achieving program objectives. In Volume I, reference is made both to utility principles on key aspects of design, development and ALWR Program implementation, and to certain formal safety principles of the Nuclear Regulatory Commission.

Pressurized Water Reactor (PWR): A nuclear power reactor cooled and moderated by ordinary water which is kept under pressure, thus preventing it from boiling at normal temperatures.

Probabilistic Risk Assessment (PRA): A methodology for determining risk based on the likelihood of events leading to a specified hazard or failure. For nuclear plants, the failure is core damage.

Radiation: The radioactive particles emitted by a radionuclide.

Radionuclide: A radioactive nucleus, produced either by fission (i.e., a fission product) or by capture of a neutron.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.

APPENDIX B GLOSSARY (CONT'D)

Reactor Coolant System (RCS): The system in an LWR that circulates coolant (i.e., water) around the fuel rods in the reactor core. The heat is picked up from the reactor fuel in a PWR and is transferred to the steam generators for conversion to steam and then to electricity. In a BWR, the heat converts the water to steam in the reactor vessel.

Reactor Vessel: The large, heavy vessel in which the core is located and which forms part of the boundary of the RCS.

Regulatory Requirement: A feature or capability specifically demanded by regulation or by supporting regulatory guidance.

Regulatory Requirement: A feature or capability specifically demanded by regulation or by supporting regulatory guidance.

Regulatory Stabilization*: An ALWR Program policy wherein the NRC's regulatory issues are defined and addressed in advance of final design such that the need for plant changes after the start of construction is minimized.

Reliability: The design attributes which assure that equipment will operate for a given time period under stated operating conditions.

Rem (Roentgen Equivalent Man): A standard unit of radiation dose. Frequently, radiation dose is measured in millirems for low-level radiation. (1Rem=10mSv)

Requirements Document*: A statement of utility desires for the next generation of nuclear power plants composed of a comprehensive set of design requirements for ALWRs.

Rulemaking: The process by which a Federal department or agency modifies regulation. For example, the process by which the Nuclear Regulatory Commission modifies Chapter I of Title 10 of the Code of Federal Regulations (10CFR).

Safe Shutdown Earthquake (SSE): The earthquake severity for which the plant is designed to be able to be safely shut down.

Safety Analysis Report (SAR): _A licensing applicant's summation of the descriptions and analyses necessary to demonstrate the safety of actions proposed before the NRC.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.

APPENDIX B GLOSSARY (CONT'D)

Safety Evaluation Report (SER): A summation of the NRC's safety review concerning action proposed by a licensee. That proposal is often in the form of a Safety Analysis Report (SAR). Generally issued first as a draft SER or DSER. The ALWR Program expects to get an SER on the Requirements Document.

Safety Margin Basis*: Portion of the ALWR Safety Foundation which provides margin beyond the minimum required by the Code of Federal Regulations and uses best-estimate methods.

Safety-related: Describes NRC-regulated systems, structures, and components relied upon to maintain the reactor coolant boundary, to shut down the reactor, or to prevent or mitigate the consequences of accidents with off-site effects.

Scram: A rapid shut down of a nuclear reactor accomplished by moving control rods into the core to halt fission.

Severe Accident: An event or sequence of events in which core damage occurs.

Severe Accident Management: Measures taken by the plant staff to terminate core damage and to maintain containment integrity.

Shielding: A mass of material that blocks radiation, protecting personnel or equipment from radiation injury, damage or interference.

Soluble Boron: A neutron absorber dissolved in the coolant to aid in controlling the reactor.

Source Term: The quantities of fission products assumed to be released from the containment following an accident with core damage.

Standardization: Life-cycle uniformity in the design, construction, operation, and decommissioning of a family of plants based on a common certified design, including physical and operational duplication among units, internal consistency of design within a unit, simplification, multi-site design enveloping, and uniformity in requirements.

Station Blackout: The complete loss of ac power other than power from station batteries through inverters.

Technical Specifications: Limits, controls, and surveillance requirements on process variables and equipment in an operating nuclear plant which cannot be changed without prior permission from the NRC.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.

APPENDIX B GLOSSARY (CONT'D)

TID 14844: An early 1960's technical report, still applicable today, which established the basis for the source term assumptions used to license nuclear plants.

Trip: A rapid shut down of reactor, turbine, or other piece of equipment.

Unit (or Plant): Individual power generating facility, including all associated support facilities.

Utility Steering Committee*: Senior executives from U.S. and international utilities who provide overall direction of the ALWR Program.

*Term or usage specific to ALWR. Other terms are common nuclear industry usage.