Volume 1

Study of Construction Technologies and Schedules, O&M Staffing and Cost, Decommissioning Costs and Funding Requirements for Advanced Reactor Designs

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Study of Construction Technologies and Schedules, O&M Staffing and Cost, and Decommissioning Costs and Funding Requirements for Advanced Reactor Designs

Volume 1 Contents

Glossary 5

Executive Summary 7

1. Introduction...18
- 1.1 Purpose 18
- 1.2 Scope 18
- 1.3 Objectives 19
- 1.4 Reactor Types...20
  - 1.4.1 Advanced Boiling Water Reactor 20
  - 1.4.2 Economic Simplified Boiling Water Reactor 21
  - 1.4.3 AP1000..21
  - 1.4.4 ACR-700 21
  - 1.4.5 Summary 22

2. Construction Technologies and Schedules for Advanced Reactor Designs..........................23
- 2.1 Introduction 23
- 2.2 Construction Schedule Evaluation 24
  - 2.2.1 Vendor Data 25
  - 2.2.2 Evaluation..30
  - 2.2.3 Conclusions 38
- 2.3 Conceptual Deployment Schedule 41
  - 2.3.1 Evaluation..41
  - 2.3.2 Results and Conclusions...45
- 2.4 Evaluation of Construction Technologies and Module Fabrication Facilities 46
  - 2.4.1 New Construction Technologies 46
  - 2.4.2 Module Fabrication Facilities..48
- 2.5 CII Project Definition Rating Index Evaluation..50
- 2.6 Assessment of Labor Availability 51
  - 2.6.1 National Trends 51
  - 2.6.2 Recent Project Labor Surveys 53
  - 2.6.3 Labor Assessment Conclusions..55
- 2.7 Conclusions 55
- 2.8 Recommendations 58

Appendix 2A Prefabrication, Preassembly, Modularization, and Offsite Assembly.................................59
Appendix 2B Assessment of Reactor Types Using the Construction Industry Institute Project Definition Rating Index 73
Appendix 2C Application of Seismic Base Isolation to Nuclear Power Plants...82

3. O&M Staffing and Cost Development for Advanced Reactor Designs 93
3.1 Overview and Approach..93
3.1.1 Overview 93
3.1.2 Approach and Assumptions..94
3.2 Operations and Maintenance Staffing Development..96
3.2.1 Staff Development Methodology 96
3.2.2 Staff Description By Department 98
3.2.3 Staff Development During Construction 104
3.3 Operations and Maintenance Cost Development 107
3.3.1 Staff Cost Development 107
3.3.2 O&M Cost Items and Estimates 108
3.3.3 Total O&M Operating Cost and Cost Per Net MWe..109
3.3.4 Fuel Cost Estimates 109
3.4 Conclusions 109
3.5 References 111
4. Decommissioning Costs and Funding Requirements for Advanced Reactor Designs.......135
4.1 Introduction 135
4.2 Background 135
4.2.1 Regulations and Regulatory Guidance 136
4.2.2 Regulatory History 136
4.2.3 Decommissioning Alternatives...136
4.2.4 Regulatory Process 137
4.2.5 Specific Regulations...138
4.2.6 Content and Format of the Decommissioning Estimates.......................................140
4.3 Decommissioning Activities 141
4.3.1 Preparations..142
4.3.2 Decommissioning Operations...143
4.3.3 Site Restoration 146
4.4 Basis for the Cost Estimates..146
4.4.1 Methodology 146
4.4.2 Financial Components of the Cost Model 150
4.4.3 Site-Specific Considerations...153
4.4.4 Estimating Assumptions (Economic) 158
4.5 Cost Estimates Summary..162
4.5.1 Comparison Among Advanced Reactor Designs 164
4.5.2 Comparison With Contemporary Reactor Designs 165
4.6 Areas of Future Cost Savings...167
4.6.1 Technology..167
4.6.2 Regulatory 170
4.6.3 Waste Disposal..170
4.7 Decommissioning Costs and NRC Funding Requirements...171
4.7.1 NRC Minimum...171
4.7.2 Decommissioning Funding Guidelines..172
4.7.3 History and Precedent...173

List of Tables

Table 1-1. Summary of Reactor Types Studied 22
Table 2-1. Vendor Response to Request for Detailed Data....25
Table 2-2. Vendor Response to Request for Simplified Schedule Information....27
Table 2-3. Advanced Reactor Schedule Durations for First New Unit in United States....30
Table 2-4. Historical, Sustained Rates for U.S. Nuclear Plant Construction....31
Table 2-5. Comparison of Reactor Building Commodity Installation Rates....32
Table 2-6. Construction Schedules for U.S. Nuclear Plants 1970-1986....34
Table 2-7. Construction Schedules for U.S. Nuclear Plants Prior to 1977....35
Table 2-8. Advanced Reactor Construction Schedules....37
Table 2-9. Advanced Reactor Construction Technologies....46
Table 2A-1. Strategic Analysis Level 1....67
Table 2A-2. Case No. 1: 40% PPMOF....69
Table 2B-1. PDRI Project Elements Key to Successful Implementation....74
Table 2B-2. Drill-Down Analysis of PDRI Results....80
Table 3-9. O&M Cost Estimates....111
Table 3-1. Staff Titles by Position....114
Table 3-2. Staffing By Title....117
Table 3-3. EUCG Staffing....128
Table 3-4. 10 CFR 50.54(M) Minimum Requirements Per Shift for Onsite Staffing of Nuclear Power Units by Operators and Senior Operators Licensed Under 10 CFR Part 55 (Notes 1 and 2)....130
Table 3-6. Plant Operational Staff Development During Construction....132
Table 3-7. O&M Cost Calculation....133
Table 3-8. Outage Cost Estimate....134
Systems/Structures Decommissioning Cost Summary....164
Table 4-1. Decommissioning Study — Plant Equipment Inventories....175
Table 4-2. Decommissioning Study - Plant Structures Inventories....177
Table 4-3. DECCER Model Inputs....178
Table 4-4. Decommissioning Waste Disposition Summary....180
Table 4-5. Decommissioning Staffing Levels....181
Table 4-6. Summary of Decommissioning Costs....182
Table 4-7. Schedule of Annual Expenditures by Decommissioning Period for the ABWR....183
Table 4-8. Schedule of Annual Expenditures by Decommissioning Period for the ACR-700, Unit 1....184
Table 4-9. Schedule of Annual Expenditures by Decommissioning Period for the ACR-700, Unit 2....185
Table 4-10. Schedule of Annual Expenditures by Decommissioning Period for the AP1000....186
Table 4-11. Schedule of Annual Expenditures by Decommissioning Period for the ESBWR....187
Table 4-12. ABWR DECON Decommissioning Cost Estimate....188
Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate....198
Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate....210
Table 4-15. AP1000 DECON Decommissioning Cost Estimate....223
Table 4-16. ESBWR DECON Decommissioning Cost Estimate....234
Table 4-17. Present Value of the Cost of Decommissioning....245

List of Figures

Figure 2-1. Conceptual First Plant Deployment Schedule....43
Figure 2A-1. Decision-Timing Map....65
Figure 2A-2. Decision-Making Flowchart....66
Figure 2A-3. Participant Prefabrication and Modularizaiton Ratings....70
Figure 2A-4. Relative Category Ratings....71
Figure 2B-1. ABWR PDRI Scores....77
Figure 2B-2. ACR-700 PDRI Scores....77
Figure 2B-3. AP1000 PDRI Scores....77
Figure 2B-4. ESBWR PDRI Scores....78
Figure 2B-5. PDRI Vendor Self-Rating Results....78
Figure 2B-6. Total Scores Across Reactor Types....79
Figure 3-1. Typical Site Organization....98
Figure 3-2. Engineering Department Organization....100

Volume 2 Contents

MPR-2627, DOE NP2010 Construction Schedule Evaluation

Executive Summary
1. Introduction
2. Discussion
3. Conclusions and Recommendations
4. Plant-Specific Conclusions and Recommendations
5. References

Appendices
    A Toshiba ABWR
    B General Electric ESBWR
    C AECL ACR-700
    D Westinghouse AP1000
    E Summary of Plant Design Characteristics
    F Glossary of Terms and Acronyms

MPR-2610, Application of Advanced Construction Technologies to New Nuclear Power Plants

Executive Summary
1. Introduction
2. Conclusions and Recommendations
3. Discussion
4. References

Appendices
    A Steel-Plate Reinforced Concrete Structures
    B Concrete Composition Technologies
    C Fiber-Reinforced Polymer Rebar Structures
    D High Deposition Rate Welding
    E Robotic Welding
    F 3D Modeling
    G Positioning Applications in Construction (GPS and Laser Scanning)
    H Open Top Installation
    I Pipe Bends vs. Welded Elbows
    J Precision Blasting/Rock Removal
    K Cable Pulling, Termination and Splices
    L Advanced Information Management and Control
    M Prefabrication, Preassembly, and Modularization
    N Construction Schedule Improvement Analysis
    O Glossary of Acronyms

Glossary

3D CAD	Three Dimensional Computer-Aided Drafting
A&G	Administrative & General Cost
ABWR	Advanced Boiling Water Reactor
ALMR	Advanced Liquid Metal Reactor
ASCE	American Society of Civil Engineers
ACR-700	700 MWe Advanced CANDU Reactor
AECL	Atomic Energy of Canada, Limited
ALARA	As Low As Reasonably Achievable
ANO	Arkansas Nuclear One
AP1000	1200 MWe Advanced Passive Reactor
BWR	Boiling Water Reactor
BOP	Balance of Plant
BWR6	Sixth Generation Boiling Water Reactor
CANDU	Canadian Deuterium Reactor
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CII	Construction Industry Institute
CRDM	Control Rod Drive Mechanism
DECCER	A proprietary decommissioning estimating code
DECON	Soon after a nuclear facility closes, equipment, structures, and systems of the facility containing radioactive contaminants are removed or decontaminated to a level that permit release of the property and termination of the NRC license.
DOC	Decommissioning Operations Contractor
ENTOMB	Radioactive contaminants are encased in a structurally sound material such as concrete, and appropriately maintained and monitored until the radioactivity decays to a level permitting release of the site.
ESBWR	Economic Simplified Boiling Water Reactor
ESP	Engineering Support Personnel
ESP	Early Site Permit
EPA	Environmental Protection Agency
EUCG	Electric Utility Cost Group
FFD	Fitness for Duty
FFD	Friction Pendulum System
FSAR	Final Safety Analysis Report
GTCC	Greater Than Class C
HP	Health Physics
HVAC	Heating, Ventilation, Air Conditioning
I&C	Instrumentation and Control
ICI	Incore Instrumentation
INPO	Institute of Nuclear Power Operations
ISI	In-Service Inspection
IT	Information Technology
ITAAC	Inspection, Tests, Analyses, and Acceptance Criteria
'Just-in-time'	Delivery of critical components at the time of installation
LLRW	Low-Level Radwaste
LSA I, II, III	Low Specific Activity (category for transportation of radioactive waste)
LTP	License Termination Plan
LWA	Limited Work Authorization
MARSSIM	Multi-Agency Radiation Survey & Site Investigation Manual
MOU	Memorandum of Understanding
MWe	Megawatt Electric
MWt	Megawatt Thermal
'Nth'	nth unit is number 5 or more in a series production
NDE	Nondestructive Examination
NEI	Nuclear Energy Institute
NIST	National Institute of Standards and Technology

NFPA	National Fire Protection Association
NRC	Nuclear Regulatory Commission
NRR	NRC's Office of Nuclear Reactor Regulation
NSP	Nuclear Steam Plant
NSSS	Nuclear Steam Supply System
NWPA	Nuclear Waste Policy Act
O&M	Operations & Maintenance
ORISE	Oak Ridge Institute for Science and Education
P&ID	Piping and Instrumentation Diagram
PBMR	Pebble Bed Modular Reactor
PCV	Primary Containment Vessel
PDRI	Project Definition Rating Index
PGE	Portland General Electric Company
PPM	Prefabrication, Preassembly, Modularization
PPMOF	Prefabrication, Preassembly, Modularization, and Offsite Assembly
PSDAR	Post-Shutdown Decommissioning Activities Report
PWR	Pressurized Water Reactor
RAB	Reactor Auxiliary Building
RFI	Request for Information
RO	Reactor Operator
RP	Radiation Protection
RPV	Reactor Pressure Vessel
SAFSTOR	A nuclear facility is maintained and monitored in a manner that allows the radioactivity to decay; afterwards, it is dismantled.
SCM	Supply Chain Management
SCO I, II	Surface Contaminated Object (category for transportation of radioactive waste)
SDC	Shutdown Cooling
SGR	Steam Generator Replacement
SRO	Senior Reactor Operator
STA	Shift Technical Advisor
TVA	Tennessee Valley Authority

Executive Summary

Since the early 1990s, the development of advanced nuclear plant designs has increased the interest of power companies in new nuclear development. These new designs are based on the latest technological innovations and promise short construction periods, low operating costs, and more economical decommissioning costs.

In this country, the last order for a nuclear power station was placed in the late 1970s. With very few exceptions, these plants were individually designed and constructed with little or no standardization in a cost environment where electric rates were regulated. Most of the later plants saw large cost increases and much longer construction times compared to their original estimates.

Today, standardized plants and advances in construction techniques promise to reduce construction costs and schedule. Nuclear plant construction experience overseas has proven that power stations can be constructed on a fixed schedule. In addition, new advanced reactor designs have been introduced that are specifically designed for reliable and efficient operation, low-cost construction, and enhanced safety.

In support of the Department of Energy's Nuclear Power 2010 program, Dominion Energy, in cooperation with industry partners, performed a study under Cooperative Agreement DE-FC07-03ID14492 of the impact of the significant advances that have been made in nuclear operations and construction techniques. Many of these advances and methodologies have not been studied in this country nor have they been tested in U.S. nuclear construction. Four advanced reactor designs were analyzed as part of the study:

- General Electric's and Toshiba's Advanced Boiling Water Reactor (ABWR)
- General Electric's Economic Simplified Boiling Water Reactor (ESBWR)
- Westinghouse's Advanced Passive pressurized water reactor (AP1000)
- Atomic Energy of Canada, Limited's Advanced CANDU Reactor (ACR-700)

All of these designs are near-term deployable and incorporate advancements of proven technology.

Each of the reactor vendors provided data packages to support the study and responded to a series of follow-up questions that were intended to try to normalize the level of detail for each reactor.

This report is a compilation of five separate studies. Bechtel Power Corporation performed the study of advanced reactor construction technologies and schedules. Dominion Energy conducted the study of operations and maintenance (O&M) staffing and costs, with advice and assistance from Entergy Corporation and Tennessee Valley Authority (TVA). TLG Services (a subsidiary of Entergy Nuclear) performed the decommissioning costs and funding requirements study.

DOE, Dominion Energy, Entergy Nuclear, and Bechtel contributed to cost share this effort. DOE also contracted MPR Associates (Contract DE-AT01-020NE23476) to perform two studies—an evaluation of reactor construction schedules and a review of advanced construction technologies.

Bechtel and MPR, using the same information from the reactor vendors, performed independent studies of advanced reactor construction technologies and schedules. The goal of these parallel reports was to provide two viewpoints on the status of nuclear construction schedules and technologies. Bechtel reviewed the overall construction schedules for project readiness using construction industry methods. They also focused on incorporating knowledge and judgment based on their extensive power plant construction experience. MPR focused on evaluating details of the vendor schedules for completeness and reasonableness to identify project risks and recommend actions to mitigate the risks. The MPR report, "DOE NP2010 Construction Schedule Evaluation," is included in Volume 2. In addition, MPR evaluated advanced construction technologies in order to identify any that would significantly shorten construction schedules. The technologies to be evaluated were selected in collaboration with the Bechtel team. This report, entitled, "Application of Advanced Construction Technologies to New Nuclear Power Plants," is also included in Volume 2.

Advanced Reactor Construction Technologies and Schedules

Study Concept

Since construction was completed at Watts Bar in 1996, no new nuclear power plant construction efforts have taken place in the United States. However, construction technologies have continued to improve and new approaches have been used on reactor construction projects overseas. Recent projects in Europe and Asia have proven that new methods of construction, including modularization and open top construction, can reduce the time and staff needed to build a new nuclear power plant.

The vendors for each of the advanced reactor designs that were analyzed for this study have focused on reducing construction durations to the extent practical including the time from the contract effective date to commercial operation, first concrete to fuel load, and fuel load to commercial operation. The schedules and approaches being proposed by the reactor vendors were evaluated to determine if they are reasonably achievable and if other, newer construction technologies are available to further improve construction schedules.

Originally, this evaluation was to be a quantitative assessment to validate construction schedule claims for the advanced reactor designs. However, none of the reactor vendors presented sufficient information to perform detailed schedule assessments of resource loadings, durations, logic, etc. Because of the lack of detailed information, only summary-level qualitative assessments could be performed. Following is a list of the assessments performed as part of this study:

- The likelihood of the vendors achieving their stated construction schedules was assessed based on two comparisons:

(1) The estimated installation rates for reactor building concrete, piping, and cable for the advanced reactor plants were compared with sustained rates for nuclear power plant construction to determine if the installation rates assumed for the new plants are reasonable. For example, it may be possible to place 10,000 cubic yards of concrete in three days if it is a mass foundation placement. It is not reasonable to assume the placement of 10,000 cubic yards of concrete in three days in a detailed wall and floor configuration.

(2) The construction schedules of the advanced reactors were compared with historical construction schedules for nuclear power plants built in the United States. This comparison was aimed at determining if any previous projects (without the benefits of simplified designs, 3-D design tools, modularization, and other advanced construction technologies) had achieved, or were expected to achieve, construction schedules comparable to those estimated for the advanced reactors.

- A conceptual schedule for the deployment of the first new commercial nuclear power plant in the United States was developed. This milestone summary schedule integrates the Nuclear Regulatory Commission (NRC) licensing process with the necessary engineering, procurement, fabrication, construction, training, and startup activities for plant deployment.

- Potential new construction technologies and module fabrication facilities were evaluated. To evaluate the construction technologies, reviewers relied on the more detailed evaluation of construction technologies performed by MPR in their report, "Application of Advanced Construction Technologies to New Nuclear Power Plants," which is included in Volume 2. Insights from Bechtel’s power plant construction experience and additional independent research were provided to supplement the MPR evaluation. Module fabrication facilities were evaluated based on visits made to several facilities in the United States and Japan.

- An assessment of U.S. labor availability for new plant construction was performed to underscore the need for early, ongoing, and thorough planning to ensure adequate labor resources.

- Two evaluations were performed, following guidance from the Construction Industry Institute (CII), that rated each design according to (1) the likelihood of successful project implementation and (2) the extent to which prefabrication, preassembly, modularization, and offsite assembly can and should be considered in its construction.

Study Conclusions and Recommendations

The conclusions of the evaluation are as follows:

- The advanced reactor construction schedules proposed by the vendors are shown in the following table.

Advanced Reactor Schedule Durations for First New Unit in United States

Schedule Activity	Duration (in months)				
	ABWR (GE)	ABWR (Toshiba)	ACR-700	AP1000	ESBWR
Contract effective date to commercial operation	*	72	63	69	*
First concrete to fuel load	43	36	40	36	39
Fuel load to commercial operation	7	7	8	6	*

* Not provided.

None of the reactor vendors presented sufficient information (such as resource loadings, durations, logic, etc.) to support a detailed assessment of their schedules. More detailed and quantitative assessments are not possible without a clear understanding of the design and the material quantities and manpower used to establish the activities in each vendor’s schedule.

Because of the lack of detailed information, only summary-level, qualitative reviews could be performed. Based on these qualitative reviews, the first concrete to fuel load durations for the GE ABWR (43 months), ACR-700 (40 months), and ESBWR (39 months) should be achievable for the first plants constructed in the United States. The Toshiba ABWR and Westinghouse AP1000 schedules of 36 months are viewed as very aggressive and may not be achievable until the U.S. nuclear construction program has been restarted and the U.S. nuclear experience base has been reestablished. The following conditions must be met for any of the vendors to achieve their stated construction schedules:

- Design is complete and regulatory issues are fully resolved before first concrete is placed.
- Nuclear materials are available at the appropriate time in correct and sufficient quantity.
- The project is located in an area where sufficient labor is available.
- Modularization is used to the extent portrayed by the vendors.

The schedules presented for the ABWR, ACR-700, and AP1000 are well thought out. They rely extensively on parallel construction through modularization and open top construction. No obvious logic or other flaws were identified in these schedules. Minimal schedule information was provided for the ESBWR but a parallel construction approach was also identified.

- Where information was received from the vendors, reactor building installation rates for the advanced reactor plants generally compare well with past nuclear plant construction projects:

  - For reactor building concrete, the ABWR, ACR-700, and AP1000 installation rates compare well with past projects. No installation rates were provided for the ESBWR, but the quantity of concrete to be placed appears reasonable for a first concrete to fuel load duration of 39 months.

  - For reactor building piping, the ABWR and ACR-700 installation rates compare well with past projects. No piping quantity or installation rates were provided for the AP1000. The piping quantity for the ESBWR appears to be significantly higher than expected and further details are needed before a conclusion can be reached.

  - For reactor building wire and cable, the ACR-700 installation rates compare well with past projects. The ABWR rates provided by Toshiba could be achieved with increased craft manhours and longer durations. For the AP1000 and ESBWR, the amount of wire/cable to be installed appears reasonable.

- The advanced reactor construction schedules are comparable to the actual nuclear plant construction schedules that were achieved before the extended delays of the late 1970s and later. However, the majority of plants built in the early to mid 1970s were small (less than 500 MWe) and medium-sized (500-1000 MWe) plants. The only large (1000 MWe or greater) plant to achieve a construction duration comparable to the new reactors was Zion 1, which was placed in service in December 1973 and had a site preparation to fuel load duration of approximately 60 months.

  The advanced reactor construction schedules do compare well with the *planned* construction schedules for various medium-sized and large units constructed through the mid 1980s. These planned schedules were the "going-in" plans developed to complete construction before the various delays that were experienced on individual projects.

- The conceptual plant deployment schedule indicates that the first in a series of new nuclear plants could be in service approximately 10 years from the start of the project. Some opportunities to improve on this schedule may exist depending on the reactor design and site chosen. Further effort is needed to focus on reducing the time required from the contract effective date to commercial operation. In addition to the plant construction sequence, several key activities must be further evaluated to reduce this duration including: plant simulator design, manufacture, and operator training; procurement of long-lead items such as reactor vessels and steam generators; the NRC Inspections, Test, Analyses, and Acceptance Criteria (ITAAC) process; and startup to commercial operation activities.

- Of all the construction technologies evaluated, parallel construction through modularization and open top construction offer the greatest potential to help achieve the aggressive construction schedules proposed by the vendors. These construction techniques hold great promise. In the past, the use of modularization and open top construction has been limited in nuclear construction as a result of two factors—fitup between modules and crane capacities. Both of these constraints have been eliminated or reduced by technological improvements in the last decade.

Adaptation of technologies, such as composite steel construction and seismic base isolation, may also help increase the probability of achieving aggressive schedules by dramatically altering the sequence and requirements for construction. Neither of these techniques is proposed to any significant extent in the designs reviewed, though the AP1000 and ABWR do have some composite construction areas planned. None of the reactor vendors have proposed seismic base isolation.

- Based on the tours of module fabrication facilities in the United States and Japan, a strong international capability exists to support the modularization approaches proposed by the vendors for their advanced reactor designs. The fabrication facilities located in Japan have extensive commercial nuclear power experience. The U.S. shipyards could adapt their U.S. Navy experience for commercial nuclear power applications. Current and projected workloads at each facility indicate the ability to handle new module fabrication work associated with advanced reactor construction over the next 5 to 10 years.

- A shortage of qualified labor appears to be a looming problem; however, there are several mitigating measures that can be taken to minimize the impact of low skill levels and short supply. Both issues can be worked around by shifting work to areas of the country where skilled labor shortages are not an issue. This is most effectively done through modularizing portions of the plants to be built. Also, aggressive programs for training craftsmen before and during the construction phase of the project will help ensure that the necessary construction skills are available.

The construction approaches, schedules, and technologies evaluated in this report present a basis for optimism when considering new nuclear generation and the ability to achieve short construction schedules for advanced reactors.

Recommendations from the evaluation are as follows:

- Each vendor should develop resource-based schedule durations and logic information so that quantitative assessments can be performed to optimize the construction schedule. In addition to the plant construction sequence, several key activities should be further evaluated to reduce the time from contract effective date to commercial operation including: plant simulator design, manufacture, and operator training; procurement of long-lead items such as reactor vessels and steam generators; the NRC ITAAC process; and startup to commercial operation activities.

- Construction approaches should maximize the use of advanced construction technologies. The greatest emphasis should be placed on parallel construction through modularization and open top construction. Several of the technologies, particularly seismic base isolation, need further technical development by the reactor vendors.

- A shortage of qualified labor will be a significant issue for new nuclear plant construction projects. Early, ongoing, and thorough planning should be performed to ensure the necessary construction skills are available.

Operations and Maintenance Staffing and Costs

Study Concept

The O&M cost of a power station is used to measure the operating cost of the plant. This cost is expressed as a unit of electric net generation, or megawatts electric, and reflects all costs that are incurred to operate and maintain the plant. More than half this cost typically comes from salaries and benefits for the plant staff, while the remaining cost includes parts, material and equipment costs for maintaining plant equipment, fees, insurance, overhead costs, and short-term contract services. (Fuel is not included, as it is usually calculated separately.)

Since staff costs typically account for more than half of a plant’s O&M cost, reducing staff should reduce O&M costs. Design concepts for new plants have focused on reducing the operations burden and thereby reducing staff, which leads to staff reduction and should ultimately lower operating costs.

This study used a task-based approach to determinine plant staff requirements for specific plant operation tasks. Starting with the staffing profile of a top-rated plant (North Anna), the study team reviewed the details of the new designs to determine if the advances in technology and information reporting would reduce overall staffing levels. Each task associated with plant operation was taken into account. A staff model was developed for each reactor type. This model maintains an adequate staff level to meet regulatory and best practice requirements.

The first new plants built in the United States will rely heavlily on current operational practices to ensure that the lessons learned over the more than 30 years of plant operation will be applied to the newest generation of plants. Therefore, for the purposes of this study, the organizational structure from the current operating philosophy was maintained. Although current staff structures differ between operating companies, they have a single overall goal—to reduce human error and equipment failure in all phases of plant operation and safety and to ensure an overall high operating capacity factor.

The staffing estimates used in this study include the onsite plant staff as well as additional staff that would be needed in the corporate office to support the additional units. These estimates also include corporate office support staff, which includes the staff who provide fuel design and procurement, safety analysis support, major modification development, and other more generic activities.

Two staffing models were developed. Since the most likely deployment of the first new units would be on existing plant sites, the staffing for the addition of a single large unit (or two smaller ACR-700 units) at an existing site was developed. In addition, staffing was developed for an undeveloped, or greenfield site.

As is done in calculating O&M costs, the staff cost was added to the other operating costs of a power plant. These costs were determined based on 2003 fee structures and estimates. Other expenses include fees for the NRC, the Institute of Nuclear Power Operations (INPO), and the Nuclear Energy Institute (NEI), along with insurance for both nuclear and commercial liability, corporate overhead, site electrical consumption during outages, and other materials and services required for plant operations.

An estimated yearly average operating and maintenance cost was produced for each of the four reactor types as well as for each siting option.

Study Conclusions and Recommendations

The total staffing estimates for each of the plants did not differ significantly between designs.

The O&M costs for a greenfield site were higher than adding a unit at an existing site. This was expected, since one of the benefits of using an existing site is the ability to share the existing infrastructure. For both types of site deployment, the lowest cost plant in terms of O&M cost is the ESBWR, with the ACR-700 being the highest. The ACR-700 was expected to be the highest total cost plant due to its twin unit configuration. However, when the plant power ratings are considered and the costs are expressed as a value of net electrical generation, the lowest cost per unit of plant generation (megawatt) is the ABWR with the AP1000 being the highest.

The costs and staffing for each deployment option are summarized in the following table:

O&M Cost and Staff

Deployment Option	O&M Yearly Cost	Number of Units	Total Staff	Total MWe (Net)	Cost per Net MWe
ABWR Additional Unit	$74,590,342	1	444	1371	$6.71
ESBWR Additional Unit	$74,178,482	1	444	1340	$6.83
ACR-700 Additional Unit	$88,111,240	2	519	1406	$7.61
AP1000 Additional Unit	$76,421,310	1	441	1150	$8.17
ABWR Greenfield	$101,818,008	1	701	1371	$9.16
ESBWR Greenfield	$101,204,268	1	700	1340	$9.32
ACR-700 Greenfield	$113,595,502	2	761	1406	$9.81
AP1000 Greenfield	$103,305,606	1	698	1150	$11.04

The study found that the overall O&M cost for each design is below the current industry average of the top 5 performing plants (sorted by O&M cost) by approximately 15%, making operation of these units competitive.

Plant staff and cost structures vary widely between power stations, as each plant site adjusts its staff profiles and levels to meet local needs. Each company planning deployment of a new nuclear unit must evaluate staffing based on the model that fits their operational preferences. A staff and cost development spreadsheet was developed to provide the information included in this report. This spreadsheet was provided to DOE as part of this study and should be used as a starting point to more accurately develop the O&M cost model for a specific site.

To completely analyze the production costs of each reactor type, the fuel costs, including the costs to procure, enrich, fabricate and dispose must also be included with the results of this study. Fuel costs between reactor designs can vary widely and estimation of those costs was not part of this study.

Decommissioning Costs and Funding Requirements

Study Concept

When a nuclear power plant is finally closed for operations at the end of its useful life, the facility must undergo a decommissioning process. The ultimate objective of the decommissioning process is to reduce the inventory of contaminated and activated material so that the license can be terminated. Approved alternatives typically include immediate or prompt remediation, an option whereby the facility is placed into safe-storage with remediation deferred, or a more aggressive encapsulation or entombment of the facility for a long-term or indefinite deferral of remediation.

The cost analysis described in this study is based upon the prompt decommissioning alternative, or DECON as defined by the NRC. In this alternative, decommissioning is undertaken shortly after the facility ceases operation. The DECON alternative is used as the basis for the NRC funding regulations. Its evaluation for the advanced reactor designs facilitates a comparison with the agency’s own estimates and financial provisions.

As defined by the NRC, the DECON alternative is "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations." This study does not include any costs beyond those required to terminate the NRC operating license, e.g., structures demolition.

This study presents estimates of the costs to decommission the advanced reactor designs following a scheduled cessation of plant operations. These cost estimates consider the unique features of the site, including the nuclear steam supply systems (NSSS), power generation systems, support services, site buildings, and ancillary facilities. This study establishes the requirements for providing reasonable assurance that adequate funds for performing decommissioning are available at the end of plant operations. This study does not address the cost to dispose of the spent fuel residing at the site; such costs are funded through a surcharge on electrical generation. However, the study does estimate the costs incurred with wet storage for the required cooling period of the fuel pending shipment by the DOE to an offsite disposal facility.

For estimating purposes, the advanced reactors were assumed to be located on an inland site in the southeastern United States.

Study Conclusions and Recommendations

The results of the decommissioning cost analysis are summarized in the following table. Costs are reported in 2003 dollars and have not been inflated, escalated, or discounted over the period of expenditure.

Total Decommissioning Costs
(all values are in thousands of 2003 dollars)

ABWR	ACR-700 Unit 1	ACR-700 Unit 2	AP1000	ESBWR
$594,991	$426,358	$444,191	$416,412	$570,433

The estimates described in this study are based on numerous fundamental assumptions, including labor costs, low-level radioactive waste disposal costs and practices, regulatory requirements, and project contingencies. Contingencies and risk factors were identified and allowances included. The primary cost contributors are either labor-related or associated with the management and disposition of the radioactive waste. As part of this study, areas for potential cost reduction were identified and specific recommendations provided.

Estimates to decommission nuclear facilities are typically comprised of several cost drivers. Some costs are directly related to the physical plant while others are more common to the management of any large remediation project. Based upon the information available, the advanced reactor designs offer comparable power production with fewer and less complex system components than similar, contemporary designs. As such, with comparable operating histories, the costs associated with the contaminated portions of the physical plant are correspondingly less for the advanced reactors. This savings has been incorporated within the estimates described in Section 4 for the advanced reactor designs and are principally reflected in those cost elements comprised of direct removal labor and materials and radioactive material disposition (processing, disposal or survey and release). Since the disposition of the plant structures was restricted to only the affected areas requiring decontamination and release necessary to support license termination, the physical differences in facility size did not have as much impact on reducing decommissioning costs as facility configuration for the advanced reactors.

While disposal of radioactive material from a nuclear unit is a contributor to the overall cost of decontamination and dismantling, it is only one of the cost drivers in executing a successful decommissioning project. Typically, the largest cost elements in an estimate for a commercial reactor are project management (including engineering, radiation protection and support, and spent fuel operations), site administration, and security. While there are many support and oversight functions that are related to the level of physical activity at a site, many management positions in the organization are independent of the field effort. The organizations (owner and contractors) and the associated costs incorporated within the decommissioning estimates for the advanced reactor designs are not assumed to be significantly different than costs at the sites currently being decommissioned. These organizations are used as a planning basis for most operating commercial reactors. The completion schedule(s) for the decontamination and dismantling of the advanced reactor designs, consistent with those developed for existing reactors, is based, in large part, upon the availability of the wet spent fuel storage facilities for decommissioning. With a common assumption that the spent fuel would require a minimum cooling period of five years before its relocation to a DOE facility or to an independent onsite dry storage facility, physical differences in the advanced reactor designs, as they pertain to the decommissioning schedule, are somewhat mitigated. Additional savings may be available if the disposition of the final core discharge can be accelerated; however, this is unlikely since higher power density cores may require additional active cooling and, correspondingly, a longer wet storage time period.

There are other costs that are also insensitive to the physical plant. Insurance, NRC fees and other "operating" expenses are driven by the overall program duration and housekeeping demands rather than design differences or component inventory. Again, there may be additional savings in schedule-dependent costs with increased scheduling efficiencies.

Overall, with consistent operating and management assumptions, the total decommissioning costs projected for the advanced reactor designs are comparable to those projected for operating reactors with appropriate reductions in costs due to reduced physical plant inventories. It is important to consider, however, that there are many site-specific factors and design variables that can affect the validity of this observation.

1. Introduction

In accordance with Cooperative Agreement DE-FC07-03ID14492, Dominion Energy, Bechtel Power Corporation, and TLG Services present this report.

1.1 Purpose

In support of DOE's Nuclear Power 2010 program, Dominion Energy in cooperation with its industry partners completed a study of the changes in nuclear plant design and construction and the impact on operational cost, decommissioning, and construction techniques. In the years since the last commercial nuclear plant was completed in the United States, domestic and international development has continued on design and construction techniques to reduce construction costs and schedules. Additionally, the industry has successfully reduced operating costs for current reactors while the new reactors are being designed for even lower O&M costs. The new reactors were also evaluated to determine whether the improved designs would reduce plant decommissioning costs and funding.

Many of these advances and methodologies have not been studied in this country nor have they been tested in U.S. nuclear construction. All of these items, however, are necessary to ensure that the stated construction timeframes and operational improvements claimed by the reactor vendors are valid and reasonable. This study reviewed three essential areas where changes were intended to improve the economics of new plants:

- Advanced construction technologies and schedules
- O&M staffing and costs
- Decommissioning costs and funding requirements

Dominion Energy, who also performed the study of O&M staffing and costs, led the study. Bechtel Power Corporation performed the evaluation of construction technologies and schedules and TLG Services evaluated decommissioning costs and funding requirements. DOE, Dominion Energy, Entergy, Nuclear, and Bechtel contributed to cost share the effort.

1.2 Scope

This study focused on three key areas where additional information was needed to support a future industry decision on nuclear power deployment. Four new reactor designs were selected for this study. They all are in advanced stages of design and have a reasonable expectation of deployment to support DOE's Nuclear Power 2010 goals. The Toshiba and General Electric ABWR, the GE ESBWR, the Westinghouse advanced passive pressurized water reactor (AP1000), and the AECL Advanced CANDU Reactor (ACR-700) are all advancements of proven technology. The reactors or their combined twin units are all rated between 1100 and 1400 MWe. The ABWR has been constructed or is under construction in Japan and Taiwan. No other plant has been ordered.

Each of the reactor vendors provided data packages covering construction, operation and decommissioning. In addition, each responded to a series of follow-up questions that were intended to try to normalize the level of detail for each reactor. This information was essential in completion of this study. DOE did not compensate the reactor vendors for their support of this study.

The design status of each reactor varied. The most detail was available from Toshiba on the ABWR. This was because, of the four designs studied, it is the only one that has units in operation as well as currently under construction. The other reactor designs are based on derivations of current plants and are in various degrees of development.

Bechtel performed the study of advanced reactor construction technologies and schedules. The construction methods and engineering design technologies proposed by the reactor vendors were identified and evaluated. This study reviewed the reactor vendor's construction schedules to determine if these schedules are attainable. Under a separate contract with DOE (DE-AT01-020NE23476), MPR Associates, Inc. performed a more in-depth evaluation of those techniques and any limitations on their application in the United States. The results of the detailed work performed by MPR Associates are contained in Volume 2. MPR also completed a detailed evaluation of the proposed reactor construction schedules that is contained in Volume 2.

Dominion Energy conducted the O&M staffing and costs study, with advice and assistance from Entergy Nuclear and TVA. Each of the new plants has been designed with the intent of reducing plant staff and lowering operating costs. This study performed a task-based analysis of these designs based on current operational practices to determine a staffing level for each plant type. Starting with that staffing profile, an operational and maintenance cost structure was developed to provide a reasonable basis for estimating O&M costs.

TLG Services (a subsidiary of Entergy Nuclear) performed the decommissioning costs and funding requirements study. Each of the designs selected for this study is based on an existing design. This study reviewed each of the designs identified to determine the cost to decommission each plant. In addition, since these designs are not yet complete, any potential improvements in design that may reduce future decommissioning costs were identified.

1.3 Objectives

The overall objectives of this study were to:

- Identify new construction technologies and methods that are being or should be considered by the reactor vendors and/or engineering construction firms to reduce construction time.
- Determine the effectiveness of these identified technologies and methods and ascertain the impact on construction.
- Identify other new techniques and technologies used in conventional (as opposed to nuclear) construction and determine their applicability and effectiveness in nuclear construction.

- Review the construction schedules provided by the reactor vendor for each reactor design and determine the validity of the duration and schedule estimates.

- Determine the effects of plant design and automation on plant staffing and develop a task based staffing model for each design.

- Estimate operating and maintenance costs for each design and, using the staffing profile for each design, develop an operational and maintenance cost model for each design.

- Determine the decommissioning costs for each reactor design based on a detailed analysis of plant design and construction.

- Provide recommendations to each reactor designer on means and methods to reduce decommissioning costs and expenses.

1.4 Reactor Types

Four reactor types were evaluated in this report: the Toshiba and GE ABWR, the GE ESBWR, the Westinghouse AP1000, and the AECL ACR-700. These designs were selected based on their level of development and potential for deployment in the 2010 timeframe. The characteristics of each design are generally described below.

1.4.1 Advanced Boiling Water Reactor

The ABWR is an evolutionary design of the boiling water reactor design marketed in the United States by both Toshiba and GE. The design is rated at 3992 MWt with a rated electrical output of 1422 MWe. The ABWR is a single cycle, forced circulation boiling water reactor. The design is based on existing BWR designs, similar to the ones operating in the United States at Clinton and Grand Gulf but incorporates several advanced features, including vessel-mounted recirculation pumps, fine motion control rod drives and an advanced digital and a multiplexed instrumentation and control system. Additional changes have improved the containment design. The Toshiba and GE versions of this design are essentially identical; however, the Toshiba version does incorporate selected improvements identified during the Japanese deployment of the ABWR. For the purpose of this study, unless otherwise stated, a single common version of the ABWR is referenced.

To date, two ABWR units have been constructed and are currently in operation in Japan. Additional units are under construction in Taiwan (2) and Japan (2), with six others in various stages of design in Japan. The ABWR is designed as a single unit stand-alone configuration.

The NRC has certified the ABWR design in Appendix A to 10 CFR 52.

1.4.2 Economic Simplified Boiling Water Reactor

The ESBWR is a further evolution from the ABWR and is designed and marketed by GE. The ESBWR is a 4000 MWt, single cycle, boiling water reactor with a rated electrical output of 1390 MWe. The ESBWR relies on natural circulation and passive safety features to enhance plant performance and simplify the design. The use of natural circulation has allowed the elimination of several BWR systems. This has also reduced the nuclear risk since eliminating active safety systems for emergency plant cooling improves their reliability.

The ESBWR has achieved its plant simplification by using innovative adaptations of operating plant systems, for example, combining shutdown cooling and reactor water cleanup systems. A significant improvement is the elimination of the recirculation pumps and the passive containment cooling system. In other cases, key components such as depressurization valves and isolation condensers are new, but use proven concepts.

The ESBWR is designed as a single, stand-alone unit. Design work is continuing. The ESBWR is currently in pre-application review by the NRC and GE expects to file a design certification application in early 2005.

1.4.3 AP1000

The Westinghouse AP1000 is a 3400 MWt pressurized water reactor with a rated electrical output of 1200 MWe. Its design is based on the NRC design certified AP600 (10 CFR 52 Appendix C), with design changes to accommodate the increase in power output. The AP1000 is a two-loop, four reactor coolant pump design using fuel, reactor vessel and internals similar to those in service today at South Texas. The reactor coolant pumps are canned-type pumps to reduce the probability of leakage and to improve reliability. The design is functionally similar to that of the AP600, with the containment building, reactor vessel, steam generators, reactor coolant pumps, and pressurizer increased in size to accommodate the increase in thermal power.

The AP1000 is designed to use passive features for accident mitigation. An externally cooled steel containment building, in-containment refueling water storage tank, rapid depressurizing capability and other design features allow the elimination of all safety-related alternating current powered equipment. Electrical power generation would be through the use of a standard steam turbine cycle.

Westinghouse filed an application for design certification in March 2002 and expects approval in December 2004. The AP1000 is designed in a single unit, stand-alone configuration.

1.4.4 ACR-700

The ACR-700 is designed by AECL and is based on the CANDU 6 design. The ACR-700 is a 2034 MWt light water cooled, heavy water moderated reactor with a rated electrical output of 753 MWe. It uses four heat transport pumps circulating light water through two steam generators to remove the heat from the horizontal reactor vessel, called a calandria. This light water primary coolant circulates through individual pressurized fuel channels in the calandria. On the other side of these fuel channels, the calandria contains a heavy water moderator at low temperature and pressure, which allows increased neutron efficiency.

The CANDU 6 design is a natural uranium fueled reactor; a design attained by using heavy water as the primary heat removal fluid. For the ACR-700, the primary coolant has been changed to light water, reducing cost and complexity of the plant. The resulting reduction in neutron efficiency requires that the fuel be slightly enriched, to approximately 2% U235. The fuel elements, however, are similar to those used in CANDU 6 with minor improvements to increase thermal efficiency.

Unlike the ABWR, ESBWR, and AP1000, the use of individual pressurized fuel channels in the ACR-700 allows the ACR-700 to be continuously refueled on power. Fueling machines are designed to isolate an individual fuel channel, remove a selected number of fuel assemblies (which are approximately 20 inches long), and return the channel to service. Electrical power generation would be through the use of a standard steam turbine cycle.

The CANDU reactor design has been in service in a number of countries. Thirty-four CANDU units have been constructed worldwide. The ACR-700 design is configured in a two-unit block, with limited shared systems between the two reactors.

The ACR-700 is currently in pre-certification review by the NRC. AECL expects to file a design certification application by March 2005.

1.4.5 Summary

A summary of the four advanced reactor designs is provided in Table 1-1.

Table 1-1. Summary of Reactor Types Studied

Reactor Type	Thermal Power (MWt)	Electric Power (MWe) gross/net	Design Certification Status
ABWR	3992	1422/1371	Issued (10 CFR 52, Appendix A).
ESBWR	4000	1390/1340	In pre-application review.
AP1000	3415	1210/1150	Application submitted. Design certification expected in December 2005.
ACR-700	2032 x 2	2 x 753 / 2 x 703	In pre-application review.

2. Construction Technologies and Schedules for Advanced Reactor Designs

2.1 Introduction

Since construction was completed at Watts Bar in 1996, no new nuclear power plant construction efforts have taken place in the United States. However, construction technologies have continued to improve and new approaches have been used on reactor construction projects overseas. Recent projects in Europe and Asia have proven that new methods of construction, including modularization and open top construction, can reduce the time and staff needed to build a new nuclear power plant.

The vendors for each of the advanced reactor designs that were analyzed for this study have focused on reducing construction durations to the extent practical including the time from the contract effective date to commercial operation, first concrete to fuel load, and fuel load to commercial operation. The schedules and approaches being proposed by the reactor vendors were evaluated to determine if they are reasonably achievable and if other, newer construction technologies are available to further improve construction schedules.

Originally, this evaluation was to be a quantitative assessment to validate construction schedule claims for the advanced reactor designs. However, none of the reactor vendors presented sufficient information to perform detailed schedule assessments of resource loadings, durations, logic, etc. Because of the lack of detailed information, only summary-level qualitative assessments could be performed.

Following is a list of the assessments performed as part of this study:

- **Construction Schedule Evaluation**. Section 2.2 describes the evaluation of construction schedules, including the extent of information received from the vendors. The schedule evaluations included:
  - First, estimated installation rates for reactor building concrete, piping, and cable were compared against sustained rates for nuclear power plant construction to determine if the installation rates assumed for new plants are reasonable. For example, it may be possible to place 10,000 cubic yards of concrete in three days if it is a mass foundation placement. It is not reasonable to assume the placement of 10,000 cubic yards of concrete in three days in a detailed wall and floor configuration.
  - Second, the advanced reactor schedules were compared against historical construction schedules for nuclear power plants built in the United States. This comparison was aimed at determining if any previous projects (without the benefits of simplified designs,

3-D design tools, modularization, and other advanced construction technologies) had achieved, or were expected to achieve, construction schedules comparable to those estimated for the advanced reactors.

Conclusions on the achievability of each of the reactor vendor's schedules are provided.

- **Conceptual Deployment Schedule**. Section 2.3 presents a conceptual schedule for the deployment of the first new commercial nuclear power plant in the United States. This milestone summary schedule integrates the NRC licensing process with the necessary engineering, procurement, fabrication, construction, training, and startup activities for plant deployment.

- **Evaluation of Construction Technologies and Module Fabrication Facilities**. Section 2.4 evaluates potential new construction technologies and module fabrication facilities. The construction technologies evaluation relies on the more detailed evaluation of construction technologies performed by MPR Associates in their report, "Application of Advanced Construction Technologies to New Nuclear Power Plants," which is included in Volume 2. Insights from Bechtel's power plant construction experience and additional independent research are provided to supplement the MPR evaluation. This section also includes an evaluation of module fabrication facilities based on visits made to several facilities in the United States and Japan. Appendix 2A includes an evaluation of prefabrication, preassembly, and modularization efforts and their application to advanced reactor designs.

- **CII Project Definition Rating Index Evaluation**. Section 2.5 and Appendix 2B present an evaluation of the four advanced reactor designs using the Construction Industry Institute's (CII's) Project Definition Rating Index (PDRI). The PDRI process can be used to objectively assess the likelihood of successful project implementation based on the level of development completed. The PDRI allows a project team to objectively assess the probability of achieving the goals of a project before authorization.

- **Assessment of Labor Availability**. Section 2.6 presents a summary-level assessment of U.S. labor availability for new plant construction that underscores the need for early, ongoing, and thorough planning to ensure adequate labor resources.

2.2 Construction Schedule Evaluation

The advanced reactor construction schedules proposed by the vendors were evaluated by comparing them against historical construction schedules for nuclear power plants built in the United States. The site assumed in the evaluation was North Anna, which has the following key characteristics that would impact the construction effort for new nuclear power plants:

- The site is located within 50 miles of major population centers, which increases the likelihood of hiring and retaining an adequate number of skilled construction workers for the project with the necessary infrastructure to support the construction workforce.

- The site already has two operating reactors, which allows for the sharing of existing facilities, programs, and infrastructure.
- The site is landlocked, with road and rail access only. This restricts the size and weight of material, equipment, modules, etc., that can be shipped to the site. (30%–40% of existing nuclear power plant sites in the United States do not have barge access.)

2.2.1 Vendor Data

Information provided by the reactor vendors formed the basis for the evaluations. Several data requests were issued to the vendors to obtain information.

2.2.1.1 Data Requests

■ Request for Detailed Schedule and Design Data

The original vision of the study was to perform a detailed review of quantities to validate the schedules being proposed by the reactor vendors. To this end, a request for detailed schedule and quantity information was issued to the reactor vendors in May 2003. Design data was also requested including plant and building layout drawings, a copy of the electronic design model, lists and quantities of equipment and commodities required, subcontracts to be placed, and detailed information concerning any modules or preassemblies planned for construction.

A large quantity of schedule data was received from the reactor vendors. However, the information varied widely, as shown in Table 2-1.

Table 2-1. Vendor Response to Request for Detailed Data

2	Advanced Reactor Construction Technologies and Schedules	ABWR	ACR-700	AP1000	ESBWR
2.1	Narrative/presentation that identifies and describes the overall construction approach.	Yes	Yes	Yes	No
2.2	Description of specialized construction methodologies and techniques planned to be used including previous applications of specialized techniques.	Yes	Yes	Yes	No
2.3	Description of the planned use of specialty equipment such as heavy-lift cranes including usage, capacity required, duration, and timing of usage.	Yes	Partial	Partial	No
2.4	Description of offsite construction activities (e.g., module fabrication, manufacturing of large components) and integration with onsite work.	Partial	Partial	Partial	No
2.5	Logic driven integrated schedule (preferred format is P3, live file) for 1st unit(s) including engineering, licensing, procurement, construction, and transition to operation activities that identifies:	No	Yes	Yes	No
2.5.1	Assumptions	No	No	No	No
2.5.2	Schedule durations and/or logic used on past construction projects	No	No	No	No

Table 2-1. Vendor Response to Request for Detailed Data

2	Advanced Reactor Construction Technologies and Schedules	ABWR	ACR-700	AP1000	ESBWR
2.5.3	Resources, including productivity rates used for schedule duration calculations by craft/commodity or piece of equipment	No	No	No	No
2.5.4	Constraints	No	In live schedule only	In live schedule only	No
2.5.5	Milestones	Yes	Yes	Yes	No
2.5.6	Procurement of long-lead items	No	No	No	No
2.5.7	Offsite fabrication/construction activities	Partial	Partial	Partial	No
2.5.8	Construction testing (hydro pneumatic testing, electrical, etc.)	Partial	Partial	Partial	No
2.5.9	Licensing and regulatory approvals	Partial	Partial	Partial	No
2.5.10	Transition to operation activities (preoperational testing, fuel load, startup testing, ITAAC)	Partial	Partial	Partial	No
2.5.11	Critical item deliveries	No	No	No	No
2.5.12	Subcontractors	No	No	No	No
2.5.13	Module installation	Partial	Partial	Partial	No
2.6	Logic driven integrated schedule for "nth" unit(s) including definition of "nth" unit and discussion/rationale for differences from 1st unit(s) schedule.	No	No	No	No

■ Request for Simplified Schedule Information

Because of the widely variant feedback from the vendors in response to the detailed data request, a second request for simplified schedule information was issued so that resource-based evaluations of the vendor schedules could be performed. The simplified schedule information request issued in October 2003 was limited to the reactor and auxiliary buildings only so as to limit the amount of additional work required of the vendors and to allow preparation of high-level parametric evaluations to assess the likelihood of meeting the proposed schedules. In addition to providing the basic resource and schedule information necessary to assess constructability, a vendor’s ability to respond to the simplified schedule information request would provide an indirect insight into the level of development of the design. Knowledge of where a design is relative to a completed design can be helpful in assessing the validity of assumptions that have been or may have to be made. The vendor response to the simplified schedule information request is shown in Table 2-2.

Table 2-2. Vendor Response to Request for Simplified Schedule Information

Request for Simplified Schedule Information	ABWR	ACR-700	AP1000	ESBWR
Concrete in cubic yards	Yes	Yes	No	No
Structural steel in U.S. tons	Yes	Yes	Yes	Yes
Number of pieces of equipment (pumps and motors >5 hp, skids, tanks >100 gallons, MCCs, etc.)	Yes	Yes	No	Yes
Conduit in lineal feet	Yes	Yes	No	Yes
Cable tray in lineal feet	Yes	Yes	No	Yes
Wire and cable in lineal feet	Yes	Yes	Yes	Yes
Piping in lineal feet	Yes	Yes	NSSS piping only	Yes
If the plant being proposed relies on prefabrication, preassembly, or modularization (PPM) to achieve a shorter field construction duration, the schedule should identify the number of PPM units per volume…and the time period expected to install those PPM items in that volume...	No	No	No	No

To compensate for the wide disparity of information provided by the vendors and to establish an objective basis for analyzing and comparing schedules for each of the reactor types, a second request for simplified schedule information was issued in December 2003. The following assumptions were made to limit the effort required to respond to this request:

- Site preparation activities will be similar for all reactor types.
- Balance of plant installations are typically not on critical path for a nuclear power plant and will be completed within the time frame allocated for construction and completion of the reactor building.
- Testing and startup durations will be similar for all reactor types.

The vendors were asked to supply a Level 1 schedule for the reactor and auxiliary buildings only based on these assumptions.[1] The vendors were requested to break the buildings into logical volumes (floors, for instance) and to provide durations and commodity resource quantities for

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[1] Schedule levels include:

Milestone	Basic level plan; activities generally measured in years (e.g., 2.5 years versus 30 months)
Level 1	Activities generally measured in months
Level 2	Activities generally measured in weeks
Level 3	Activities generally measured in days
Level 4	Most detailed plan; activities generally measured in hours

each volume. The summary-level format of the requested information would allow comparisons against plants actually constructed.

All vendors responded, at least partially, to the follow-up request for simplified information.

2.2.1.2 Schedule Information Received

The following is a summary of the schedule information received from the vendors. The schedule durations provided are for a first new unit in the United States.

- ABWR

  The package of information provided by GE for the ABWR was substantial and indicative of a large amount of planning and development. Schedule information received included a 15-page integrated summary schedule (Level 1 to Level 2 in detail), a list of fragnets (small portions of the schedule that help expedite scheduling of similar activities), a listing of the codes used during schedule development, and a fully developed construction schedule risk analysis.

  The information received from Toshiba was similar to the GE package in quantity and quality. The Toshiba schedule information was Level 1 in detail. Toshiba also provided quantities for major materials. (For the purposes of evaluating construction schedules, the design differences between the GE and Toshiba ABWRs are not significant.)

  The schedule estimates from GE and Toshiba were as follows:

GE	Toshiba	
Not provided	72 months	Contract effective date to commercial operation
43 months	36 months	First concrete to fuel load
7 months	7 months	Fuel load to commercial operation

  The durations provided by Toshiba have been achieved on projects in Japan.

- ACR-700

  AECL submitted a well-developed package that clearly demonstrates the concepts and techniques planned for construction of the ACR-700. Schedule information received included a Level 2 schedule with 8,000 activities and a 3,300-activity construction schedule that was extracted from the overall schedule. The effort required to prepare such detailed schedules indicates that a significant amount of planning has been performed.

  The schedules supplied by AECL were not resource-loaded. AECL did however supply overall quantities for major materials to be used in construction of the plant.

The schedule estimates from AECL were as follows:

63 months	Contract effective date to commercial operation
40 months	First concrete to fuel load
8 months	Fuel load to commercial operation

AP1000

Westinghouse provided an extensive documentation package in support of the AP1000. Additionally, an electronic version of their AP1000 schedule was provided. The schedule is of Level 2 detail, and contains in excess of 5,700 activities. The schedule structure is well thought out and logical.

Westinghouse provided limited material quantity rates and only for concrete.

The schedule estimates from Westinghouse were as follows:

69 months	Contract effective date to commercial operation
36 months	First concrete to fuel load
6 months	Fuel load to commercial operation

ESBWR

The information package provided for the ESBWR was sparse and insufficient detail was provided to perform evaluations similar to the other 3 reactor types.

GE did provide summary level and bulk quantity information in response to the request for simplified schedule information.

The schedule estimates from GE were as follows:

Not provided	Contract effective date to commercial operation
39 months	First concrete to fuel load
Not provided	Fuel load to commercial operation

The GE ESBWR duration for first concrete to fuel load is based on their SBWR design and the fact that the ESBWR offers a number of advantages over the ABWR and other earlier BWR designs by simplifying operational systems and requirements and incorporating a passive safety system.

2.2.1.3 Summary

None of the vendors provided adequate resource-based schedule durations and logic information for the performance of the detailed schedule analyses originally planned for the study. Table 2-3 summarizes the schedule durations received from the vendors.

Table 2-3. Advanced Reactor Schedule Durations for First New Unit in United States

Schedule Activity	Duration (in months)				
	ABWR (GE)	ABWR (Toshiba)	ACR-700	AP1000	ESBWR
Contract effective date to commercial operation	*	72	63	69	*
First concrete to fuel load	43	36	40	36	39
Fuel load to commercial operation	7	7	8	6	*

* Not provided.

2.2.2 Evaluation

Using the information received from the vendors, several evaluations were performed. These evaluations were primarily qualitative however because of the lack of resource-based schedule durations and logic information from the vendors. More detailed and quantitative assessments are not possible without a clear understanding of the material quantities and manpower used to establish schedule activities.

2.2.2.1 Comparison of Installation Rate Curves Against Historical Installation Rates

Data from past Bechtel nuclear plant construction projects indicates that the installation of the following 3 commodities accounts for approximately 50% of the total direct construction hours expended: concrete, piping, and wire/cable. Further, the data shows that completion of the reactor/containment building concrete was frequently on or near critical path for the schedule.

For the first evaluation, reactor building installation rate curves for cubic yards of concrete per month, feet of large and small bore piping per month, and feet of wire/cable per month were prepared for each reactor type based on input received from the vendors. These installation rate curves were then compared with historical installation rates for U.S. nuclear plant construction to determine if the vendor assumptions are reasonable and likely achievable. (Note: The advanced reactor installation rates and quantities are proprietary to the vendors and are not reproduced in this report.) Historical, sustained installation rates for U.S. nuclear plants are provided in Table 2-4 based on Bechtel construction projects.

Table 2-4. Historical, Sustained Rates for U.S. Nuclear Plant Construction

Commodity	Minimum Rate	Maximum Rate	Average Rate
Concrete (cubic yards per month)	2400	6800	4000
Large Piping (lineal feet per month)	2700	3700	3100
Wire and Cable (lineal feet per month)	105,000	131,000	118,000

The results of comparing reactor building installation rates for the advanced plants with historical installation rates are provided in Table 2-5. As can be seen from the table, where information was received from the vendors, the reactor building commodity installation rates generally compare well with past nuclear plant construction projects.

- For reactor building concrete, the ABWR, ACR-700, and AP1000 installation rates compare well with past projects. No installation rates were provided for the ESBWR, but the quantity of concrete to be placed appears reasonable for a first concrete to fuel load duration of 39 months.

- For reactor building piping, the ABWR and ACR-700 installation rates compare well with past projects. No piping quantity or installation rates were provided for the AP1000. The piping quantity for the ESBWR appears to be significantly higher than expected and further details are needed before a conclusion can be reached.

- For reactor building wire and cable, the ACR-700 installation rates compare well with past projects. The ABWR rates provided by Toshiba could be achieved with increased craft man-hours and longer durations. For the AP1000 and ESBWR, the amount of wire/cable to be installed appears reasonable.

Table 2-5. Comparison of Reactor Building Commodity Installation Rates

Commodity	ABWR	ACR-700	AP1000	ESBWR
Concrete Placement Rate	The average cubic yards of concrete per month for the reactor building compare well with historical, sustained rates for past nuclear projects in the United States (Note that the reactor building incorporates the auxiliary, fuel handling, and diesel generator buildings and is approximately 50% of the total concrete.) A short-term, high rate of concrete placement for the reactor building occurs at the front end of the schedule. This short peak should be achievable because the placement is for the basemat that requires continuous, uninterrupted concrete placement and is relatively simple. The placement rates that can be achieved in large contiguous volumes can greatly exceed placement rates for smaller, elevated, wall, foundation, and floor placements.	The average cubic yards of concrete per month for the reactor building compares well with historical sustained rates for past nuclear projects in the United States	The average cubic yards of concrete per month for the reactor building compares well with historical sustained rates for past nuclear projects in the United States A short-term, high rate of concrete placement for the reactor building occurs at the front end of the schedule. This short peak should be achievable because the placements are large foundation walls and mats that require continuous, uninterrupted concrete placement. The placement rates that can be achieved in large contiguous volumes can greatly exceed placement rates for smaller, elevated, wall, foundation, and floor placements.	GE provided summary-level concrete quantity information only. Based on a limited and high-level examination, it appears that the ESBWR concrete quantity is within the range of possibility for a first concrete to fuel load duration of 39 months.
Piping Installation Rate	The average piping installation rate for the reactor building compares well with sustained rates on past nuclear projects.	The average piping installation rate for the reactor building compares well with average sustained rates on past nuclear projects. The peak rate is short term and compares well with peak historical rates.	Westinghouse did not provide any piping installation rate or quantity information. No conclusions can be reached.	GE provided summary-level piping quantity information only. The piping quantity appears to be significantly higher than expected; further details are needed before a conclusion can be reached in this area.

Table 2-5. Comparison of Reactor Building Commodity Installation Rates

Commodity	ABWR	ACR-700	AP1000	ESBWR
Wire and Cable Installation Rate	Toshiba's wire and cable quantities indicate a required installation rate in excess of that historically achieved on Bechtel nuclear projects. Bechtel believes this higher than normal requirement can be accommodated by adjusting the ABWR wire and cable schedule to allow installation of cable over a longer period of time and by increasing the number of man-hours expended to install the cable by working longer hours and or additional shifts. Both adjustments are normal work practices and have been successfully applied on numerous projects in the past.	The average cable installation rate for the reactor building compares well with average sustained rates on past nuclear projects. The peak rate is short term and compares well with peak historical rates.	Westinghouse provided summary-level wire and cable quantity information only. Based on this limited information, the AP1000 wire/cable quantities appear reasonable.	GE provided summary-level wire and cable quantity information only. Based on a limited and high-level examination of the material quantities, it appears that the ESBWR wire/cable quantities are within the range of possibility for a first concrete to fuel load duration of 39 months.
Conclusions	The ABWR concrete and piping installation rates are from information received from Toshiba and compare well with past U.S. nuclear projects. The Toshiba rates are actuals from ABWR construction projects in Japan. Increasing the activity duration and/or increasing the number of man-hours expended could achieve the wire/cable installation rates identified by Toshiba.	The ACR-700 concrete, piping, and wire and cable installation rates compare well with past nuclear projects.	The AP1000 concrete placement rate compares well with past nuclear projects. Westinghouse did not provide quantity or rate information for piping. No conclusions can be reached. The summary-level wire/cable quantity information received for the AP1000 appears reasonable.	Based on a limited and high-level examination of the material quantities, it appears that the ESBWR concrete and wire/cable quantities are within the range of possibility for a first concrete to fuel load duration of 39 months. The piping quantity appears to be significantly higher than expected; further details are needed before a conclusion can be reached in this area.

2.2.2.2 Comparison of Major Milestone Durations Against Actual Construction Schedules

In the second evaluation, the advanced reactor construction durations were compared with historical construction schedules for U.S. nuclear plants. The purpose of this comparison was to determine if any previous U.S. plants had been built on schedules comparable to what is being proposed for the advanced reactors.

Table 2-6 provides average construction schedules for the 90 U.S. nuclear power plants that entered commercial operation from 1970 to 1986. Construction durations are defined in the table as the number of months from receipt of the construction permit to receipt of the operating license. The table shows that construction durations in the early 1970s were in the 40-50 month range and increased to the 60-70 month range in the mid 1970s. Construction durations became greatly extended after 1976 when licensing and engineering delays increasingly impacted construction.

Table 2-6. Construction Schedules for U.S. Nuclear Plants 1970-1986

Initial Year of Commercial Operation	Number of Units	Average Duration of Activity in Months	
		Construction[1]	Fuel Loading and Startup[2]
1970	3	42.3	5.7
1971	5	46.0	8.2
1972	6	49.0	6.7
1973	8	60.1	9.9
1974	12	69.2	7.9
1975	9	61.3	9.9
1976	3	67.0	7.7
1977	7	82.7	8.0
1978	4	89.5	9.8
1979	2	64.5	41.0
1980	2	89.5	13.0
1981	4	112.3	13.8
1982	1	133.0	12.0
1983	3	91.7	11.0
1984	7	113.6	13.4
1985	7	115.9	17.6
1986	7	125.1	10.1

[1] From issuance of construction permit to issuance of operating license.
[2] From issuance of operating license to commercial operation.

Source: Info Data, Nuclear Power Facts and Figures, Atomic Industrial Forum, July 1987.

In order to focus on construction durations for those reactors built before the extended delays experienced in the late 1970s and later, Table 2-7 provides a breakdown of construction schedules by plant through 1976. This data is taken from NRC NUREG-0300 and includes the time from the start of site preparation (not including mobilization activities) through receipt of the operating license.

Table 2-7. Construction Schedules for U.S. Nuclear Plants Prior to 1977

Unit[1]	Type	Design Rating (MWe)	Commercial Operation Date	Construction Duration (months)[2]
Dresden 1	BWR	200	8/60	40.9
Yankee Rowe	PWR	175	7/61	28.3
Indian Point 1	PWR	265	10/62	63.8
Humboldt Bay	BWR	63	8/63	21.9
Big Rock Point	BWR	72	12/65	30.0
San Onofre 1	PWR	430	1/68	32.1
Connecticut Yankee	PWR	575	1/68	39.0
Lacrosse	BWR	50	11/69	61.1
Oyster Creek	BWR	650	12/69	67.3
Nine Mile Point 1	BWR	610	12/69	73.7
Prior to 1970 Average				**45.8**
Dresden 2	BWR	794	6/70	51.7
Ginna	PWR	490	7/70	41.6
Point Beach 1	PWR	497	12/70	45.1
1970 Average				**46.1**
Millstone 1	BWR	690	3/71	55.2
Robinson 2	PWR	707	3/71	42.0
Monticello	BWR	545	6/71	48.2
Dresden 3	BWR	809	11/71	58.4
Palisades	PWR	821	12/71	31.8
1971 Average				**47.1**
Point Beach 2	PWR	497	10/72	58.5
Vermont Yankee	BWR	514	11/72	81.7
Pilgrim	BWR	655	12/72	64.2
Maine Yankee	PWR	790	12/72	51.5
Turkey Point 3	PWR	745	12/72	66.6
Surry 1	PWR	822	12/72	65.8
1972 Average				**64.7**
Quad Cities 1	BWR	809	2/73	60.0
Quad Cities 2	BWR	809	3/73	66.0
Surry 2	PWR	822	5/73	73.9
Oconee 1	PWR	887	7/73	71.2
Turkey Point 4	PWR	745	9/73	75.3
Fort Calhoun	PWR	457	9/73	63.7
Zion 1	PWR	1050	12/73	60.2
Prairie Island 1	PWR	530	12/73	62.3
1973 Average				**66.6**
Kewaunee	PWR	560	6/74	72.7
Peach Bottom 2	BWR	1065	7/74	78.2

Table 2-7. Construction Schedules for U.S. Nuclear Plants Prior to 1977

Unit[1]	Type	Design Rating (MWe)	Commercial Operation Date	Construction Duration (months)[2]
Cooper	BWR	778	7/74	71.6
Indian Point 2	PWR	873	8/74	69.6
Browns Ferry 1	BWR	1065	8/74	81.8
Three Mile Island 1	PWR	792	9/74	75.6
Zion 2	PWR	1050	9/74	67.4
Oconee 2	PWR	887	9/74	79.2
Prairie Island 2	PWR	530	12/74	76.9
Oconee 3	PWR	887	12/74	80.6
Peach Bottom 3	BWR	1065	12/74	89.0
Arkansas 1	PWR	850	12/74	65.7
			1974 Average	**75.7**
Duane Arnold	BWR	538	2/75	41.7
Browns Ferry 2	BWR	1065	3/75	93.9
Rancho Seco	PWR	918	4/75	64.5
Calvert Cliffs 1	PWR	845	5/75	78.0
Fitzpatrick	BWR	821	7/75	69.5
Cook 1	PWR	1100	8/75	67.8
Brunswick 2	BWR	821	11/75	62.9
Hatch 1	BWR	786	12/75	71.2
Millstone 2	PWR	830	12/75	69.0
			1975 Average	**78**
Trojan	PWR	1130	5/76	68.7
Indian Point 3	PWR	965	8/76	98.4
Beaver Valley 1	PWR	852	10/76	80.0
St. Lucie 1	PWR	810	12/76	84.5
			1976 Average	**82.9**

[1] The number of units per year differs from those reported in Table 2-6. This difference has no impact on the qualitative evaluations performed for this study.

[2] From start of site preparation (excluding mobilization) to issuance of operating license. Source: NUREG-0300, "Construction Status Report – Nuclear Power Plants, December 1977."

The durations in Table 2-7 can be compared with the advanced reactor construction schedules under the following assumptions:

- The operating license issue date for the reactors listed in Table 2-7 is approximately the fuel load date. For these early plants, the start of fuel loading typically occurred close to the operating license date.

- 18 months is added to the advanced reactor first concrete to fuel load schedules to account for site preparation activities at the base site, which is North Anna:

Table 2-8. Advanced Reactor Construction Schedules

Reactor Design	First Concrete to Fuel Load Duration (months)	Site Preparation to Fuel Load Duration (months)[1]
ABWR (GE)	43	61
ABWR (Toshiba)	36	54
ACR-700	40	58
AP1000	36	54
ESBWR	39	57

[1] Site preparation to fuel load duration obtained by adding 18 months to first concrete to fuel load duration.

Comparing the advanced reactor durations in Table 2-8 with the data in Tables 2-6 and 2-7 yielded the following results:

- The estimated site preparation to fuel load schedules for the advanced reactor designs range from 54 to 61 months. These advanced reactor construction durations are comparable to the averages for U.S. plants constructed before 1973, but significantly shorter than the averages for U.S. nuclear plants after 1973.

- Most small plants (less than 500 MWe) achieved construction durations in this range (54-61 months) or shorter.

- Various medium-sized plants (500-1000 MWe) achieved construction schedules in this range (54-61 months) or shorter including Connecticut Yankee, Dresden 2, Millstone 1, Robinson, Monticello, Dresden 3, Palisades, Maine Yankee, Quad Cities 1, Prairie Island 1, Duane Arnold, and Brunswick 2.

- The only large U.S. plant (1000 MWe or greater) to achieve a construction duration in this range was Zion 1, a 1050 MWe PWR, at 60.2 months, which entered commercial operation in December 1973.

- The estimated duration from fuel load to commercial operations for the advanced reactors is approximately 6-8 months. This duration compares well with the industry averages before 1978, as shown in Table 2-6.

2.2.2.3 Comparison Against Planned Construction Schedules

In the third and final evaluation, the advanced reactor schedules were compared with *planned* construction schedules. The estimated first concrete to fuel load durations for the advanced reactors were compared against the planned construction schedules for various medium-sized and large Bechtel nuclear plants built in the United States during the 1970s and 1980s. These historical schedules were the "going-in" plans developed to complete construction for each plant before the various delays that were experienced on individual projects. (Note: The planned construction schedules are proprietary to Bechtel and are not reproduced in this report.)

This evaluation concluded that the advanced reactor construction durations compare well with the historical planned durations. If engineering is completed and licensing issues are resolved before the start of construction, many of the issues that delayed the construction of nuclear plants in the late 1970s and 1980s will be avoided for advanced reactors.

2.2.3 Conclusions

The results of the construction schedule evaluations provide a basis for concluding that the first concrete to fuel load durations for the GE ABWR, ACR-700, and ESBWR should be achievable for the first plants constructed in the United States. The Toshiba ABWR and Westinghouse AP1000 schedules of 36 months are viewed as very aggressive and may not be achievable until the U.S. nuclear construction program has been restarted and the U.S. nuclear experience base has been reestablished. It became clear during these evaluations that several conditions must be met for any of the vendors to achieve their stated construction schedules:

- Design is complete and regulatory issues are fully resolved before first concrete is placed.
- Nuclear materials are available at the appropriate time in correct and sufficient quantity.
- The project is located in an area where sufficient labor is available.
- Modularization is used to the extent portrayed by the vendors.

The evaluations were based on comparisons and qualitative analyses of summary level historical data from past nuclear power plants. More detailed and quantitative assessments are not possible without a clear understanding of the material quantities and manpower used to establish the activities in each vendor's schedule.

Because of the lack of detailed quantities, it was also not possible to evaluate the amount of work that could be performed offsite through prefabrication, preassembly, and modularization. However, it is clear that moving work offsite through modularization will reduce the amount of congestion onsite and also the amount of onsite labor. It is reasonable to expect that by reducing congestion and work interferences, there will be some reduction in the time required to complete the onsite work. In a facility such as a nuclear power plant, the shortest achievable schedule is frequently defined by completion of the concrete work in the reactor building. With just-in-time deliveries of modules and open top construction for rapid installation of the modules, it is reasonable to expect the maximum benefit to schedule reduction will approximate the period from first concrete to completion of the reactor building structure, plus some period of time to complete tie-ins of the modules to each other and final testing of the completed installations before fuel load. Parallel assembly through prefabrication, preassembly, and modularization will help to reduce the risk of a project being stopped or slowed by problems that typically slowed or halted serial construction activities. And, allowing work to proceed on multiple parallel fronts ensures flexibility in resolution of schedule problems.

2.2.3.1 ABWR

GE's 43-month duration from first concrete to fuel load appears reasonable, but only if the conditions on the bulleted list in Section 2.2.3 are met.

The modularization plan presented by GE is well thought out and appears to offer significant schedule benefits through parallel construction. (It should be noted that GE's descriptions of the modules being considered fall more closely under the definition of prefabrications and preassemblies than that of a true module. However, the benefits of parallel construction are applicable to prefabrication and preassembly also. See the discussion in Appendix 2A for more information on prefabrication, preassembly, modularization, and offsite assembly.)

The Toshiba information indicates a first concrete to fuel load duration of 36 months and a first concrete to commercial operation duration of 43 months. It is important to note that ABWR projects in Japan have successfully completed first concrete to commercial operation in the high 40-month range and Toshiba has plans to improve on this to get to the low 40-month range. But these durations could only be achieved in the United States once the U.S. nuclear construction program has been restarted, the U.S. nuclear experience base has been reestablished, and then only if issues such as labor shortages, design changes, and material delivery problems can be avoided.

2.2.3.2 ACR-700

The 40-month duration from first concrete to fuel load for the ACR-700 appears reasonable, but only if the conditions on the bulleted list in Section 2.2.3 are met.

The ACR-700 is unique in the fact that the reactor building has been designed from ground up with modularization as the driving design philosophy. The concrete reactor building structure is slip-formed and erected in much the same manner that high-rise concrete buildings are constructed. Viewed from overhead, the interior of the reactor building consists of vertical shafts referred to as vertical installation compartments. Completed modules are set into the compartments with a heavy lift crane and tie-ins are made to adjacent modules. This technique has the advantage of allowing flexibility in scheduling around late arriving modules and equipment. For instance, if the bottom module in one shaft were to arrive late, work could be shifted to other shafts while delivery of the late module is coordinated.

2.2.3.3 AP1000

The limited evaluation of concrete placement rates indicated a very high level of concrete placement for the first 2 months, but the overall reactor building concrete schedule appears achievable. The 36-month first concrete to fuel load duration could only be achieved in the United States once the U.S. nuclear construction program has been restarted, the U.S. nuclear experience base has been reestablished, and then only if issues such as labor shortages, design changes, and material delivery problems can be avoided. And, the conditions on the bulleted list in Section 2.2.3 must be met.

Westinghouse has done an excellent job in considering constructability in development of the AP1000 and the design relies on modularization and open top construction to achieve the 36-month first concrete to fuel load schedule. While the design is not as fully modularized as the ACR-700, the design team has developed a larger number of smaller modules that can be fabricated in smaller shops. This difference in design concept may prove to be advantageous for several reasons. First, by allowing more shops to bid on modules, better prices may be realized. Second, by spreading the workload through more shops, a larger labor pool can be accessed. Finally, smaller modules will result in more flexible shipping possibilities. Some of these advantages will be partially offset by the increased coordination and management needed for the increased number of shops supplying modules.

Westinghouse has developed a 4D (the 4th dimension being time) presentation that links the AP1000 design drawings to the construction schedule. This combination allows the plant to be built in a virtual environment where construction sequences can be optimized for maximum efficiency in resource utilization. A number of the design drawings reviewed had a table relating various construction components, such as groups of structural members, to a specific schedule activity. When fully implemented, this capability could provide a valuable tool for detail design and construction execution.

2.2.3.4 ESBWR

GE provided minimal schedule information. However, because the ESBWR is a simpler version of the ABWR and earlier BWR designs, the 39-month duration from first concrete to fuel load appears reasonable, but only if the conditions on the bulleted list in Section 2.2.3 are met. Based on the limited and high-level examination of the material quantities, it appears that the ESBWR concrete and cable quantities are within the range of possibility for a first concrete to fuel load duration of 39 months. The piping quantity appears to be significantly higher than expected; further details are needed before a conclusion can be reached in this area.

GE has greatly simplified the BWR concept with this plant and has eliminated a number of systems with pieces of large equipment. By doing this, they have been able to reduce the building volume which ultimately results in fewer cubic yards of concrete and steel per megawatt. While the design is not sufficiently complete to allow a detailed analysis, a high-level review of the pictorials and drawings that are available confirms that significant benefits in constructability should be realized. GE should be able to adapt the final configuration to maximize the benefits available through modularization and standardization of the plants components.

2.3 Conceptual Deployment Schedule

This section develops a conceptual schedule for the deployment of the first new commercial nuclear power plant in the United States. The schedule integrates the licensing process with the necessary engineering, procurement, fabrication, construction, training, and startup activities for plant deployment.

2.3.1 Evaluation

Figure 2-1 is a conceptual milestone summary schedule for the first advanced reactor deployment in the United States. The schedule begins with a January 2004 decision to proceed with new plant deployment.

The following assumptions were made to develop the conceptual schedule:

- Early Site Permit, Design Certification, and Combined License Schedules

  The untested 10 CFR 52 combined license (COL) process will be a major focus of the first several years of the plant deployment effort. The 10 CFR 52 process for design certification has been extensively tested and the early site permit (ESP) process is currently being demonstrated for the North Anna, Grand Gulf, and Clinton sites. But no one has ever applied for a COL and the process is largely undefined. The industry is just beginning to evaluate COL requirements through the NEI COL Task Force. Working with the NRC to mutually understand the COL process, preparing a full and complete COL application, and actively supporting the NRC review will be vital to project success.

  The schedule in Figure 2-1 is based on obtaining a design certification and ESP and relying on the results, issue resolutions, and information developed in those licensing proceedings as part of the COL process. Although a combined license can be applied for and issued without an ESP and design certification, the schedule assumes that an ESP and design certification are obtained for the following reasons:

  - Pursuing an ESP and design certification allows for the early identification and resolution of issues.

  - The COL application is simplified because it can incorporate a large amount of information from the ESP and design certification applications by reference.

  - A reactor vendor will pursue NRC design certification in order to promote its standard plant design to future customers.

  The ESP schedule includes 15 months to prepare the application, 20 months for the NRC safety and environmental review, and 12 months for the hearing. This schedule is consistent with the ongoing Grand Gulf, Clinton, and North Anna ESP projects.

The COL schedule includes 24 months to prepare the application, 20 months for the NRC review, and 12 months for the hearing. The 24-month time to prepare the application is reasonable considering: (1) approximately 15 months was needed to prepare the much more limited ESP applications for North Anna, Grand Gulf, and Clinton; (2) this would be the first license application for a new nuclear plant in many years; and (3) the NRC's regulatory guidance is out of date in many existing technical areas and it has not been developed for the new 10 CFR 52 process. The 20-months for NRC review and 12 months for the hearing are taken from the predicted durations for the ESP projects. Preparation of the COL application begins 3 months after the ESP application is submitted to the NRC because many of the same resources would likely be used to prepare both documents and additional time is needed to complete the higher level of reactor design engineering that is needed for the COL application.

The design certification schedule includes about 18 months for the NRC pre-application review and preparation of the application and approximately 42 months for the NRC review through the final rulemaking. These durations are consistent with current/projected design certification reviews for the AP1000, ACR-700, and ESBWR.

■ Engineering Schedule

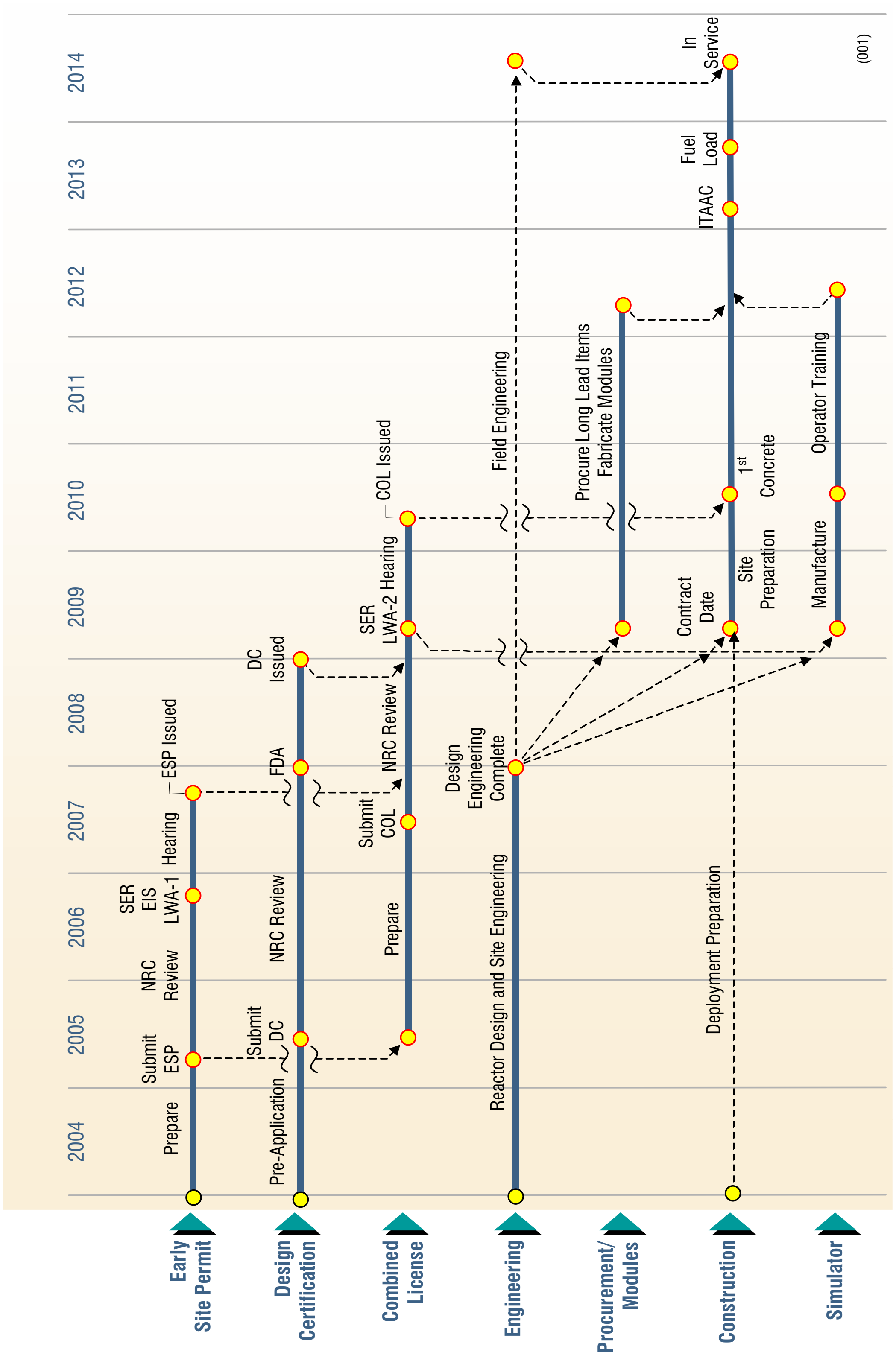
Approximately 48 months is included for reactor design engineering (including nuclear island and BOP) and site engineering (cooling water, transmission, etc.). This duration could be more or less depending on the reactor design and chosen site. Engineering is assumed to be complete before the start of construction, but also to support the ESP, design certification, and COL applications and NRC reviews.

■ Construction and Startup Schedule

Plant construction and startup durations, for an existing commercial nuclear power plant site, are as follows:

- The contract effective date to commercial operation is approximately 68 months, which is the average of the values in Table 2-3. Procurement of long lead items would begin on the contract effective date.
- Site preparation activities before first concrete will take approximately 18 months.
- The first concrete to fuel load duration is about 39 months, which is the average of the values in Table 2-3.

Figure 2-1. Conceptual First Plant Deployment Schedule



- The fuel load to commercial operation duration is about 7 months, which is the average of Table 2-3.
- Approximately 18 months is needed for plant simulator manufacture and delivery, and another 18 months for operator training. The reactor vendor and utility input on these durations varied widely and average durations were chosen.

No engineering, licensing, labor availability, equipment availability (including long lead items), or other delays are assumed.

■ Limited Work Authorizations

Two limited work authorizations (LWAs) could be requested from the NRC under the ESP and COL processes:

LWA-1

As part of the ESP review, an applicant can request the NRC to issue an authorization under 10 CFR 50.10(e)(1) to allow certain limited, nonsafety-related, site preparation work to be performed. This limited work authorization is typically known as an "LWA-1." An LWA-1 would allow the following activities to be performed:

- Preparation of the site for construction of the facility including such activities as clearing, grading, construction of temporary access roads and borrow areas
- Installation of temporary construction support facilities including such items as warehouse and shop facilities, utilities, concrete mixing plants, and construction support buildings
- Excavation for facility structures
- Construction of service facilities including such facilities as roadways, paving, railroad spurs, fencing, exterior utility and lighting systems, transmission lines, and sanitary sewerage treatment facilities
- Construction of nonsafety-related structures, systems, and components

LWA-2

Under the COL process, an applicant can request an "LWA-2" from the NRC in accordance with 10 CFR 50.10(e)(3)(i). An LWA-2 would permit each of the LWA-1 activities to be performed plus the installation of structural foundations, including any necessary subsurface preparation, for safety-related structures, systems, and components.

For the conceptual schedule in Figure 2-1, it is assumed that (1) site preparation activities do not begin until receipt of an LWA-2, and (2) safety-related concrete would not begin until receipt of the COL. These assumptions reflects a conservative business approach that would avoid committing potentially large sums of money until the outcomes of the COL process are well understood.

- Activities Not Shown

Business decisions (e.g., contract negotiation, financing, need for power); activities associated with development of the infrastructure necessary to support a new plant (e.g., quality assurance, design control, maintenance); and deployment preparation (e.g., supplier qualification, construction planning) are not included on the schedule.

2.3.2 Results and Conclusions

A review of Figure 2-1 yields the following results:

- The first in a series of new nuclear plants could be in service approximately 10 years from the start of the project, beginning with preparation of an ESP application.
- The critical path during the first several years of the project will be the COL effort including preparation of the COL application and supporting design engineering, the NRC review, and the hearing.
- The time required to manufacture and deliver the simulator and train operators is not well understood at this time. Further evaluation of these activities is needed.
- The manufacture and delivery of long-lead items (e.g., reactor vessel, steam generators, turbine-generator) and modules could be on the critical path and should be evaluated further when details are available.
- The timely closure of the ITAAC approved as part of the COL in accordance with 10 CFR 52.79(c) will be critical to completing construction and proceeding to fuel load and startup. Further evaluation of this activity is needed.

It is recognized that some opportunities may exist to improve on the Figure 2-1 schedule. For example, the ABWR design could be chosen for deployment at an existing nuclear power plant site. The engineering duration in this case should be less than 4-5 years because the time needed would only be to modify the existing ABWR design documents (from the operating ABWRs in Japan) for a U.S. nuclear site. Also, the ABWR standard design is already NRC-certified—and Toshiba's improvements to the standardized design would likely not require 5 years to receive NRC approval. If it is further assumed that a separate ESP is not pursued and site issues are addressed as part of the COL, the overall schedule might be improved by 15-18 months. This would be possible provided that (1) the effort to modify the engineering documents supports the dates when this information is needed to prepare sections of the COL application, and (2) the inclusion of ESP issues in the COL process does not delay and/or complicate the NRC review and hearing. A 56-month COL duration is still appropriate for this case because it would be the first new advanced reactor to be licensed in the United States.

The time required from contract effective date to commercial operation is a key evaluation factor for new power plant construction. Efforts must be focused on reducing this duration (estimated at 68 months average from Table 2-3) to the extent possible. Detailed design, quantity, resource, modularization, long-lead procurement, and other information will be needed to develop and optimize an integrated schedule and execution plan for these activities.

Once the industry and NRC have demonstrated the COL process on the first plant(s), and the U.S. nuclear construction program has been restarted, shorter overall durations should be achievable, but only if issues such as labor shortages, design changes, and material delivery problems can be avoided.

2.4 Evaluation of Construction Technologies and Module Fabrication Facilities

As part of the constructability evaluation, an assessment of potential new construction technologies and module fabrication facilities was performed.

2.4.1 New Construction Technologies

MPR Associates performed a detailed evaluation of advanced construction technologies in their report, MPR-2610, "Application of Advanced Construction Technologies to New Nuclear Power Plants,’ which is contained in Volume 2. MPR evaluated 13 advanced construction technologies as shown in Table 2-9.

Table 2-9. Advanced Reactor Construction Technologies

No.	Description	Recommended For Advanced Reactor Implementation
Sufficiently Mature with Proven Economic Benefits		
1	Concrete composition technologies	Yes
2	High deposition rate welding	Yes
3	Robotic welding	Yes
4	3D modeling	Yes
5	GPS applications in construction	Yes
6	Open-top installation	Yes
7	Pipe bends versus welded elbows	Yes

Table 2-9. Advanced Reactor Construction Technologies

No.	Description	Recommended For Advanced Reactor Implementation
8	Precision blasting/rock removal	Yes
Show Promise But Further Technical Development Needed		
9	Prefabrication, preassembly, modularization	Yes
10	Cable pulling, termination, and splices	Yes
11	Steel-plate reinforced concrete structures	Yes
12	Advanced information management and control	Yes
Not Recommended		
13	Fiber-reinforced polymer rebar structures	No

Bechtel construction representatives reviewed the MPR report and they agree with the conclusions shown in Table 2-9 with the following additional comments. These comments are based on Bechtel's evaluation of the advanced reactor construction schedules, our experience in power plant construction, and independent research on construction technologies performed for this study.

- Of all the technologies evaluated, parallel construction through modularization and open top construction offer the greatest potential to help achieve the aggressive construction schedules proposed by the vendors. The vendors for each of the reactor designs have proposed these techniques. In the past, the use of modularization and open top construction has been limited in nuclear construction as a result of two factors—fitup between modules and crane capacities. Both of these constraints have been eliminated or reduced by technological improvements in the last decade.

- Appendix 2A discusses a recent study performed by the CII related to advances in design and information technologies. These advances combined with increasing emphasis to address cost, schedule, and labor issues have renewed interest in prework and the use of prefabrication, preassembly, modularization, and offsite assembly (PPMOF) as tools to reduce cost and schedule and to compensate for declining work forces by spreading work over a larger geographical area. Application of PPMOF methods for new nuclear construction could result in major schedule and cost improvements. An evaluation of PPMOF features for the advanced reactor designs is included in Appendix 2A.

- The application of technologies such as composite steel construction and seismic base isolation may also help to increase the probability of achieving aggressive schedules by dramatically altering the sequence and requirements for construction. Neither of these techniques is proposed to any significant extent in the designs reviewed, though the AP1000 and ABWR do have some composite construction areas planned. None of the reactor vendors have proposed seismic base isolation.

Use of composite steel construction (http://web.umr.edu/~ccfss/rd11.html) has the potential to revolutionize how plants are scheduled and constructed. Two major contributors to the amount of time required to build a concrete structure are formwork and rebar installation. Composite steel construction virtually eliminates both as bottlenecks. By using the composite construction technique, formwork is fabricated from steel plate and remains in place after the concrete is placed. By fabricating composite steel formwork in the same manner as machinery modules, the amount of time to erect a wall can be reduced from weeks to days. By using approved concrete accelerants, concrete can reach design strength in days, allowing the next level of formwork to be installed almost immediately. Use of these technologies has the potential to radically change the way a power plant is constructed.

Seismic base isolation (earthquake isolators; see http://nisee.berkeley.edu/lessons/kelly.html) is a relatively new concept though it has been used in several large buildings constructed during the 1980s and 1990s. As described in Appendix 2C, seismic base isolation for a nuclear plant is intended to isolate the plant from the effects of an earthquake. Base isolators are currently in use at the Koeberg nuclear station in South Africa and at several nuclear plants in France. Seismic base isolation has the potential for dramatic improvements in cost and schedule with potential benefits including:

- Truly standardized designs for power blocks by removal of site-specific seismic influences.
- Elimination or minimization of specialized seismic supports for piping, steel, and cable tray.
- Maximization of the use of commercial-grade equipment in place of expensive seismically qualified equipment.

These and other emerging technologies present a basis for optimism when considering new nuclear generation and the ability to achieve short construction schedules for advanced reactors.

2.4.2 Module Fabrication Facilities

Each of the four advanced reactor designs relies on some degree of modularization to achieve their short construction schedule. In order to assess module fabrication facilities that could be used to support new plant construction in the United States, visits were made to five facilities that represent the current state-of-the-art for nuclear grade fabrications. Tours were conducted at each facility to assess the current state of modular fabrication technologies and shop availability for module fabrication over the next 5 to 10 years.

Fabrication facilities such as those involved in commercial building construction and offshore gas platform fabrications were not reviewed because it is thought that the issues related to nuclear grade assemblies are not fully appreciated by those not familiar with the nuclear industry. It is reasonable to expect however that commercial and offshore gas platform facilities could be adapted to support nuclear grade fabrication in the future should such a need arise.

The five facilities selected were:

- Newport News Shipyard, operated by Northrop Grumman, in Newport News, Virginia
- Electric Boat Shipyard, operated by General Dynamics, in Groton, Connecticut
- Mitsubishi Heavy Industries Fabrication Facilities, in Kobe, Japan
- Hitachi Industries Fabrication Facilities, in Hitachi City, Japan
- Toshiba and IHI Fabrication Facilities, in Yokohama, Japan

Each of the locations selected has experience with the manufacture and assembly of nuclear systems and components. Each of the facilities in Japan has significant experience with commercial nuclear power fabrications. The Newport News and Electric Boat shipyards are primarily focused on U.S. Navy ship fabrication, with limited experience in commercial nuclear power work.

The facility tours were conducted in October and November 2003. Attendees on the tours included representatives from DOE, MPR Associates, Bechtel Power Corporation, and, for the U.S. shipyards, a representative from Dominion. A representative from AECL accompanied the tour group during the visits to the MHI and Hitachi fabrication facilities.

2.4.2.1 Findings

The following findings resulted from the module fabrication facility tours:

- Each facility has successfully addressed the issues associated with modular fitup when the modules are finally shipped to their installation location. Field fitup had been an area of significant difficulty in attempts at modularization with earlier nuclear plants.
- All parties have experienced significant overall project schedule improvements as a result of parallel construction of major portions of their projects.
- All parties agree productivities in the shop are significantly better than those that would be realized with traditional "stick-built" techniques in the field. The U.S. shipbuilders claim productivity improvements follow a 1-3-8 rule where a task taking 1 jobhour in a fabrication shop would take 3 jobhours in an onsite temporary facility and 8 jobhours if done in-place using traditional construction techniques. These ratios are not applicable to all activities however.

- All parties agreed that fabrication in properly equipped shops reduced the overall labor demand to complete a project.
- All parties agreed that shop fabrication improved safety performance.
- All parties agreed that shop fabrication resulted in improved quality performance.
- At each facility, shop management stated that current and project workloads were down and trending further down. None of the shops foresaw a shortage of shop space for module fabrication within the next decade.

2.4.2.2 Conclusions

Based on the tours of module fabrication facilities in the United States and Japan, a strong international capability exists to support the modularization approaches proposed by the vendors for their advanced reactor designs. The fabrication facilities located in Japan have extensive commercial nuclear power experience. The U.S. shipyards could adapt their U.S. Navy experience for commercial nuclear power applications with some effort. Current and projected workloads at each facility indicate an ability to handle new module fabrication work associated with advanced reactor construction over the next 5 to 10 years.

2.5 CII Project Definition Rating Index Evaluation

The Construction Industry Institute is an organization of 80 owners, designers, constructors, and architects with a strong interest in improving both the products and processes associated with construction of industrial and manufacturing plants. Among its many activities, the CII conducts basic research into construction and engineering work processes. One such research activity is pre-project planning associated with project development.

Several years ago, the CII developed the Project Definition Rating Index to measure project development and provide a tool for predicting successful implementation of a project based on the level of development completed. The PDRI is based on empirical evidence from 40 small ($1 million) to medium ($600 million) capital projects and extensive interviews with project participants.

The PDRI is the only known practical, nonproprietary tool of its kind that allows a pre-project planning team to objectively assess the probability of achieving a project's goals before authorization. An advantage of such a tool is that the PDRI can be customized to fit the needs of almost any company.

Appendix 2B describes the PDRI process. As part of Appendix 2B, the four advanced reactor designs were rated using the PDRI. The results of the survey yielded the following conclusions:

- Vendor self-ratings show the ABWR to be the most developed technology and the ACR-700 the least with the AP1000 and the ESBWR falling midway between the ABWR and ACR-700.

- Ratings of the various technologies by study participants other than the reactor vendors indicate that all of the designs require further development. The ABWR is believed to be the most fully developed with the AP1000 and the ACR-700 following reasonably closely. The ESBWR assessment indicates significant development is still required.

2.6 Assessment of Labor Availability

The availability of labor for new nuclear plant construction in the United States is a significant concern. All indications are that the construction labor pool in the United States is aging and diminishing in number and skill level. The following assessment of U.S. labor availability was performed to underscore the need for early, ongoing, and thorough planning to ensure adequate labor resources for new nuclear plant construction projects.

2.6.1 National Trends

Research was performed to assess the general state of the construction labor pool in the United States. This research was web-based, but also included discussions with labor relations experts.

In general, the United States is experiencing the following construction labor trends:

- A diminishing number of people are being attracted to construction

- The existing construction labor workforce is rapidly reaching retirement age

- There has been little or no training of replacement work forces

- The United States will face a construction labor job boom starting in the 2005-2006 time frame that will result in severe labor shortages given the aging and diminishing labor force.

The following are just a few excerpts from the national press and other sources that support the trends identified above.

- In April 2002, Time magazine published an article by Daniel Eisenberg titled, "The Coming Job Boom," which forecasts a shortage of skilled labor for the United States:

  "Though the average retirement age is creeping up--and a growing share of Americans, by choice or necessity, are planning to work at least part time well past 65--demographers say there still will not be enough qualified members of the next generation to pick up the slack. So with 76 million baby boomers heading toward retirement over the next three decades and only 46 million Gen Xers waiting in the wings, corporate America is facing a potentially mammoth talent crunch. Certainly, labor-saving technology and immigration may help fill the breach. Still, by 2010 there may be a shortage of 4 million to 6 million workers."

The article goes on to discuss various economic sectors of the American economy and makes the following observations:

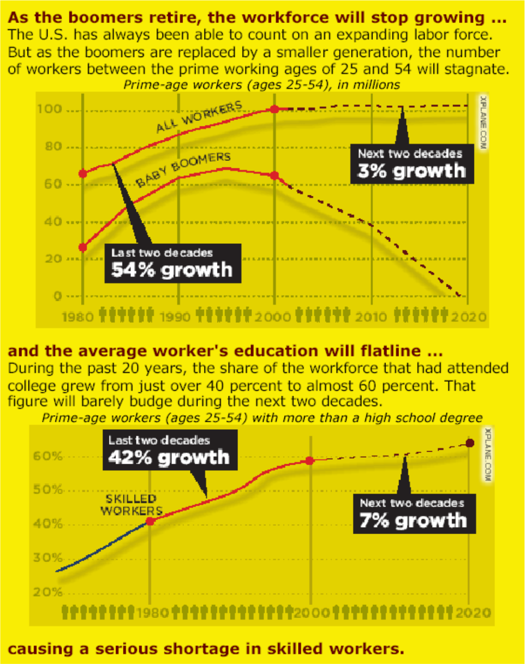
"In the dotcom mania of the '90s, it was easy to forget that skilled tradespeople can make good money.

“--CONSTRUCTION A recent industry study showed that at least one-third of St. Louis' 80,000 construction workers are expected to retire in the next five years--a microcosm of the situation nationwide; the industry needs to attract 240,000 new workers each year, from project managers to iron workers, just to compensate for the exodus. The top tradespeople in their fields, such as plumbers, electricians, carpenters, bricklayers, roofers and painters, can make upward of $100,000 a year.”

“--MANUFACTURING Even in this beleaguered sector, in which many firms have made huge layoffs, companies are having a hard time finding the right people. More than 80% of firms say they face a shortage of qualified machinists, craft workers and technicians, according to a recent survey by the National Association of Manufacturers. That deficit is likely to widen. Although manufacturing will not grow much overall during the next decade, a rapidly aging work force will create more than 2 million job openings--with many positions paying more than $50,000--for welders, tool- and diemakers, line managers and others."

- In September 2003, Business 2.0 magazine published an article by Paul Kaihla titled "The Coming Job Boom," which describes agreement between executives and economists that the supply of labor is about to fall seriously short of demand. The article describes a white paper released by the National Association of Manufacturers predicting that a skilled worker shortage will appear in 2005 and grow to a shortage of 5.3 million by 2010 and 14 million by 2020, and this is based on a long-term growth rate of just 3 to 3.5 percent per year.

From September 2003 article in Business 2.0 magazine.



As the boomers retire, the workforce will stop growing ...
The U.S. has always been able to count on an expanding labor force. But as the boomers are replaced by a smaller generation, the number of workers between the prime working ages of 25 and 54 will stagnate.

Prime-age workers (ages 25-54), in millions

and the average worker's education will flatline ...
During the past 20 years, the share of the workforce that had attended college grew from just over 40 percent to almost 60 percent. That figure will barely budge during the next two decades.

Prime-age workers (ages 25-54) with more than a high school degree

causing a serious shortage in skilled workers.

The Business 2.0 article relates primarily to high-tech and medical field workers, but the arguments are equally valid for the engineering and construction fields. The following excerpt from the article gives a sense of the urgency of their view of the upcoming problem:

"Executives at Cigna (CI), Intel (INTC), SAS, Sprint (PCS), Whirlpool (WHR), WPP (WPPGY), and Adecco (the world's largest placement firm) have told Business 2.0 that they, too, worry that the supply of labor is about to fall seriously short of demand. Former treasury secretary and current Harvard University president Larry Summers regards a skilled labor shortage as all but inevitable."

The article goes on to consider that many forecasts are based on projections that cannot be verified. The cause of this predicted shortage of skilled labor however is based in reality and fact:

"The cause of the labor squeeze is as simple as it is inexorable: During this decade and the next, the baby boom generation will retire. The largest generation in American history now constitutes about 60 percent of what both employers and economists call the prime-age workforce -- that is, workers between the ages of 25 and 54. The cohorts that follow are just too small to take the boomers' place. The shortage will be most acute among two key groups: managers, who tend to be older and closer to retirement, and skilled workers in high-demand, high-tech jobs."

"No sentient adult could have made it through the past decade without developing a healthy distrust of forecasts like these. But the case for the worker gap differs from the usual economic entrail reading in one crucial regard: It's based on demographics, a far more certain discipline. When Carnevale's model, for instance, shows that within seven years 30 million people now in the workforce will be older than 55, that's not a guess. It is virtually a certainty. ‘Any kind of demographic projection with respect to people who have already been born is notoriously accurate," agrees former Treasury Secretary Summers.’"

"...The projections assume, for instance, that the baby boomers will leave the workforce at roughly the same age as their predecessors, but how do we know that they won't delay retirement to make up for recent stock market losses and depressed 401(k)s? The answer is that the trend toward early retirement is a deeply entrenched pattern established during the past four decades, and neither bull nor bear markets have made a dent in it. Even the Social Security Administration, which would love nothing more than to make the case that the retirement age will soon rise dramatically -- the better to prove its own solvency -- has been unable to find any data to support that view."

2.6.2 Recent Project Labor Surveys

Constructors typically perform labor surveys for large near-term to medium-term (1 to 3 years) projects to ensure an understanding of potential staffing and infrastructure difficulties. Recent labor surveys indicate the construction labor group is aging and diminishing in number and skill level. Labor surveys with a time horizon in excess of 3 years have proven to be indicative of trends but of little value for detailed project planning. In a recent labor study for a steam generator replacement (SGR) project in the southeastern United States, the Bechtel labor relations department made the following observations:

> "We note that [the contractor] was unable to adequately staff the Unit #1 SGR in March 2002 and ran substantially over its 75 day completion date."
>
> "If not efficiently and effectively coordinated, staffing will be a major concern for Bechtel and the customer. Due to the abundance of work at Oak Ridge, Bechtel cannot count on drawing labor from the Knoxville area to staff the project. In fact, the opposite may be true—Oak Ridge may be seeking to attract workers from other areas to meet their staffing requirements."
>
> "As the demand for skilled craft workers has continued, employers in the construction industry in general and contractors engaged in SGR, SCR [steam condenser replacement], and power plant outage work in particular, have utilized various forms of incentives to attract and retain skilled workers to their projects."
>
> "It is necessary to understand that skilled craft workers will seek out work opportunities based upon a sound economic principal – the opportunity to increase their earning capabilities. Workers follow the money."
>
> "Business representatives spoken to as part of this assessment indicated they have members traveling to New York, Boston, and other areas of the country to work on projects that pay higher wages, offer substantial amounts of overtime and/or offer per diem, rather than remain in the TVA system."
>
> "Use of travelers, crafts workers from other jurisdictions or regions of the country, is a normal accepted pattern in the construction industry. This is due, in part, to the nature of the industry that is known for dramatic employment swings. It would be impractical, if not impossible, to have labor waiting and available in a local area or region to meet all demands."
>
> "Attracting skilled workers also becomes exacerbated due to the fact that they must face the scrutiny of a NRC background check in order to gain a security clearance necessary to work on a nuclear facility. In many instances workers are unable to gain access to sites. Finally, Bechtel Construction Company and the customer, require that all workers possess certain certifications to work on site. These include crane, and mobile equipment operations, welding, scaffold erection, rigging and OSHA 10 hour certifications."
>
> "While all of these requirements are driven by business necessity, they also tend to reduce the number of available workers in an existing labor pool because they fail to meet the established employment criteria or choose not work on "short-term" projects. As a

> result incentives have been used both to attract and retain workers with their requisite skill sets to various projects throughout the region."

Labor surveys for projects in other areas of the country have generally supported the observations listed above. For a single project almost anywhere in the United States, it is likely a contractor will be able to staff a nuclear project (if history is any indicator, the estimated peak population will be from 2,000 to 5,000 craft) assuming wage rates are sufficient to attract the craft.

2.6.3 Labor Assessment Conclusions

Attracting craft with the high skill levels and regulatory employment criteria for new nuclear plant construction will be more difficult than attracting craft to complete a standard industrial project. The group of craft currently doing nuclear work is significantly smaller than the total construction craft population and is in higher demand because of the higher skill levels and greater capability to meet strict employment standards. Higher demand and lower supply imply higher wage expectations.

A strategy to reduce or minimize these problems is to shift portions of the work to areas of the country where skills and craft are available in sufficient quantity. Modularization allows this to happen and will become an important aspect of new nuclear construction.

2.7 Conclusions

This section evaluated construction schedules for advanced reactor designs. Research was also conducted into advances in construction and engineering design technologies that have been identified as candidates to support improved performance in construction of new nuclear plants. The conclusions of the evaluation are as follows:

- None of the reactor vendors presented sufficient information to perform a detailed schedule assessment of resource loadings, durations, logic, etc. More detailed and quantitative assessments are not possible without a clear understanding of the design and the material quantities and manpower used to establish the activities in each vendor’s schedule.

- Because of the lack of detailed information, only summary-level, qualitative reviews could be performed. Based on these qualitative reviews, the first concrete to fuel load durations for the GE ABWR (43 months), ACR-700 (40 months), and ESBWR (39 months) should be achievable for the first plants constructed in the United States. The Toshiba ABWR and Westinghouse AP1000 schedules of 36 months are viewed as very aggressive and may not be achievable until the U.S. nuclear construction program has been restarted and the U.S. nuclear experience base has been reestablished. The following conditions must be met for any of the vendors to achieve their stated construction schedules:

    - Design is complete and regulatory issues are fully resolved before first concrete is placed.
    - Nuclear materials are available at the appropriate time in correct and sufficient quantity.

  - The project is located in an area where sufficient labor is available.
  - Modularization is used to the extent portrayed by the vendors.

  The schedules presented for the ABWR, ACR-700, and AP1000 are well thought out and rely extensively on parallel construction through modularization and open top construction. No obvious logic or other flaws were identified in these schedules. Minimal schedule information was provided for the ESBWR but a parallel construction approach was also identified.

- Where information was received from the vendors, reactor building installation rates for the advanced reactor plants generally compare well with past nuclear plant construction projects:

  - For reactor building concrete, the ABWR, ACR-700, and AP1000 installation rates compare well with past projects. No installation rates were provided for the ESBWR, but the quantity of concrete to be placed appears reasonable for a first concrete to fuel load duration of 39 months.

  - For reactor building piping, the ABWR and ACR-700 installation rates compare well with past projects. No piping quantity or installation rates were provided for the AP1000. The piping quantity for the ESBWR appears to be significantly higher than expected and further details are needed before a conclusion can be reached.

  - For reactor building wire and cable, the ACR-700 installation rates compare well with past projects. The ABWR rates provided by Toshiba could be achieved with increased craft manhours and longer durations. For the AP1000 and ESBWR, the amount of wire/cable to be installed appears reasonable.

- The advanced reactor construction schedules are comparable to the actual nuclear plant construction schedules that were achieved before the extended delays of the late 1970s and later. However, the majority of plants built in the early to mid 1970s were small (less than 500 MWe) and medium-sized (500-1000 MWe) plants. The only large (1000 MWe or greater) plant to achieve a construction duration comparable to the new reactors was Zion 1, which was placed in service in December 1973 and had a site preparation to fuel load duration of approximately 60 months.

  The advanced reactor construction schedules do compare well with the *planned* construction schedules for various medium-sized and large units constructed through the mid 1980s. These planned schedules were the "going-in" plans developed to complete construction before the various delays that were experienced on individual projects.

- The conceptual plant deployment schedule indicates that the first in a series of new nuclear plants could be in service approximately 10 years from the start of the project. Some opportunities to improve on this schedule may exist depending on the reactor design and site chosen. Further effort is needed to focus on reducing the time required from contract effective date to commercial operation. In addition to the plant construction sequence, several key activities must be further evaluated to reduce this duration including: plant simulator design, manufacture, and operator training; procurement of long-lead items such as reactor vessels and steam generators; the NRC ITAAC process; and startup to commercial operation activities.

- Of all the construction technologies evaluated, parallel construction through modularization and open top construction offer the greatest potential to help achieve the aggressive construction schedules proposed by the vendors. These construction techniques hold great promise. In the past, the use of modularization and open top construction has been limited in nuclear construction as a result of two factors—fitup between modules and crane capacities. Both of these constraints have been eliminated or reduced by technological improvements in the last decade.

  Adaptation of technologies, such as composite steel construction and seismic base isolation, may also help increase the probability of achieving aggressive schedules by dramatically altering the sequence and requirements for construction. Neither of these techniques is proposed to any significant extent in the designs reviewed, though the AP1000 and ABWR do have some composite construction areas planned. None of the reactor vendors have proposed seismic base isolation.

- Based on the tours of module fabrication facilities in the United States and Japan, a strong international capability exists to support the modularization approaches proposed by the vendors for their advanced reactor designs. The fabrication facilities located in Japan have extensive commercial nuclear power experience. The U.S. shipyards could adapt their U.S. Navy experience for commercial nuclear power applications. Current and projected workloads at each facility indicate the ability to handle new module fabrication work associated with advanced reactor construction over the next 5 to 10 years.

- A shortage of qualified labor appears to be a looming problem; however, there are several mitigating measures that can be taken to minimize the impact of low skill levels and short supply. Both issues can be worked around by shifting work to areas of the country where skilled labor shortages are not an issue. This is most effectively done through modularizing portions of the plants to be built. Also, aggressive programs for training craftsmen before and during the construction phase of the project will help ensure that the necessary construction skills are available.

The construction approaches, schedules, and technologies evaluated in this report present a basis for optimism when considering new nuclear generation and the ability to achieve short construction schedules for advanced reactors.

2.8 Recommendations

Recommendations from the evaluation of construction technologies and schedules are as follows:

- Each vendor should develop resource-based schedule durations and logic information so that quantitative assessments can be performed to optimize the construction schedule. In addition to the plant construction sequence, several key activities should be further evaluated to reduce the time from contract effective date to commercial operation including: plant simulator design, manufacture, and operator training; procurement of long-lead items such as reactor vessels and steam generators; the NRC ITAAC process; and startup to commercial operation activities.

- Construction approaches should maximize the use of advanced construction technologies. The greatest emphasis should be placed on parallel construction through modularization and open top construction. Several of the technologies, particularly seismic base isolation, need further technical development by the reactor vendors. See also the recommendations in MPR's report, MPR-2610, in Volume 2 for other advanced construction technologies.

- A shortage of qualified labor will be a significant issue for new nuclear plant construction projects. Early, ongoing, and thorough planning should be performed to ensure the necessary construction skills are available.

Appendix 2A
Prefabrication, Preassembly, Modularization, and Offsite Assembly

1. Introduction

The Construction Industry Institute (CII) is an organization of 80 owners, designers, constructors, and architects with a strong interest in improving both the products and processes associated with construction of industrial and manufacturing plants. Among its many activities, the CII conducts basic research into construction and engineering work processes.

A recent study performed by the CII relates to advances in design and information technologies. These advances combined with increasing emphasis to address cost, schedule, and labor issues have renewed interest in the use of prefabrication, preassembly, and modularization as tools to reduce cost and schedule and to compensate for declining work forces by spreading work over a larger geographical area.

Successful implementation of prework requires a systematic analysis and decision-making process to evaluate the potential benefits and barriers to using these methods on projects. CII formed a research team to identify state-of-the art practices of prework and develop a decision framework to assist project teams in considering possible use of prework on their projects.

In developing the decision framework, the research team focused on identifying the requirements for effective use of prework on industrial projects. Prework may not be appropriate for every project, but it can bring major schedule and cost improvements for the right ones.

The various components of prework—***P***refabrication, ***P***reassembly, ***M***odularization, and ***OF***fsite assembly (PPMOF)—are terms used interchangeably, and frequently incorrectly, during discussions relating to modularization. Each of the PPMOF terms has a specific definition that will help clarify key discussion points when used consistently:

- **Prefabrication** — A manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of a final installation. Prefabricated components often involve the work of a single craft.
- **Preassembly** — A process by which various materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a subunit; generally focused on a single system.
- **Modules** — Completed component sections of a plant including all equipment, piping, electrical, instrumentation, insulation, and painting. Modules have been tested to the maximum extent and are ready to plug in and start up (with limitations). Modules can weigh from a few thousand pounds to hundreds of tons.

- **Offsite Fabrication** — The practice of preassembly or fabrication of components both off the site and on site at a location other than at the final installation location.

2. Application of PPMOF

Successful application of PPMOF construction methods requires proper planning and decision-making processes. It is generally recognized that the tradeoffs for realizing the benefits of pre-work include increases in the amount of preplanning, earlier completion of engineering, and a higher degree of coordination required for the project. The nature of prework tends to increase requirements for design and procurement logistics.

Because of new technologies and a changing construction environment, factors influencing the prework decision-making process have expanded and changed in the last decade. These changes have resulted in the need to reevaluate the role of prework and how decisions are to be made regarding the level and scope of its implementation.

New technologies such as computer-controlled fabrication equipment, 3D CAD, electronic data transfers, and the Internet have provided opportunities for advances in design efficiency and coordination. While these technologies may provide overall project benefits regardless of the construction method, certain prework impediments can be directly reduced through the use of these information technologies.

Recent trends in construction emphasize assemblies that exploit the capabilities of 3D CAD technology to ensure accuracy, precision, and visualization. In a CII study at the University of Texas, it was estimated that the use of prefabrication and preassembly has increased approximately 90% over the last 15 years. The study was based on a survey of over 27 construction professionals with a combined experience of more than 700 years.

Other recent developments in information technology include advances in supply chain management. Information technologies have the potential to allow transmission of a "just-in-time" order for a rebar assembly to a fabrication plant and have that plant deliver the assembly within 24 hours, from scrap metal to final assembly and delivery. More common industrial applications include structural assemblies, piping spools, wiring harnesses, and precast concrete modules.

The capability and beneficial use of information technology on design and construction projects is advancing rapidly. The ability to develop CAD models that include knowledge required for use of prework along with extensive engineering, procurement, and construction information about all the components of a plant is a major advantage for the potential use of modularization and preassembly. By its nature, prework contains more physical and organizational interfaces, providing opportunities for improvement through the automation made possible with CAD and other information technologies.

Changes in the current construction industry climate also align well with the concepts of prework, further justifying the updated frameworks reflecting these changes. Shortages of adequate labor and skills can potentially be handled by prework. Increased emphasis on safety, cost, and schedule control for projects can also be addressed by prework.

Adequate decision-making with regard to prework requires the inclusion of these technologies and consideration of other influencing factors driving or impeding implementation. While some companies have employed prework methods successfully, the overall power plant construction industry culture still has not fully recognized the potential for project improvements.

Providers of prework, such as companies specializing in modularization, have identified decision factors in industry journals and through their own marketing efforts. One major modular fabricator identified the factors below for use when considering the use of modularization. Each area under consideration contains quantifiable costs and benefits.

Project parameters for feasibility of modularization include:

- Overall cost
- Schedule
- Safety
- Operability and maintenance
- Quality
- Impact on the local environment
- Marketability
- Detailed design
- Procurement
- Fabrication
- Transportation
- Construction
- Secrecy

Traditional project factors driving desired benefits also apply prominently when considering prework. Cost, schedule, quality, and safety are the main drivers. Subcategories supporting these themes include productivity, risk reduction, and environmental factors. Prework has the potential to positively affect the project in each of these areas. The reduced cost of fabricator labor compared to onsite workers combined with the increased productivity of the manufacturing facility translates into schedule compression (through parallel construction) with minimal cost impact. A shortage of skilled, onsite labor may also play a factor into the decision to use prework. Anticipated shortages of skilled labor will likely be a strong driving force in the decision to use prework for new nuclear construction.

Cost savings mostly consist of the differences between field work and shop fabrication productivity and support costs. Other savings may be associated with overhead reduction, transportation, and installation efficiencies and future projects. A CII study of industrial construction projects found that in some cases, estimates in cost reduction were 10% for overall project cost and 25% for onsite labor costs (Tatum et al, 1987). Cost reductions were attributed to the lower cost of offsite labor. Shop productivity is better than field productivity because of controlled conditions, closer supervision, and easier access to tools. Controlled conditions such as ground-level work, climate control, and consistent lighting directly impact productivity. The proximity of workers and workspaces (1) reduced supervision requirements and the time to access necessary tools and (2) increased productivity. Often in the field, the supervisor or the worker in need of a tool must cover large distances to accomplish tasks.

Since some or all of the work may be relocated to an offsite location, costs associated with site infrastructure and overhead can be reduced. Fewer workers on site translate into fewer costs for accommodations in remote locations, simplified scheduling for onsite work, and other onsite logistics. Other cost savings may include savings from fewer material deliveries and reduced crane usage. The cost of transporting a large assembled unit may provide savings over many shipments of individual pieces, including tracking and storage costs. Future requirements for expansion or conversion of capital facilities may benefit from the use of prework on existing projects. Some prework can be designed for expansion or relocation. For example, modular units may be designed for replacement or expansion depending on regulatory or technological improvements. Prework designs also provide opportunities for replication, reducing costs associated with learning curves and engineering.

Schedule frequently drives the use of many forms of prework. Increased productivity and activity desequencing through parallel construction are typical ways of improving schedule with prework. By relocating work to offsite locations with higher productivity, cost and schedule savings are possible. One CII study in the area of building construction estimated a reduction in onsite labor of 40%–50%, along with compressed schedules due to shorter critical paths (Warszawski 1990). Nuclear reactors designed using modular methods and offsite fabrication have seen improvements in schedule length and control (Kupitz and Goodjohn 1991). Desequencing examples include fabricating structural steel offsite while foundations are poured onsite. Desequencing may also be appropriate when permitting delays onsite work. Fabrication may continue offsite while permitting delays activities at the project location.

Other schedule benefits associated with prework include risk management. While prework provides opportunities to compress schedule, some of the most attractive drivers are improvements in schedule control. Offsite work schedules by nature contain fewer inherent risks due to conflicting crews, weather delays, or interferences with ongoing operations.

Prework may be driven by quality requirements. Fabricating components away from the site allows higher levels of quality control because of the controlled manufacturing environment in which the components are constructed. Pipe racks that were once assembled on site—subjected to the weather and taking up space on site for assembly—can be assembled in a fabricating facility under controlled conditions and then shipped to the project site. For example, a structural steel assembly that was once constructed over a hundred feet in the air can be fabricated at ground level, in a controlled environment. The assembly can later be hoisted as a whole into place requiring only a few connections.

With prework, workers face less exposure and companies receive more opportunities for decreasing safety risk. Prework may reduce exposure to weather, heights, hazardous operations, and neighboring construction activities. Workers indoors at a fabrication shop are not affected as much by temperature, wind, and precipitation extremes. Since much of the prework is done at grade level, fewer safety harnesses are required and workers can focus more on the work. Fewer workers on site also translates into reduced craft congestion and exposure to ongoing operations.

While the drivers for prework help determine the use of prework as an option, the decision to implement is influenced by the balance between the potential benefits and impediments. Challenges faced by projects include increased engineering requirements, increased transportation considerations, and decreased flexibility of scope. Other impediments can be grouped into site constraints, along with coordination, communication, and organizational requirements.

While earlier decisions are best for any use of PPMOF, high degrees of modularization require early decisions for optimum cost effectiveness. Modularization decisions made at the start of detailed design result in cost premiums for additional engineering. Since modularization shipping envelopes and interfaces typically dictate many constraints of detailed design, early decisions are generally more successful. In contrast, many decisions to preassemble or prefabricate components can be made during or after the detailed design phase. In these cases, the level of design already complete limits efficient use of PPMOF. Optimizing the benefits of PPMOF options such as modularization and complex preassemblies requires early layout of the plot plan. Attempting to optimize later in the design phase can result in reengineering and extensive design rework.

3. PPMOF Decision Making Process

The successful application of PPMOF in the life cycle of a project requires a structured decision-making process. Timely, informed decision-making on the extent and type of PPMOF that is appropriate for use in a project will maximize the benefits of the approach and prevent wasted motion later in the project. This section describes a framework for PPMOF decision-making, which is derived from several key research findings.

The CII project team collected data from project managers during site visits, by interviewing personnel in companies actively using PPMOF, and by a literature review. The key findings from these efforts provide the basis for a proposed framework for decision-making regarding the use of PPMOF. The key findings are:

- **Project scope and complexity determine the timing of decisions on the possible use of PPMOF.** Companies involved in full modularization stress the importance of early decisions during preplanning when using high degrees of PPMOF. In cases with a lesser degree of complexity and scope, such as prefabrication, decisions can often be delayed until detailed design. The more complex the project, the earlier the decision must be made.

- **The selection and use of PPMOF involves a spectrum of choices rather than a single, all-or-nothing alternative.** The emphasis today in companies that are using PPMOF is to ask, "How much and which techniques should be used to maximize the benefit?"

- **The selection and use of PPMOF require integrated involvement of project participants.** The most common practice with PPMOF projects is for key management personnel to select a form and degree of PPMOF early in the project. Such a decision is usually based on the experience of seasoned staff members and key business or project driver(s), such as a need to compress schedule or to mitigate a shortage of craft labor.

- **Evaluation of PPMOF feasibility requires careful analysis of labor differentials.** Moving work offsite can take advantage of lower wages in shops and potentially lower costs related to equipment and overhead. Companies must carefully evaluate the differences in wage rates, productivity, overall risks, equipment, and overhead costs associated with labor. Companies also use PPMOF to address anticipated shortfalls in an available skilled work force at the site by replacing mobile, site-based skilled labor with shop-based skilled labor.

- **Adequate use of PPMOF in a project requires extensive and specific transportation planning and expediting.** Careful analysis of shipping options and routes often dictates the size and extent of PPMOF use. Successful companies have maintained a specific department to handle transportation logistics and expediting of equipment and PPMOF components. This effort includes extensively planned transportation routes, including options for expanding or improving infrastructure to meet the optimum PPMOF size requirements.

- **PPMOF enhances the supply chain.** From a supply chain point of view, PPMOF is a form of outsourcing that lets the work be done where it is done best and at the lowest cost. These methods allow projects to take advantage of economies of scale when modules can be assembled from off-the-shelf modular components. They also allow thorough shop testing and verification of components before they arrive at the site.

- **PPMOF can benefit from advances in material tracking technologies and in computer-controlled equipment.** By minimizing the total number of units used on site to construct a facility, PPMOF can make materials management easier and applications such as radio frequency tagging and bar coding more economical since fewer tags will be required. Use of such technologies, especially when integrated with a material-tracking database, provides in-transit status of materials. This enables lifting equipment to be staged at the correct location and time when assemblies arrive. In addition, PPMOF can potentially increase productivity through the use of automation and robotics. Examples include plasma steel cutting tables and automated vessel welders. In general, key enabling technologies that support the use of PPMOF include:

  - Advanced computer design and visualization
  - Improved communication through information technology
  - Advanced factory fabrication equipment
  - Advanced tracking technologies

The CII PPMOF Project Team proposed a decision-making framework based on the following four elements:

- Decision-Timing Map (Figure 2A-1)
- Decision-Making Flow Chart (Figure 2A-2)
- Conceptual Framework for Strategic Analysis
- Conceptual Framework for Tactical Analysis of PPMOF Alternatives

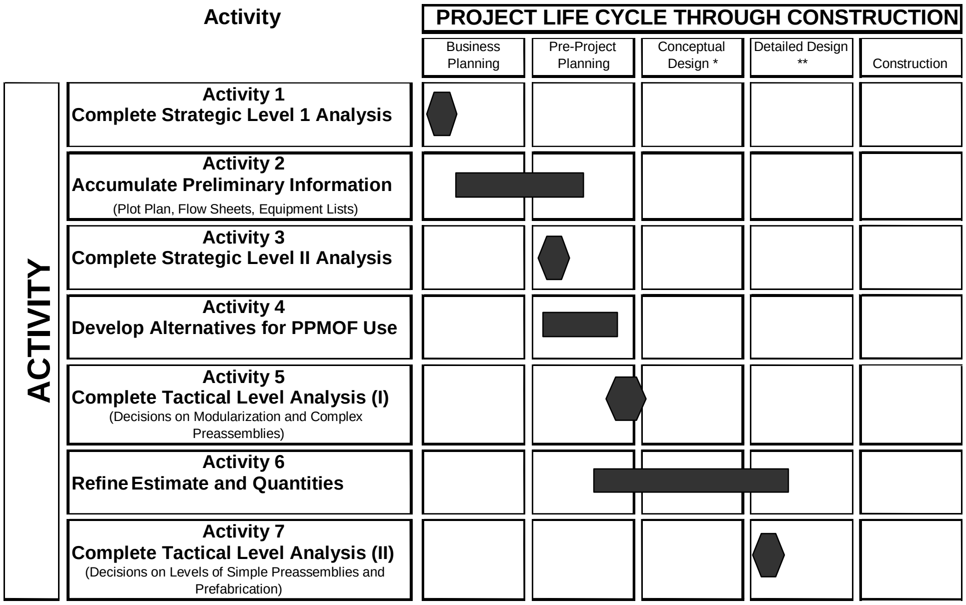
The CII PPMOF team developed a computer-based decision support system to address the strategic level analysis. This system is described in the project team's publication, "CII Implementation Resource 171-2, Implementing the Prefabrication, Preassembly, Modularization, and Offsite Fabrication Decision Framework: Guide and Tool." The framework provides a general methodology and guidelines that companies may follow in evaluating the possible use of PPMOF. While the primary source data for the development of the framework is industrial projects, the framework is flexible enough to be applicable and relevant to other types of projects. The Decision-Timing Map (Figure 2A-1) and the Decision-Making Flowchart (Figure 2A-2) were designed to identify recommended stages in the project life cycle for using the PPMOF tools.

The basic process is used as follows:

- The decision-making process begins with the completion of the Strategic Level I Analysis (Activity 1 in Figure 2A-1) during the business-planning phase. This framework provides a screening tool for project preplanners to identify opportunities for PPMOF with regard to business objectives.

- If the use of PPMOF is not applicable to the project, the project team proceeds to develop a Project Execution Plan based on conventional construction methods. If applicable, preliminary information is gathered to define the project. This would include such items as the plot plan, equipment lists, flow sheets, and other relevant information that will assist in the decision-making process (Activity 2).

Figure 2A-1. Decision-Timing Map



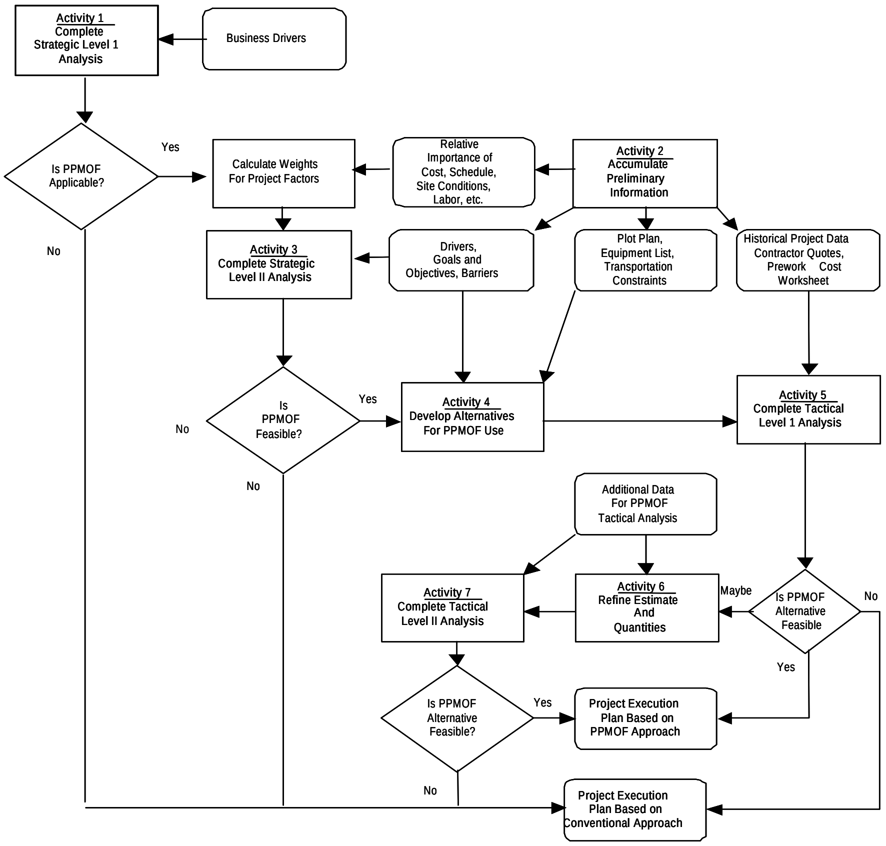
* At start of conceptual design: Estimate approximately 30% +/-, team has plot plan, flow sheets, equipment list

** At start of detailed design: Estimate approximately 30% +/-; quantities determined

- The project team then proceeds to complete the Strategic Level II Analysis (Activity 3). At this point, if the use of PPMOF is not feasible, the project team continues with a conventional Project Execution Plan. If it is feasible, however, the project team proceeds to develop alternatives for the use of PPMOF (Activity 4).
- The project team then completes a preliminary Tactical Level Analysis (Activity 5). At this point, if there is no feasible PPMOF alternative, the project team continues with a conventional Project Execution Plan. If it is, the project team proceeds to develop a Project Execution Plan based on the use of PPMOF.
- If the team does not reach a decision, it continues the analysis by refining the estimate, quantities, and other additional information and then proceeds to complete a final Tactical Level Analysis. At this point in the process, if there is no feasible PPMOF alternative, the project team continues with a conventional Project Execution Plan.

The decision-making flowchart is provided in Figure 2A-2.

Figure 2A-2. Decision-Making Flowchart



3.1 Strategic Analysis Level I

The purpose of Strategic Analysis Level I is to provide preliminary insight regarding possible applicability and benefits of using PPMOF. It is designed to aid pre-project planners in identifying opportunities early in the business-planning phase based on major drivers and barriers to the use of PPMOF. This level contains a concise list of questions outlining major drivers and barriers, based on the research findings.

The layout of the Level 1 tool requires a "yes," "maybe," or "no" answer to a series of questions, as shown in Table 2A-1. The first column represents the section or category of the question. The second column presents the question related to the section as well as how PPMOF influences the section. Scoring is completed in the final columns. An answer of "yes" means the factor strongly drives PPMOF. An answer of "maybe" means the factor may drive PPMOF. An answer of "no" indicates that the factor of concern does not drive PPMOF. A majority of "yes" or "maybe" answers indicates that PPMOF may be advantageous to the project and further analysis is merited. A majority of "maybe" and "no" answers indicate that PPMOF may be partially feasible or not appropriate. However, other forms of PPMOF may still be advantageous at a later phase in the project (for example, modularization may not be appropriate, but prefabrication may be beneficial for later phases of the project).

After completing the questions in this level of analysis, the project team will have identified potential factors that favor the use of PPMOF and which need to be considered in more detail. By identifying these factors now, the framework provides discussion and prepares the team for early decisions required for some types of PPMOF. Adequate scoring on this strategic level or the passage of time leads the user to the next level of strategic analysis.

Table 2A-1. Strategic Analysis Level 1

Section	Question	Yes	Maybe	No
Schedule	Are there significant constraints or requirements for the project schedule? PPMOF may help to meet schedule constraints such as outage duration and time to market or decision needs.			
Labor	Is there a lack of good local labor available in the project area? PPMOF may help by moving work to areas with adequate labor.			
Safety	Is there an opportunity to decrease safety risks by using PPMOF? PPMOF may be able to relocate work to less hazardous environments such as ground level or controlled climates.			
Environmental, Legal, and Regulatory	Are there significant environmental, legal and/or regulatory considerations that may constrain the project? PPMOF may help to alleviate constraints by allowing parallel work while such issues are handled.			

Table 2A-1. Strategic Analysis Level 1

Section	Question	Yes	Maybe	No
Site Attributes	Are there significant site attributes such as extreme weather or lack of infrastructure that may impact project performance? PPMOF can potentially relocate work to more favorable conditions.			
Site Access	Do available routes and lifting paths allow using modules with the dimensions set by truck, rail, or barge shipment? Using the largest possible modules increases the benefits of PPMOF.			

3.2 Strategic Analysis Level II

The conceptual framework for Strategic Analysis Level II is designed for use during the preplanning phase. Its purpose is to further:

- Evaluate in more detail the factors identified in Strategic Analysis Level I, as project definition increases.
- Determine the feasibility of using PPMOF.

This analysis includes additional categories of questions beyond those contained in Level I, and consequently requires more knowledge about the project. This knowledge may include plot plan, equipment list, and process flow sheets as well as the general characteristics of site location, existing infrastructure, required labor, permitting, and legal issues.

This framework does not attempt to provide a comprehensive list of all of the factors that may influence the use of PPMOF. Rather, it is designed to serve as a guide for provoking thought and discussion among the members of the project team. While many of the factors included in this framework are common to various types of projects, any individual or any project team can add or subtract questions to customize the analysis to the specific context of the project.

The framework contains 10 categories for analyses: Schedule, Cost, Labor, Safety, Site Attributes, Mechanical System, Project and Contract Type, Design, Transportation and Lifting Requirements, and Supplier Capability. Each category is further divided into specific factors of analysis.

Based on the description of what the factor includes, the project team can establish the level of impact on PPMOF of a particular factor, using a scale that goes from –5 (strongly does not support the use of PPMOF in the project), to +5 (strongly supports the use of PPMOF in the project). The total set of scores is then aggregated in a Summary Score Sheet.

After completing the questions in the Level II framework, the team will begin to identify specific drivers and barriers to PPMOF as well as their relative weights. Knowing these and supplemented with the additional information generated during pre-project planning, the project team can then develop several alternatives of varying levels of PPMOF. These alternatives are the basis for the next level of analysis: Tactical Analysis of PPMOF Alternatives.

3.3 Tactical Level Analysis

The purpose of the conceptual framework for the Tactical Analysis of PPMOF alternatives is to provide the project team with a methodology to evaluate the cost impact of PPMOF strategies. It is for use during conceptual design and at the beginning of detailed design. While the frameworks for strategic analysis focused on global project drivers, goals, objectives, and barriers, the tactical framework focuses on the cost-per-unit level of the project. Although this level of detail may be neither required nor appropriate for making decisions on the use of modularization and complex preassemblies, research shows that many decisions on the use of preassemblies and prefabrication are often based on unit cost comparisons between PPMOF and conventional approaches.

In general, the conceptual framework for Tactical Analysis consists of a series of tasks for making cost comparisons. This analysis requires the project team to complete the Strategic Analysis Level II, to obtain project information (including plot plan, equipment list, transportation constraints, and flow sheets), and to develop several alternatives using varying levels of PPMOF. For example, alternatives for a project may include conventional, stick-built option, an option for maximum use of modularization, or selected preassemblies and prefabricated components. Table 2A-2 shows a sample structure for compiling PPMOF alternatives.

Table 2A-2. Case No. 1: 40% PPMOF

PPMOF Type	Length	Width	Height	Weight
<u>Modules</u> e.g., Reactor in Area 1				
<u>Preassemblies</u> e.g., Compressors in Area 2, 3				
<u>Prefabrication</u> e.g., Pipe Spools in Area 3, 4, 5				

Once these alternatives have been identified and the proposed levels and scopes of PPMOF have been determined, a Tactical Analysis is used to determine cost effectiveness.

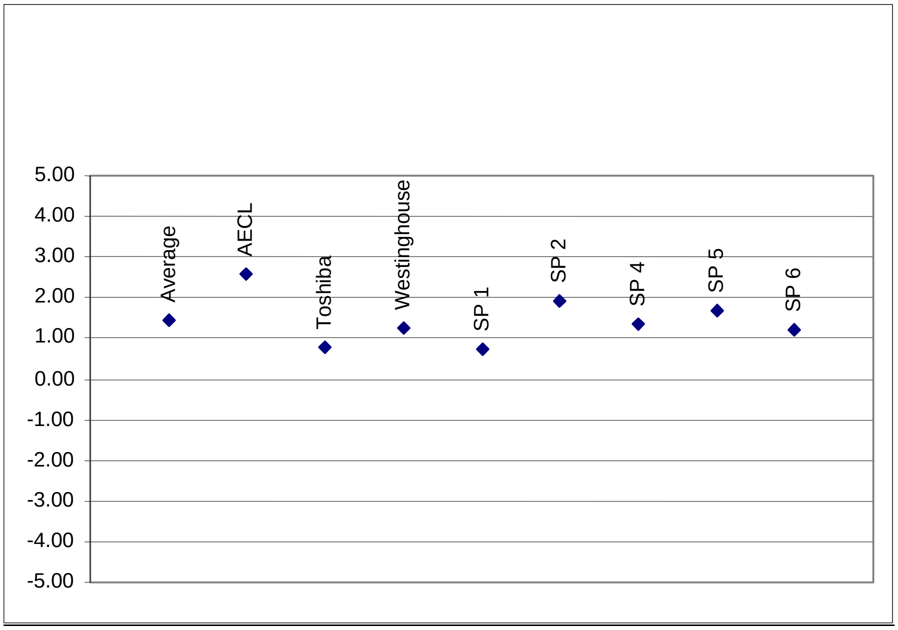
4. PPMOF Evaluation of Advanced Reactors

In order to determine the likelihood of achieving the proposed construction schedules, study team members were asked to complete the Level II strategic analysis spreadsheet. The purpose of this exercise was to develop a consensus on the applicability of modularization to the proposed reactor types.

A PPMOF project score is on a –5 to +5 scale where –5 indicates a project strongly suited to field erected construction techniques and a +5 indicates a project strongly suited to prefabrication and modular construction. Cost, schedule, labor, safety and 6 other attributes are individual project categories considered in development of the final score. Each of the project categories is weighted in terms of overall importance to project goals. Each category is further broken down into a number of factors that are rated for preference relative to field erected or prefabricated and modular construction.

Participant ratings for prefabrication and modularization are provided in Figure 2A-3. The participants in the rating process are all experienced professionals with broad experience in nuclear plant design, fabrication, construction, and/or operations. Included in the group are project engineers, construction managers, design engineers, and nuclear industry consultants.

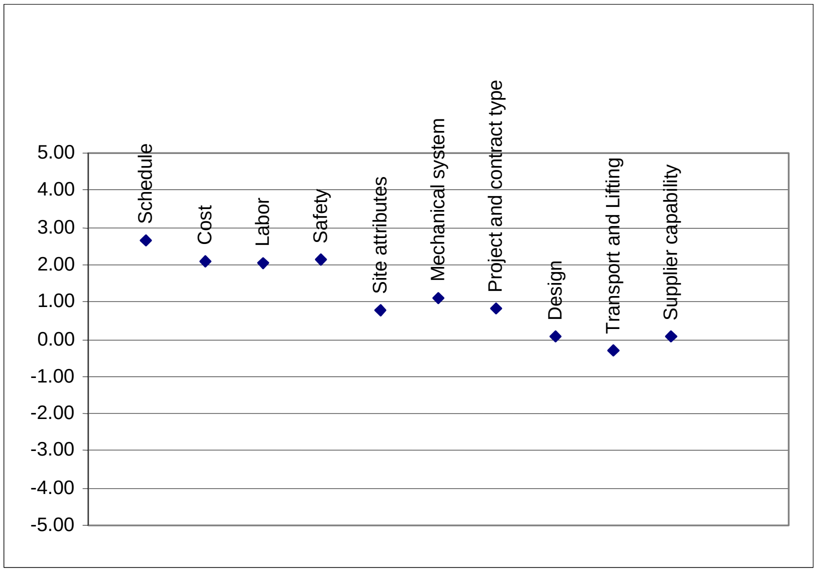
Figure 2A-3. Participant Prefabrication and Modularization Ratings



All participant ratings are above zero indicating a consensus of preference toward prefabrication and modularization. The range of preferences with zero as neutral is from 0.75 to 2.57. It is interesting to note that of the vendors AECL indicated the strongest preference for prefabrication/modularity and Toshiba/GE rated prefabrication/modularity the lowest (for vendors) but all vendors and non-vendors were positive towards the concept.

Figure 2A-4 provides relative category ratings on the relative importance of each of the PPMOF categories. As expected, cost, schedule, labor, and safety are rated as the most important categories when making decisions to use prefabrication and modularization.

Figure 2A-4. Relative Category Ratings



The conclusion to be drawn from the PPMOF survey is that the study participants agree that prefabrication and modularization will play a positive role in the construction of a new nuclear plant. The largest benefits will be seen in schedule, cost, labor, and safety. This conclusion is consistent with various industry publications available on the Internet and through industry-related publications.

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Appendix 2B
Assessment of Reactor Types Using the Construction Industry Institute Project Definition Rating Index

The four reactor types were evaluated in Summer 2003 using the Construction Industry Institute's PDRI process. This appendix describes the PDRI process, the evaluation performed, and the results.

1. Introduction to the PDRI

1.1 Description

The CII defines pre-project planning as the process of developing sufficient strategic information to allow owners to address risk and decide to commit resources that will maximize the chance for a successful project. Pre-project planning has many names such as front-end loading, front-end planning, feasibility analysis, programming, conceptual planning, and others. Previous CII research has documented that project success is greater when an increased level of pre-project planning is used. Pre-project planning can yield:

- Increased predictability of cost and schedule
- Reduced probability of project failures
- Improved operational performance
- Better achievement of business goals
- Better definition of risks
- Fewer scope changes

Several years ago, the CII formed a Front-End Planning Research Team to develop a method to measure project development and provide a tool for predicting successful implementation of a project based on the level of development completed. The method the research team arrived at is called the PDRI.

The PDRI is based on empirical evidence from 40 small ($1 million) to medium ($600 million) capital projects and extensive interviews with project participants. The research team identified 70 elements of a project that are key to successful implementation. Table 2B-1 provides a list of the 70 elements.

Table 2B-1. PDRI Project Elements Key to Successful Implementation

I. BASIS OF PROJECT DECISION
A. Manufacturing Objective Criteria
A1. Reliability Philosophy
A2. Maintenance Philosophy
A3. Operating Philosophy
B. Business Objective
B1. Products
B2. Market Strategy
B3. Project Strategy
B4. Affordability/Feasibility
B5. Capacities
B6. Future Expansion Considerations
B7. Expected Project Life Cycle
B8. Social Issues
C. Basic Data Research & Development
C1. Technology
C2. Processes
D. Project Scope
D1. Project Objective Statement
D2. Project Design Criteria
D3. Site Characteristics Existing/Required
D4. Dismantling and Demolition Requirements
D5. Lead/Discipline Scope of Work
D6. Project Schedule
E. Value Engineering
E1. Process Simplification
E2. Design & Material Alternatives Considered/Rejected
E3. Design for Constructability Analysis

II. FRONT END DEFINITION
F. Site Information
F1. Site Location
F2. Surveys & Soil Tests
F3. Environmental Assessment
F4. Permit Requirements
F5. Utility Sources with Supply Conditions
F6. Fire Protection & Safety Considerations
G. Process/Mechanical
G1. Process Flow Sheets
G2. Heat & Material Balances
G3. Piping & Instrumentation Diagrams (P&IDs)
G4. Process Safety Management
G5. Utility Flow Diagrams
G6. Specifications
G7. Piping System Requirements
G8. Plot Plan
G9. Mechanical Equipment List
G10. Line List
G11. Tie-in List
G12. Piping Specialty Items List
G13. Instrument Index
H. Equipment Scope
H1. Equipment Status
H2. Equipment Location Drawing
H3. Equipment Utility Requirements
I. Civil, Structural, & Architectural
I1. Civil/Structural Requirements
I2. Architectural Requirements
J. Infrastructure
J1. Water Treatment Requirements
J2. Loading/Unloading/Storage Facilities Requirements
J3. Transportation Requirements
K. Instrument & Electrical
K1. Control Philosophy
K2. Logic Diagrams
K3. Electrical Area Classifications
K4. Substation Requirements/Power Sources Identified
K5. Electric Single Line Diagrams
K6. Instrument & Electrical Specs.

III. EXECUTION APPROACH
L. Procurement Strategy
L1. Identify Long Lead/Critical Equipment & Materials
L2. Procurement Procedures and Plans
L3. Procurement Responsibility Matrix
M. Deliverables
M1. CADD/Model Requirements
M2. Deliverables Defined
M3. Distribution Matrix
N. Project Control
N1. Project Control Requirements
N2. Project Accounting Requirements
N3. Risk Analysis
P. Project Execution Plan
P1. Owner Approval Requirements
P2. Engineering/Construction Plan & Approach
P3. Shut Down/Turn-Around Requirements
P4. Pre-Commissioning Turnover Sequence Requirements
P5. Startup Requirements
P6. Training Requirements

These 70 elements are combined in a weighted checklist format to produce the PDRI. PDRI scores can range from 0 to 1000 points, with lower scores indicating a higher probability of success. Scores of 200 or less have been empirically shown to be significantly more likely to be successful than those scoring above 200 points. A detailed explanation of the development of the PDRI can be found in the CII Research Summaries "113-1, Pre Project Planning Tools, PDRI and Alignment" and "113-2 Project Definition Rating Index." CII participants can download these documents from the CII website (http://construction-institute.org/).

A PDRI version specific to power plants has not yet been developed by the CII. As a result, the PDRI tool used in this study is the original industrial plant version. (Note: The CII recognizes that different industries have unique elements and is considering versions specifically tailored to discrete industries.) Many of the PDRI industrial plant elements are applicable to power plant development, though some of the terminology used reflects the PDRI’s industrial plant heritage. For instance, Part A of Section 1 of the PDRI "Basis of the Project Decision" is entitled Manufacturing Objective Criteria. Manufacturing criteria is not a term commonly used in power plants but the components of the manufacturing criteria—reliability philosophy, maintenance philosophy, and operating philosophy—are all components of decision processes implemented during development of a power project. Similar arguments can be made for most if not all of the elements of the PDRI listed. Despite its industrial orientation, the overall model is a reasonable and unbiased method for establishing an approximate measure of project development.

1.2 Uses

The PDRI is the only known practical, nonproprietary tool of its kind that allows a pre-project planning team to objectively assess the probability of achieving a project's goals before authorization. An advantage of such a tool is that the PDRI can be customized to fit the needs of almost any company. Elements that are not applicable to a specific company’s projects can be "zeroed," thus eliminating them from the final scoring calculation.

Another advantage is that the PDRI is simple to use and can serve as a best-practices tool that can provide numerous benefits to the evaluators, including:

- A checklist that can be used for determining the steps to follow in defining the project scope.
- A standardized terminology for scope definition.
- An industry standard for rating the completeness of the project scope definition to facilitate risk assessment, prediction of escalation, and evaluation of the potential for disputes.
- A means to monitor progress at various stages during the pre-project planning effort and to focus efforts on high-risk areas that need definition.
- A tool that aids in communication between owners and design contractors by highlighting poorly defined areas in a scope definition package.

- A means for project team participants to reconcile differences using a common basis for project evaluation.

- A benchmarking tool for interested parties to use in evaluating the completion of scope definition versus the probability of success on future projects.

The PDRI provides a tool to help the process of evaluating the development of nuclear technologies. Owner companies can use the tool to help establish a "comfort level" at which they are willing to proceed with projects. Contractors can use it as a means to identify poorly defined project scope elements. The PDRI provides a means for all project participants to communicate and reconcile differences using an objective tool as a common basis for project scope evaluation.

The PDRI methodology was selected for this study to provide a common reference point for assessing the level of development of each reactor type. The use of a neutral evaluation process also helps to minimize biases that may be present in the evaluators. By allowing each vendor to prepare his own assessment of development using the PDRI and then comparing the scores from the vendors with PDRI scores from the study participants, it is possible to develop an informed assessment of the stage of development for each reactor type.

2. PDRI Assessment and Results

In Summer 2003, study participants from the reactor vendors, Dominion, Bechtel, and MPR were asked to prepare PDRI score sheets for each of the reactor technologies. The reactor vendors were asked to prepare score sheets for their technology only.

As described earlier, PDRI scores of 200 or less have been shown to reflect a greater likelihood of project success given the state of project development at the time of the scoring. This should not be interpreted as anything other than a measure of a project's level of development at a point in time. Projects that score high (low likelihood of success) today may see sufficient development before the start of construction to reflect a much lower score with a higher likelihood of success.

It must be emphasized that the PDRI rating process as applied here is not a precise evaluation that lends itself to statistical analysis but rather a general indication of project development based on currently available information.

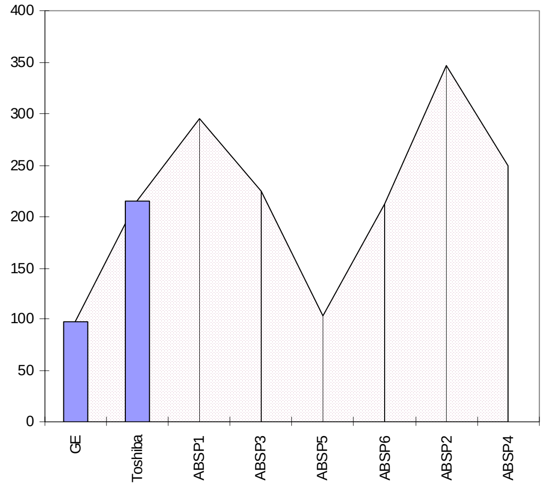
2.1 Reactor Ratings

Each reactor type was individually rated by a cross-section of study team members. Each study team member was assigned an individual Study Participant (SPx) designator. The reactor vendors also performed a self-rating of their own reactor designs for comparison.

2.1.1 ABWR

The PDRI ratings for the ABWR are shown in Figure 2B-1. As can be seen from this figure, the study participants are in general agreement with GE and Toshiba concerning the level of project definition for the ABWR. The average score from the team members (without considering the GE and Toshiba scores) is 239, which is indicates a reasonable expectation of project success for the ABWR.

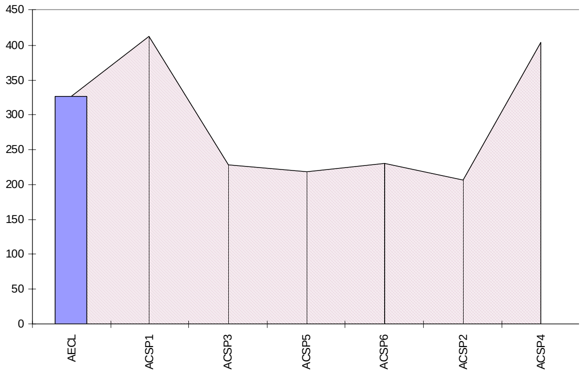
Figure 2B-1. ABWR PDRI Scores



2.1.2 ACR-700

The ratings for the ACR-700 are shown in Figure 2B-2. The average non-vendor PDRI score is 283 versus AECL's self-rating of 326. The 283 average score also indicates a somewhat lesser state of development as compared to the ABWR, which scored an average of 239. This difference in rating is consistent with the fact that an ACR-700 project has not yet been fully designed or constructed but that most of the concepts and components of the ACR-700 exist in other ACR CANDU plants. The difference in ratings between the team members and AECL may be because of AECL's unfamiliarity with licensing and construction practices in the United States.

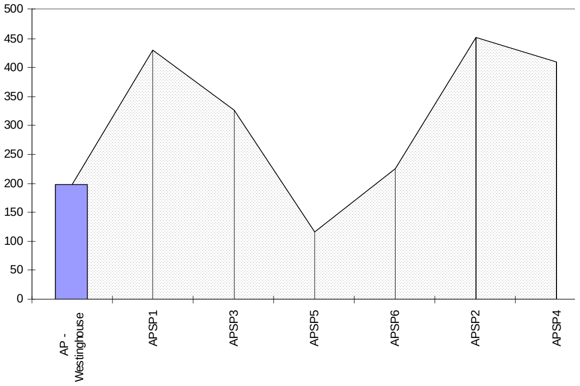
Figure 2B-2. ACR-700 PDRI Scores



2.1.3 AP1000

The average non-vendor score for the AP1000 (Figure 2B-3) is 327 versus Westinghouse's self-assessment of 198. While the AP1000 is close to receiving NRC design certification (expected December 2004) and is an out-outgrowth of the AP600 design, no AP1000s have been constructed. Consequently, a somewhat lesser state of development would be perceived for the AP1000 compared to the ABWR (239), which has been constructed, and the ACR-700 (283), which is an extension

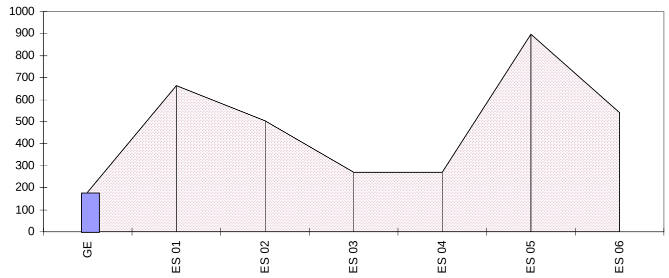
Figure 2B-3. AP1000 PDRI Scores



of the CANDU 6 design that is in operation. The difference in ratings between the team members and Westinghouse are likely because Westinghouse did not provide detailed quantity and resource information in support of this study.

2.1.4 ESBWR

Figure 2B-4. ESBWR PDRI Scores



The PDRI ratings for the ESBWR are shown in Figure 2B-4. The average non-vendor score for the ESBWR is 525 versus a vendor assessment of 180. The higher rating for the ESBWR versus the other reactor types is likely a result of the need to pursue design certification and that no similar designs have been constructed. The difference between the team member ratings and GE’s rating may be the result of the sparse information provided by GE in support of this study.

But it is interesting to note that several of the team members were much closer to GE in their assessments of the level project development than were the other reviewers. A review of the 15 categories in the PDRI indicates the majority of the numerical scoring differences for the ESBWR come from differences in opinion concerning status of development of process and mechanical information.

2.1.5 Vendor Self-Ratings

Figure 2B-5. PDRI Vendor Self-Rating Results

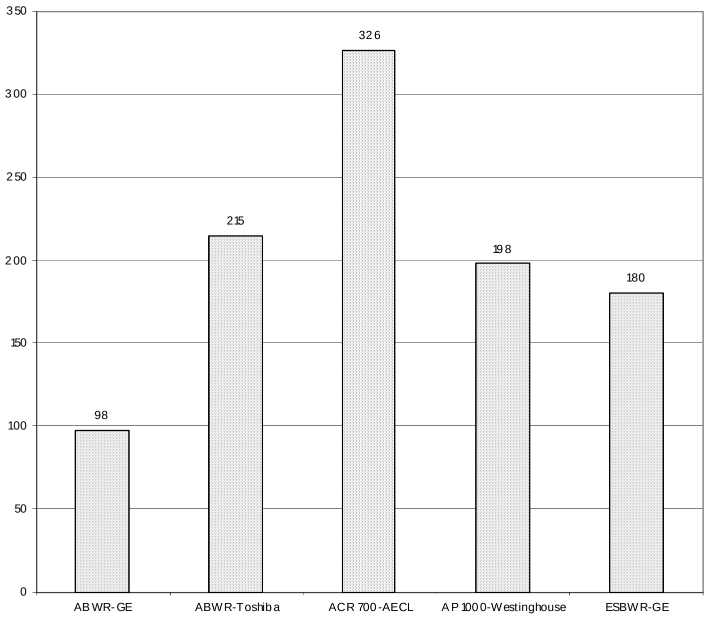


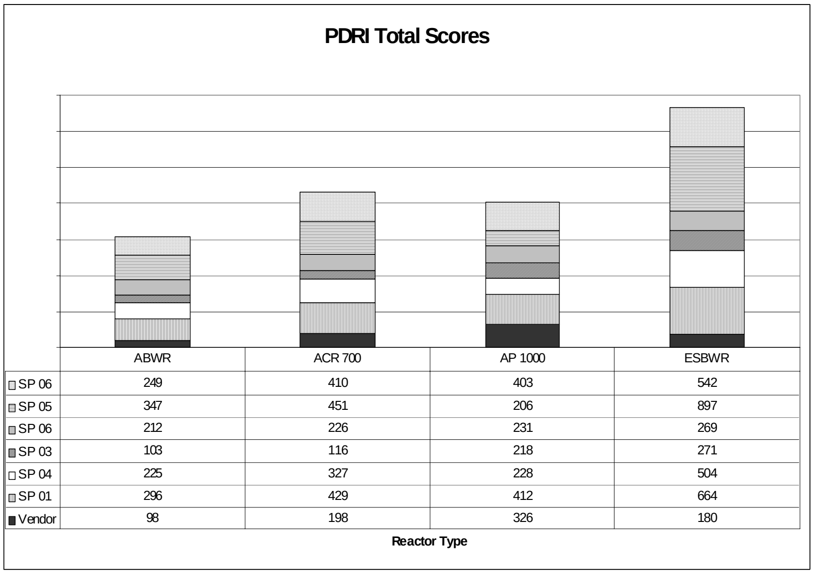
Figure 2B-5 presents the vendor self-ratings for their reactor designs. The results of Figure 2B-5 indicate the following:

- Both GE and Toshiba rate their ABWR designs as having a good likelihood of project success. This result might be expected given that this reactor type is currently in operation in Japan.
- The AECL rating of their reactor design is somewhat more pessimistic than the GE rating of their ESBWR design and the Westinghouse rating of their AP1000 reactor.

2.1.6 Total Scores Across Reactor Types

Figure 2B-6 provides the total scores for each reactor type by study team member. The results shown in this figure confirm the expectations that the ABWR is the most fully developed of the reactor technologies, with the ACR-700 and the AP1000 following reasonably close. Note that the ABWR vendor score used for Figure 2B-6 is the GE score, which is believed to more closely reflect the state of development of the ABWR for U.S. deployment.

Figure 2B-6. Total Scores Across Reactor Types



	ABWR	ACR 700	AP 1000	ESBWR
▨ SP 06	249	410	403	542
▤ SP 05	347	451	206	897
▨ SP 06	212	226	231	269
▨ SP 03	103	116	218	271
□ SP 04	225	327	228	504
▥ SP 01	296	429	412	664
■ Vendor	98	198	326	180

The most dramatic difference between reactor types is with the ESBWR where the general consensus is that the ESBWR has significant development opportunity. It is interesting to note a sizeable degree of difference between participant evaluations for the ESBWR, which range from 180 to 897 out of a possible score of 1000.

2.1.7 Conclusions

The survey results yield the following conclusions:

- Vendor self-ratings show the ABWR to be the most developed technology and the ACR-700 the least with the AP1000 and the ESBWR falling midway between the ABWR and ACR-700. The ACR-700 vendor self-rating is not consistent with the data received. This is believed to be the result of AECL's uncertainty concerning the regulatory environment in the United States.

- Ratings of the various technologies by study participants other than the reactor vendors indicate that all of the designs require further development. The ABWR is believed to be the most fully developed with the AP1000 and the ACR-700 following reasonably closely. The ESBWR assessment indicates significant development is still required.

2.2 Drill-Down Analysis

A drill-down analysis of the PDRI scores was performed in Table 2B-2 to gain some insight into areas where each of the reactor types can strengthen their proposed projects.

As described previously, the PDRI process states that projects with total PDRI scores of 200 or less have been shown to be significantly more likely to succeed than projects with scores above 200. For the drill-down analysis, each element of the reactor's PDRI average rating (average of study participant scores only) were compared to a value equal to 20% of the maximum score for that element. Elements that may need attention are marked with an "X."

Table 2B-2. Drill-Down Analysis of PDRI Results
(Study Participant Ratings Only)

CATEGORY Element	Avg Max Score	AP1000	ABWR	ESBWR	ACR-700
A. MANUFACTURING OBJECTIVES CRITERIA (Maximum Score = 45)					
A1. Reliability Philosophy	20	X		X	X
A2. Maintenance Philosophy	9	X	X	X	X
A3. Operating Philosophy	16	X		X	X
B. BUSINESS OBJECTIVES (Maximum Score = 213)					
B1. Products	56			X	
B2. Market Strategy	26	X	X	X	X
B3. Project Strategy	23	X	X	X	X
B4. Affordability/Feasibility	16	X	X	X	X
B5. Capacities	55			X	
B6. Future Expansion Considerations	17			X	
B7. Expected Project Life Cycle	8			X	
B8. Social Issues	12	X	X	X	X
C. BASIC DATA RESEARCH & DEVELOPMENT (Maximum Score = 94)					
C1. Technology	54	X		X	X
C2. Processes	40	X		X	X
D. PROJECT SCOPE (Maximum Score = 120)					
D1. Project Objectives Statement	25	X		X	X
D2. Project Design Criteria	22	X	X	X	X
D3. Site Characterization Available vs. Required	29	X	X	X	X
D4. Dismantling and Demolition Requirements	15	X	X	X	X
D5. Lead/Discipline Scope of Work	13	X	X	X	X
D6. Project Schedule	16	X	X	X	X
E. VALUE ENGINEERING (Maximum Score = 27)					
E1. Process Simplification	8				
E2. Design & Material Alternatives Considered Rejected	7	X		X	X
E3. Design for Construction Analysis	12	X	X	X	X
F. SITE INFORMATION (Maximum Score = 104)					
F1. Site Location	32	X		X	X
F2. Surveys & Soil Tests	13	X	X	X	X
F3. Environmental Assessment	21			X	
F4. Permit Requirements	12	X	X	X	X
F5. Utility Sources w/Supply Conditions	18	X	X	X	X
F6. Fire Protection & Safety Considerations	8	X	X	X	X
G. PROCESS/MECHANICAL (Maximum Score = 196)					
G1. Process Flow Sheets	36	X		X	X

Table 2B-2. Drill-Down Analysis of PDRI Results
(Study Participant Ratings Only)

CATEGORY	Avg Max Score	AP1000	ABWR	ESBWR	ACR-700
Element					
G2. Heat & Material Balances	23	X	X	X	X
G3. Piping & Instrument Diagrams (P&IDs)	31	X		X	X
G4. Process Safety Management	8	X	X	X	X
G5. Utility Flow Diagrams	12	X	X	X	X
G6. Specifications	17	X	X	X	X
G7. Piping System Requirements	8	X	X	X	X
G8. Plot Plan	17	X	X	X	X
G9. Mechanical Equipment List	18	X	X	X	X
G10. Line List	8	X	X	X	X
G11. Tie-In List	6	X	X	X	X
G12. Piping Specialty Items List	4	X	X	X	X
G13. Instrument Index	8	X	X	X	X
H. EQUIPMENT SCOPE (Maximum Score = 33)					
H1. Equipment Status	16	X	X	X	X
H2. Equipment Location Drawings	10	X	X	X	X
H3. Equipment Utility Requirements	7	X	X	X	X
I. CIVIL, STRUCTURAL, & ARCHITECTURAL (Maximum Score = 19)					
I1. Civil/Structural Requirements	12	X	X	X	X
I2. Architectural Requirements	7	X	X	X	X
J. INFRASTRUCTURE (Maximum Score = 25)					
J1. Water Treatment Requirements	10	X	X	X	X
J2. Loading/Unloading/Storage Facility Requirements	10	X	X	X	X
J3. Transportation Requirements	5	X	X	X	X
K. INSTRUMENT & ELECTRICAL (Maximum Score = 46)					
K1. Control Philosophy	10	X	X	X	X
K2. Logic Diagrams	4	X	X	X	X
K3. Electrical Area Classifications	9	X	X	X	X
K4. Substation Requirements Power Sources Identification	9	X	X	X	X
K5. Electric Single Line Diagrams	8	X	X	X	X
K6. Instrument & Electrical Specifications	6	X	X	X	X
L. PROCUREMENT STRATEGY (Maximum Score = 16)					
L1. Identify Long Lead Critical Equipment & Materials	8	X		X	X
L2. Procurement Procedures and Plans	5	X	X	X	X
L3. Procurement Responsibility Matrix	3	X	X	X	X
M. DELIVERABLES (Maximum Score = 9)					
M1. CADD Model Requirements	4	X		X	X
M2. Deliverables Defined	4	X	X	X	X
M3. Distribution Matrix	1	X	X	X	X
N. PROJECT CONTROL (Maximum Score = 17)					
N1. Project Control Requirements	8	X	X	X	X
N2. Project Accounting Requirements	4	X	X	X	X
N3. Risk Analysis	5	X	X	X	X
P. PROJECT EXECUTION PLAN (Maximum Score = 36)					
P1. Owner Approval Requirements	6	X	X	X	X
P2. Engineering/Construction Plan & Approach	11	X	X	X	X
P3. Shut Down/Turn-Around Requirements	7	X	X	X	X
P4. Pre-Commissioning Turnover Sequence Requirements.	5	X	X	X	X
P5. Startup Requirements	4	X	X	X	X
P6. Training Requirements	3	X	X	X	X

Appendix 2C
Application of Seismic Base Isolation to Nuclear Power Plants

1. Introduction

Seismic base isolation is achieved by inserting a flexible or sliding interface between a structure and its foundation. The purpose of such isolation is to decouple the horizontal motions of the ground from the horizontal motions of the structure, thereby reducing earthquake damage to the structure and its supported systems/equipment.

Seismic isolation can have two advantageous effects in terms of the seismic response of a structure: reduction of lateral forces in the superstructure, and concentration of lateral displacements at the isolation interface. The isolation system lengthens the fundamental period of the structure, and adds damping. Both of these effects reduce the acceleration response of the structure, and consequently the lateral forces in the structure. Also, since the predominant mode of vibration is that related to displacement of the isolation system, the structure above the isolation system tends to move as a rigid body, and interstory displacements within the superstructure are greatly reduced. That is, the isolation system concentrates lateral displacements at the isolation interface, and minimizes lateral displacements in the superstructure.

Reduced levels of forces and deformations in the superstructure lead to decreased member sizes and also result in reduced acceleration levels in the in-structure response spectra, which in turn causes reduction in the cost of supported systems and components. An application of base isolation to a nuclear power plant as a seismic isolation system will provide important benefits from the perspective of reduced cost/schedule, and increased standardization. This appendix provides a discussion of the various design and construction issues pertaining to the application of base isolation to a commercial nuclear power plant.

2. History of Base Isolation

The first building to use a rubber isolation system was a three-story school building constructed in 1969 in Skopje, Yugoslavia. The building rests on solid blocks of rubber, not impregnated with horizontal steel reinforcing plates, as would be the practice today. In 1978, the first structure to use an isolation system with added damping was the Toetoe Viaduct in the North Island of New Zealand. The isolation system consists of laminated steel and rubber bearings incorporating a specially formulated high damping natural rubber; it also contains a central lead core for energy dissipation.

This type of isolation system used on the Toetoe Viaduct is now in wide use, and is commonly referred to as the lead rubber bearing isolation system. A friction pendulum system is another type of base isolation method that is also in wide use. A friction pendulum system isolator consists of a polished stainless steel spherical concave surface, an articulated slider, and a low friction composite liner. During an earthquake, the articulated slider moves along the concave surface, causing the superstructure to move in a pendulum motion. With this friction pendulum system method, the fundamental frequency of the isolated structure is governed by a pendulum behavior that depends on the radius of the concave surface and mass of the superstructure.

The first seismically isolated building in the United States was the Foothill Communities Law and Justice Center in Rancho Cucamonga, California, constructed in 1984-85. This building is located about 20 km (12 miles) west of the San Andreas Fault.

To date, over 600 structures (buildings, bridges and tanks) have been seismically isolated around the world, including over 150 in the United States. The applications have involved a wide range of sizes, weights, and functionality. The technology has been successfully applied to hospitals, commercial buildings, large/complex government and historic buildings, airport terminals, bridges, and industrial facilities (including LNG tanks). Base isolation has also been used for nuclear power plants in France and South Africa. Base isolation has thus been recognized as a cost-effective method for protecting nuclear and other mission-critical infrastructure assets in many countries.

3. Application of Base Isolation to Nuclear Facilities

There are currently six seismically isolated pressurized water reactor (PWR) units: four in France and two in South Africa. At the Cruas plant in France, each of the four units has been constructed on 1,800 neoprene pads measuring 500 by 500 by 65 mm. The seismicity at these plants is moderate, with a safe shutdown earthquake design acceleration of 0.20g (Postollec 1983). In Koeberg, South Africa, two units are isolated on a total of 2000 neoprene pads measuring 700 by 700 by 100 mm. In this case, the safe shutdown earthquake design acceleration is 0.3g. The pads are outfitted with flat sliders on the top surface, consisting of a lead-bronze alloy lower plate and a polished stainless steel upper plate. The sliding feature was implemented so that the lateral force transmitted to the reactor vessel is limited to the frictional resistance of the sliding interface. (Today, the friction pendulum system method is widely preferred over flat sliders as it has a built-in re-centering ability without requiring the use of any special springs, as in case of flat sliders).

The Japanese government has sponsored various initiatives over the last 15 years to evaluate the viability of base isolation technology for nuclear facilities. In 1997, the Central Research Institute of Electric Power Industry issued appropriate guidelines for application to Fast Breeder Plants and Light Water Reactors. Although there are currently no seismically isolated nuclear reactors in Japan, these guidelines make them a possibility. Work has also commenced in Japan on applying seismic isolation to the International Thermonuclear Experimental Reactor.

In the United States, DOE has sought to use the base isolation technology for the nuclear island facilities of its Advanced Liquid Metal Reactor (ALMR) project in order to improve safety and to allow the development of a standard design for varying regions of seismicity. The prototype ALMR design incorporates 66 high damping rubber bearings. Prototypes of these bearings have been tested extensively. DOE has also sponsored development of the Sodium Advanced Fast

Reactor, which incorporates seismic isolation. The prototype design is supported on 100 elastomeric isolators. Reduced scale isolators have been tested to verify their performance.

4. Why Consider Base Isolation for Nuclear Power Plants?

The most important advantage to using seismic base isolation in nuclear power plants is that the overall reliability and safety of plants can be improved. Another important advantage is that the design of the reactor vessel, other major equipment, and the plant superstructure can be standardized irrespective of the design ground motion. Varying seismic conditions can be accommodated by adjustments to the isolation system. Standardization involving base isolated plant structures could reduce design, procurement, and construction costs and shorten construction schedules for advanced reactor designs.

Following are several advantages of base isolation include:

- Reduction in design acceleration levels could reduce the construction cost of the plant
- Base isolation would permit standardization of plant structure, systems, and components regardless of the seismic acceleration levels
- Development of designs for equipment, piping, and components could be largely decoupled from the structural design as generic in-structure response spectra could be used upfront to get a jumpstart
- Base isolation could improve plant seismic margins

5. Performance Criteria for Base Isolated Nuclear Power Plant

Lead rubber bearings and friction pendulum systems are the most commonly used methods of base isolation in the United States. Either of these systems could be adopted for isolation of nuclear power plant structures.

To minimize the number of flexible couplings for systems that traverse between isolated and non-isolated facilities, it is preferable to isolate the entire nuclear island (i.e., all structures other than the BOP facilities) using a common diaphragm to support the associated structures above the isolators. This would avoid large relative displacements between the superstructures of the various nuclear island facilities. Despite its appeal, this may be a difficult goal because of the uneven mass/stiffness distribution and the differing base slab thickness requirements for the various nuclear island structures (including their internals). These factors are not conducive from the standpoints of ease of construction and/or achieving a relatively uniform distribution of seismic demand on individual isolators. On the other hand, use of separate diaphragms for each nuclear island structure will increase cost as well as schedule complexity, factors that will need to be weighed against the alternative of common diaphragm.

It must be noted that the NRC stipulates most of the structural performance criteria for a nuclear power plant. It is further acknowledged that, except in cases of very high design seismic accelerations, the seismic response consideration does not significantly affect the design of most of the nuclear power plant structures (radiation shielding, accident loading, etc., often govern the design thickness). The same however is not true for much of the major equipment and their supports. Therefore, it is envisioned that the nuclear island equipment suppliers, seeking to standardize their designs, will drive the design process by preselecting the required response spectra for their equipment based on known equipment fragility (the preselection of required response spectra will likely be an iterative process in the beginning, involving close collaboration with the customer, reactor vendor, constructor, and suppliers of isolators). Given the required response spectra levels, the incident shaking level that can be transmitted to the superstructure of the planned base isolated facility must be determined such that the selected required response spectra levels are not exceeded. For standardized advanced reactor designs, the reactor vendors will need to work with isolation specialists to select the right isolation method and its associated parameters such that the design interstory shears/displacements and the preselected required response spectra (for various equipment/floor levels) for the standardized structure(s) are not exceeded.

Advanced reactors will likely be licensed for 60-year operation. Accordingly, the isolation system will need to have the requisite long-term reliability. Also, an aggressive examination of the requirements concerning in-service inspection/surveillance and maintenance for each type of the isolation system will need to be performed to specify appropriate performance requirements in this regard.

Finally, it is noted that, in theory, an isolation system can be devised for any level of equipment required response spectra since the size/number/arrangement of isolators can be appropriately configured to reflect the seismicity for a given site. Having said this, it must be recognized that reactor vendors will need to specify their required response spectra wisely so as not to unduly challenge the practicality of base isolation application. A composite industry dialog, involving customers, reactor vendors, constructors, equipment suppliers, vendors for isolation systems, isolation specialists/researchers, and the NRC, will be needed to properly establish the performance criteria for a base isolated nuclear power plant.

6. Design/Analysis Considerations for Application of Base Isolation

There are many design-related issues that must be carefully addressed when performing design analyses for a base isolated structure. Selection and detailing the isolation system is the most important and challenging step in the design of a base isolated structure. This is a complex problem that involves balancing competing design objectives, and which may have more than one acceptable solution. One of the biggest challenges in the design of an isolated structure is incorporating the effects of nonlinear isolator behavior in the analysis. Furthermore, the seismic response of an isolated structure can be sensitive to variations in the properties of the isolators. Therefore, bounding analyses must be obtained by considering the least favorable set of isolator properties. Finally, while the use of response spectrum methods may be permissible for analysis under limited conditions, a time-history analysis is warranted for most practical situations.

6.1 Governing Codes/Standards

In recent years, there has been much relevant development concerning the design of base isolated structures. There are many codes and standards that include technical requirements pertaining to the design of base isolated structures. With the exception of ASCE 4-98, the documents are geared toward nonnuclear facilities. This notwithstanding, many of the requirements from the various codes and standards can be adapted or modified to establish appropriate requirements for the design of a base isolated nuclear power plant. An industry-wide initiative will be needed to come up with a suitable standard/design guide for this purpose.

The following is a partial list of existing codes, standard, specifications, and guidelines that could be useful for base isolation system design:

- ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary." Section 3.5.6 of this document provides the analysis requirements for seismic-isolated structures; NRC does presently not endorse this section.
- ASCE 7-02, "Minimum Design Loads for Buildings and Other Structures." Section 9.13 of this standard includes provisions for seismically isolated structures; the requirements therein are based on the NEHRP 2000 document (FEMA 368/369) and are not intended for nuclear power facilities.
- IBC 2003. Section 1623 of this building code endorses the requirements of Section 9.13 of ASCE 7-02 with minor exceptions.
- NFPA 5000-2003. Section 35.10 of this building code generally endorses the requirements of the entire Section 9 of ASCE 7-02 with minor exceptions.
- NEHRP 2003 (FEMA 450/451). Chapter 13 of this document, to be published in March 2004, provides the most current requirements for design of base isolated structures. The provisions of this document are also not meant for nuclear power facilities.
- NIST Report NISTIR 5800, "Guidelines for Pre-Qualification, Prototype and Quality Control Testing of Seismic Isolation Systems," National Institute of Standards and Technology, January 1996.
- ASCE Standard for Testing Seismic Isolation Systems. In 1996, a committee was formed by the American Society of Civil Engineers (ASCE) to develop code provisions for testing seismic isolation systems. The committee used as a resource document an earlier guideline on testing developed at the National Institute of Standards and Technology (NIST Report NISTIR 5800). The standard will include procedures for basic property testing, prototype testing, and quality control testing of both elastomeric and sliding isolation systems. The standard is scheduled for completion in near future.

6.2 General Approach

The analysis of an isolated structure is an iterative process. First, preliminary characteristics of the required isolation system are estimated. Using these properties, the global response of the superstructure is computed and expressed in terms of maximum displacements, floor spectra, and story shears (at the base and within the superstructure) for the operating basis earthquake and design basis earthquake events. This first analysis step will likely be accomplished using a linear time history analysis procedures, and incorporating preliminary isolator properties supplied by isolator manufacturers (often these preliminary properties are based on test data from previous projects). Second, the approximate floor spectra, displacements, and story shears from the initial analysis will be compared to the preestablished performance criteria (see section 4 for a discussion of the performance criteria) to evaluate the effectiveness of the isolation system considered in the first step. The characteristics of the isolation system and/or superstructure are then modified to improve the performance, as needed, and more refined analyses (including nonlinear time-history analysis, if necessary) will be performed until satisfactory performance is indicated.

6.3 Diaphragm Above the Plane of Isolation

The diaphragm between the isolators and the superstructure is a unique feature for base isolated structures compared to fixed base structures. This diaphragm is necessary to redistribute lateral loads from the superstructure into the isolation system. Because this diaphragm represents additional complexity and cost, it must be considered when comparing fixed base and seismically isolated alternatives. As mentioned in Section 4, the decision concerning the use of a common diaphragm for nuclear island structures will be also be critical.

A related consideration concerning the diaphragm is the placement of the plane of isolation. For a nuclear power plant application, it is envisioned that the plane of isolation will be located below grade, such that an appropriate seismic isolation gap, or "moat" has to be provided around the perimeter of the isolated structure(s). Aside from the design consideration for providing proper gap/rattle space at the moat, there are many construction considerations that must be factored. See Section 7.2 for more discussion on moat.

6.4 Uplift of Isolators

Uplift of isolators is generally considered an undesirable action in an isolated structure although it can be accommodated in some isolation systems. To avoid or at least minimize uplift, changes may be required in the superstructure. These may include reconfiguration of mass to position more dead load over certain isolators (especially corner isolators, which are often the most susceptible to uplift); broadening of the base to reduce the tendency for uplift at the end of the frames or walls; increasing bay widths; and reducing the overall height of the superstructure. Considering that the reactor vendors' standardized designs for the superstructures, it will be necessary to conduct some negotiations/iterations to agree on any superstructure changes.

The tendency for uplift in certain isolators may not be recognized in the early conceptual design phase of a project, and may not become apparent until a detailed computer analysis of a proposed structure has been carried out. Therefore, the design team should be cautioned about the possibility of uplift in isolators, and made aware that changes in configuration may be necessary following initial computer modeling analysis of the isolated building. Considering the obstacles, it is likely that only systems that accommodate isolator uplift should be considered for nuclear applications. In any case, isolator uplift is not expected to be a serious issue because of the relative massiveness of nuclear facilities.

6.5 Vertical Deformations & Effects of Vertical Seismic Acceleration

All seismic isolation systems, with the exception of flat sliding systems (which are not likely to be considered for nuclear application), undergo small vertical deformations in combination with lateral deformation of the isolator during an earthquake. Furthermore, the design and analysis for nuclear structures require explicit consideration of the vertical component of ground motion. Isolation of the vertical seismic excitation has been a rather elusive goal thus far, especially in conjunction with the isolation of the horizontal components (the approach to isolate all directions is sometimes referred to as "3-D isolation"). Therefore, the effects of simultaneous horizontal and vertical excitation on a conventional 2-D (horizontal) isolation system need to be properly investigated to ensure that both the superstructure and the isolation system are not adversely impacted. While the vertical deformations are generally not a concern for the superstructure, care should be taken to ensure that vertical deformations are small and relatively uniform over the expanse of the diaphragm to minimize undesirable stresses in the superstructure.

6.6 Isolator Longevity

Longevity is a critical issue for assessing viability of applying the base isolation technology to nuclear power plant. The new advanced reactors could have licensed lives as long as 60-80 years. This is a rather long service period for a sensitive application warranting a close scrutiny of the following long-term behavioral changes that the isolators may experience:

- Softening or stiffening and differential compaction under sustained gravity loads
- Softening or strength degradation at service/accident temperature levels
- Potential property changes (including the friction coefficient for friction pendulum system) due to radiation exposure during service/accident conditions

Because the history of seismic isolation application is relatively young, there is limited data on variations in isolator properties when isolators are subject to sustained gravity loads over long periods of time (in excess of 15 years). The available evidence suggests that well constructed and maintained isolations systems of the types most commonly in use—elastomeric and sliding systems—generally exhibit stable long-term performance. It must be noted however that these observations correspond to ordinary applications not involving radiation exposure and/or elevated temperatures. In fact, the use of flat sliding surfaces using neoprene (as done by the French at their Cruas plant) has been found to result in a variable friction coefficient over the life of the plant. Such potential variability warrants that estimates of the possible range of property variations must be made, and their effects on the superstructure be assessed using bracketed analyses (see Section 4 for a discussion about testing requirements).

6.7 Analysis Techniques/Software and Division of Responsibility

There are a number of commercially available structural engineering software applications that can perform the design analysis for structures with base isolation. Nonlinear time history analysis can be performed using programs such as SAP 2000, ETABS, DRAIN-2D, ANSR, 3D-BASIS, and RUAUMOKO, assuming the appropriate quality assurance controls are implemented.

It is customary to have an independent peer-review of the specifications, calculations, and drawings associated with a base-isolated facility. The current U.S. codes require this for building and bridge projects. It is only logical that such a peer review be done for a nuclear facility. Specialty consultants in the field of isolation system are also likely candidates for this task.

6.8 Superstructure Configuration

As with fixed-base structures, there are certain attributes of seismically isolated superstructures that are conducive to good seismic performance. A regular distribution of mass and stiffness reduces torsional motions, and a direct and continuous load path for lateral forces avoids areas of the structure with highly localized demands. These attributes in turn reduce displacement and force demands on the isolation system. It is acknowledged that it will be easier to isolate the containment structure by itself since it has a relatively uniform mass and stiffness distribution. This however may necessitate separate isolation diaphragms for the auxiliary building and containment structure, which is not desirable from cost and schedule standpoint. The final selection of the type of isolation system will depend, in part, on its ability to cope with potentially substantial uneven mass/stiffness distribution.

Limitations on superstructure height-to-width aspect ratio, necessary to control overturning and uplift of isolators, is not expected to be serious issue for nuclear facilities because of their large weight.

6.9 Variations In Isolator Properties

Because seismic response can be sensitive to variations in properties of the isolation system, it is important that the analysis reflect as accurately as possible the actual properties of the isolators installed in the structure. The isolation system must be modeled using parameters verified by representative tests on prototype isolators. Furthermore, bounding analyses must be performed to assess the influence of expected variations in isolator properties. These variations can result from the manufacturing process, or from factors such as aging, temperature, contamination, etc. This is especially relevant to a mission-critical application such as a nuclear power plant. If aging is shown to result in reduced ability to provide seismic isolation, it would be necessary to carry out an "end-of-the-life" analysis, with appropriately conservative values of the isolator properties.

6.10 Connection with BOP Systems

BOP systems, particularly feedwater and main steam (in BWR plants) that traverse from non-isolated facilities will need to be fitted with special flexible expansion joints which can absorb the relative movements between the facilities. It is expected that such relative movements will be in the neighborhood of a few feet, a significant challenge for the design of isolation joints so as not to cause distress to the piping. The procurement and design of these specialty items will need to be planned ahead of time with close dialog and coordination between the concerned parties. The viability of seismic base isolation will depend on the industry’s ability to produce appropriate expansion joints for isolating the BOP systems.

7. Construction Considerations for Application of Base Isolation

Application of base isolation to nuclear power plant structures will involve several planning, scheduling, and execution challenges. On the whole, the construction schedule for a base isolated facility could be reduced because the superstructure and major equipment design will be standardized. Some of the construction challenges are discussed below.

7.1 Isolator Foundation/Isolation Diaphragm

A common foundation/isolation diaphragm for the reactor building plus the auxiliary building will be a significant construction challenge because of its size and expected thickness changes. It is possible that thickness variations in the foundation and especially the diaphragm can be minimized, albeit at an increase in concrete and rebar quantities. It will be necessary to perform a cost-benefit analysis on the increase quantities versus the ease of construction (and the expected schedule expediency). Proper and early coordination between the design and construction team will be needed to reach the right decision in this regard. The option to have separate diaphragms/foundations for the nuclear island structures is easier from a construction standpoint; however, it likely will have adverse schedule implications.

The headroom between the diaphragm and the isolator foundation will need to be of sufficient height so as to permit easy access to isolators for inspection, maintenance, and surveillance.

7.2 Moat/Seismic Gap

To accommodate lateral movements of an isolated building, a clearance space, or "seismic gap" must be provided around the perimeter of the base. For partially buried structures such as the containment and auxiliary buildings, the isolation system will be located below grade such that the seismic gap will take the form of a moat. The width of the moat corresponds to the ultimate permitted lateral displacement of the isolation system (preferably exceeding some "beyond-design-basis" seismic design criterion).

Special architectural features are associated with the seismic gap. If a moat is formed around the perimeter of the base a cover is usually provided over the seismic gap. This cover must support gravity loads associated with ingress and egress from the building (pedestrians, freight) but must not restrict lateral movement of the superstructure. The simplest and most common form of seismic gap cover consists of horizontal steel plates attached to the superstructure. The outer free edge of the plates rests on the top of the moat wall, with enough overlap to prevent the plates from falling into the gap under the maximum possible lateral displacement of the structure. If a moat cover is not provided, access to the building is sometimes provided by access bridges that are attached to the building at one end and are free to slide on the ground surface at the other end. Another architectural consideration is the configuration of elevator pits. Typically in isolated buildings the elevator pits are suspended below the first floor of the structure, within the space provided for the seismic isolators. Sufficient clearance is provided around the elevator pits to avoid interference when the isolation system undergoes the maximum possible lateral displacement. Note that center piston hydraulic elevators are not normally considered for use in isolated structures because the piston would have to cross the plane of isolation.

Construction of a moat will require retaining walls to hold the soil in place. For deeper embedment of the reactor and auxiliary buildings, the design and construction of the moat will need to be a carefully planned activity. As an option, it may be possible to locate the isolation plane closer to the grade elevation such that the embedded parts of the structure will in direct contact with the surrounding soil and will not be isolated (and hence not standardized).

8. Procurement/Quality Assurance/Quality Control Issues

None of the current vendors of isolation systems possess QA programs that can meet NRC requirements. The isolator industry will need to be indoctrinated to what it takes to meet such rigorous requirements during the entire design, construction, testing, and handling/delivery processes. Appropriate qualification testing programs will need to devised to ensure that the isolators can provide long-term service in an environment that may include high radiation levels and elevated temperatures. The ability and willingness of this industry to embrace the necessary programs will be key to the success of base isolation application.

9. Pre-Service/In-Service Testing/Inspection

A serious effort will be needed to identify appropriate in-process tests and pre-service tests (and sampling frequency) so as to have a high level of confidence in the ability of the individual isolators and the isolation system to deliver the performance needed. During service, it will be necessary to define appropriate nondestructive tests/inspections to ensure continued reliability of the isolation system.

10. Summary

Application of seismic base isolation holds an exciting promise for nuclear power plant structures. Incorporation of base isolation could result in significant standardizations that would in turn help reduce the construction schedule and overall plant cost. In this way, the isolation technology would go a long way toward making nuclear power an attractive choice for interested utilities.

While the technology holds obvious promise for the nuclear power industry, it is essential that missteps be avoided by forging a solid collaboration between the various stakeholders such as the customer, reactor vendors, isolator vendors, constructors, specialty consultants, isolation researchers, and the NRC.

11. Recommendations

It is recommended that the reactor vendors perform additional research on seismic base isolation technology to quantify the cost benefits of deploying the technology for of a new nuclear unit. This research should consider:

- The cost and schedule to license the technology
- The capital cost to deploy the technology
- The overall cost reduction to plant engineering considering that the seismic design costs should be much reduced
- The overall construction cost reduction due to decreased material quantities
- The life cycle cost reduction by elimination of seismic equipment supports
- The cost reduction of safety-related equipment with lower seismic design requirements
- The cost increase due to the need to design, qualify, license and install base isolation
- The cost increase to maintain base isolation over the life of the plant
- The cost increase related to scheduled inspection and possible replacement of aged isolators

3. O&M Staffing and Cost Development for Advanced Reactor Designs

3.1 Overview and Approach

3.1.1 Overview

The designs of nuclear power stations have evolved since the last plant order in the United States in the late 1970s. Advances in technology, plant automation, and system and component reliability have led to new designs that are more energy efficient, easier to test, faster to troubleshoot, and simpler to repair.

The O&M cost of a power station is used to measure the normal operating cost of the plant. This cost is expressed as unit of electric net generation, or megawatts electric, and reflects all costs that are incurred to operate and maintain the plant. Included in this cost are salaries and benefits for the plant staff, parts, material and equipment costs for maintaining plant equipment, fees, insurance, overhead costs, and short-term contract services. Fuel is not included because it is usually calculated separately.

In general, after achieving operating maturity, these designs are expected to be easier to operate and require less manpower to accomplish daily tasks. However, many staff duties for current and advanced design plants are driven not by component complexity, but rather by task and human efficiency concerns. This study determined a staff profile considering how the design improvements would reduce staffing levels, while maintaining an adequate staff to meet regulatory and best practice requirements. Therefore, this study provides a firm basis for estimating staffing rather than asserting that advanced plant-staffing levels will be lower than current plants based on a simple assumption.

This study developed staffing estimates for an established plant design, not for the first-of-a-kind deployment of a particular reactor type. First-of-a kind deployment will require additional staff for a longer period to identify and correct design issues. These first-of-a-kind issues cannot be easily categorized and are not considered as part of the scope.

The four reactor designs selected for this study reflect a mix of passive and active safety features, advanced automation, and proven technologies. The characteristics of each design are generally described in Section 1. As stated in Section 1, each reactor vendor was asked to provide design and operational data on their designs. The varying levels of detail provided by the reactor vendors impacted both the advanced reactor construction technologies and schedule study and the decommissioning costs and funding study. However, for the purpose of this study, information was needed on plant layout, systems, and design enhancements and the level of detail provided by the vendors on these topics was found to be adequate for performing this study.

The most detailed information was available on the ABWR. With two plants operating, and four others under construction, the final design details are available for the design. In addition, staffing and plant maintenance requirements for this design were determined from actual operating experience. The ABWR is the only design that has an equivalent of a U.S.-type human factors review of the control room design (completed for Lungmen).

In order to develop the staffing model, a number of assumptions were made to define the organization and the support staffs. First, two separate staffing models were developed. The first was for a greenfield site deployment of approximately 1100 to 1400 megawatts. For the designs evaluated in this study, this would be a single new unit or a twin unit for the ACR-700. The ACR-700 is designed only as a twin unit and the total electrical output for a twin ACR-700 is within the deployment range being evaluated.

Another staffing model was developed for the deployment of the same 1100 to 1400 megawatt range of new reactor types on an existing operational nuclear site. This staffing model assumes that, where possible, site staff and services will be shared and the staff levels listed here reflect increases in the staff for those positions.

3.1.2 Approach and Assumptions

- **New Staff Experience and Expertise –** Two different deployment models were studied for this report; i.e., placing the new reactor on an existing site or on a greenfield site. The most probable for early deployment of new plants is to place new reactors on existing sites. Many sites throughout the United States were originally designed for more units than were completed. These sites have well-known features and suitability for additional development and would provide optimal sites. In addition, the existing reactors can provide an excellent training environment for the new plant staff to gain experience. Also, new plants may be nonregulated merchant plants. Placement of these plants at existing sites will reduce the licensing uncertainty and improve the economics.

  For this study, it was assumed that early plant construction would focus on existing sites. This would readily allow some staff from the existing plants to transfer to the new designs, providing experience to the new plant staff while allowing new hires to be initially exposed to plant operations in an operating facility. Operations and maintenance personnel would gain experience working on the operating unit before transitioning to the new plant staff.

  As the industry matures and new sites are used for plant deployment, it was assumed that the previously completed new plants as well as the older operating units would provide the same staffing incubation.

- **Engineering Units –** In the development of the staffing models, some general assumptions were made to ensure that each design was addressed equally. The first was that the plant would be designed, constructed, and maintained in English engineering units. Three of the designs were developed or are deployed in other countries where metric units are common. The use of metric engineering units in the United States is possible and construction projects have been completed in metric units. However, the models include the addition of power plants at an existing site, use of metric units may create human error opportunities or other human factor issues. Maintaining English unit consistency across the utility's fleet will make maintenance, engineering, and operations simpler. Note that designing in dual units or converting from one set to another creates additional design risks and costs.

- **Corporate Office Support –** For the staffing model used at Dominion, corporate office support staff perform a few selected tasks in support of the unit and maintain programs and plans that apply system wide. Task support includes major modification development and management, fuel procurement and management, and maintenance of the plant safety evaluations. Program management and development exists in the areas of chemistry, health physics, and licensing. Some companies perform these duties onsite. The costs associated with these functions are included in the site staffing and cost model. The staff levels are intended to augment the staff of an existing operator of nuclear power stations. Where site staff was developed for the two site types outlined above, it is assumed that the plant owner already has an existing corporate office support staff that will be augmented to support the additional units. With the exception of site staff, no corporate management changes are assumed.

- **Shift Rotation –** A five-shift rotation was assumed for all shift-based staff. This is a common staff model for the nuclear industry, and allows a standard 8-hour workday, with four shifts required to operate the plant and the fifth shift in training. For operations, this allows 32 hours of classroom and simulator time for each shift during a five-week rotation.

- **Minimum Operator Staffing –** The existing requirements of 10 CFR 50.54, Conditions of Licenses, as well as the supporting Statements of Consideration were reviewed as they pertain to plant staff. The applicable sections are paragraphs (i) through (m). Some of the items addressed in these sections include requirements for licensed operator requalification programs and control room minimum staff requirements. These sections were used in developing the staffing requirements. The advancements in plant design for the selected new plant types do not affect these requirements.

- **Standardized Assumptions for all Reactor Types –** Each of the four reactor suppliers provided an extensive catalogue of data to support the development of this task. Each of the four reactor types is in a different stage of design development and, as such, has varying levels of detail available. In order to simplify the task, several assumptions were made where obvious similarities exist. The first addressed the turbine building and other nonnuclear support structures. All four reactors supply steam to a steam turbine that drives the generator. This portion of the plant is nearly identical for each of the reactor types. The ABWR and the ESBWR will require some additional radiological controls and shielding for the turbine that are not required for the ACR-700 or the AP1000, but in general, the equipment and personnel requirements for these systems are the same. The plant designs were assumed to have identical circulating water cooling methods as well as identical plant corrosion control systems and issues. These assumptions standardized the basis for the analysis and made for a clear comparison between designs.

- **Other Site Buildings** – Other support structures, including, but not limited to an administration building, fabrication shops, a vehicle maintenance area, and other structures that are needed to support a site were also considered as a group. No differentiation was made between the reactor types for these support structures and the staff or costs required to operate them.
- **Support from Other Operating Utilities** – In order to provide additional utility insight into operational staffing, Entergy Nuclear and TVA provided assistance and input into this task. Dominion Energy, Entergy Nuclear, and TVA operate several nuclear power plants and the inclusion of three operators in the study provides a range of perspectives on staffing and operational cost issues.

3.2 Operations and Maintenance Staffing Development

3.2.1 Staff Development Methodology

Plant staff is a significant portion of the overall O&M cost basis for nuclear power stations. Staff costs, including overheads for the staff (which includes payroll taxes, benefits, and other items), typically amount to approximately half the total O&M operating cost for a large unit. Reduction of staff levels can therefore significantly impact plant overall costs.

In developing a staffing structure for new light water reactor designs, previous studies have usually taken a high-level general approach and reduced staff based on technological innovations. These studies also assumed that restructuring of the plant staff, including combining job responsibilities, could further reduce the overall staffing levels.[2]

For this study, a task-based approach was used. Plant designs were studied to determine similarities and differences. In addition, technology changes that affect plant staffing were reviewed and used to determine staffing levels. No changes in overall staff structure from the current operating philosophy were assumed. The reason for this was simple: the first new plants built in the United States would rely heavily on current operational practices to ensure that the lessons learned over the more than 30 years of plant operation were applied to the newest generation of plants. Current staff structures differ between operating companies but have a single overall basis—to re-

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[2] These studies include the Westinghouse internal report, "Improvements in Nuclear Plant Staffing Resulting From The AP600 Design Program," C. Mycoff, no date and "A Small Passive ALWR Draft Staffing Study," developed for Advanced Reactor Corporation, draft dated December 1996 and never issued.

duce human error and equipment failure in all phases of plant operation and safety and to ensure an overall high operating capacity factor.

3.2.1.1 Staffing Basis

As a baseline, the current staff functions for Dominion's North Anna Power Station were used to begin the staff analysis for each reactor type. These staff positions were reviewed and titles modified as necessary to make the position titles as descriptive as possible. This analysis identified over 200 staff positions, from site vice president to laborer. A listing of those positions is included in Table 3-1. (Tables 3-1 through 3-8 are located at the end of Section 3).

To develop the required staffing for the plant types, a baseline station was adopted to develop a base staff level. The ABWR was selected as the baseline design. Of the designs reviewed, the ABWR is closest to the plant types operated in the United States today. It consists of a typical steam turbine cycle and conventional active safety systems. The operation of the ABWR is similar to that of the BWR6 series plants currently in operation. The ABWR has some additional redundancy and employs modern control and protection equipment that has operating history in other countries. Staffing for the other designs considered was modified as appropriate to reflect differences in design including use of passive versus active safety systems and additional reliance on batteries.

3.2.1.2 Site Integration

Adding a new unit to an existing site does not allow universal sharing of staff between the units. The design of these plants is significantly different from any previously deployed in the United States. Plant layout, reactivity response, level of automation, and control system design will not allow much synergy between the existing units and a new plant in technology-based positions. These positions include operations, maintenance, and some engineering positions.

Operationally, the new plant designs are significantly different from existing plants. Reactor operators and senior reactor operators will be licensed separately on each unit design at the site, precluding sharing of these individuals between the unit types. Because of the differences in technology and systems design, non-licensed operators will not be able to be shared, since these positions are usually used as advancement positions to licensed operational jobs. Other operations support positions can be combined with the existing units. Current sites have a license condition that requires the operations manager and the supervisor of shift operations to hold or previously have held licenses on the existing units. Because the new designs are significantly different, a separate supervisor of shift operations has been added for the new plant. In addition, the position of assistant manager – operations will be created with a requirement that the manager or the assistant manager hold or have held licenses on both unit types. These requirements only apply to those designs constructed on existing sites.

Some site engineering positions will not be shared. System engineers at existing sites frequently are assigned the same systems on each multi-site unit. This is common because, in most cases, these systems are identical or mirror image systems with the same technologies. On sites with different reactor types (Millstone and ANO for example), it is often not practical to assign system engineers between units due to the differences in plant design. For the purposes of this study, system engineering for the new reactor designs is staffed independent of the existing units. Design engineering, as well as in-service inspection support, predictive analysis, and component and reliability engineering were augmented from the existing unit staff. Because of the significant technological changes in component design between the units, component engineering staff is additionally increased to compensate.

The maintenance staff will also be precluded from working on all unit types. Due to the technological differences between the existing plants and the new designs, many systems and component differences will not allow maintenance staff to be interchanged easily. Advances in control systems, electrical breakers and protective devices, as well as pump design, will require that additional maintenance staff be dedicated to the new unit.

Other plant staff, such as security, emergency planning, and radiological protection, will transition between units relatively easily, allowing staff to be shared between units.

It should be noted that in all cases, the turbine cycles for the four reactor types are relatively identical. Each design uses a single standard turbine per reactor, consisting of a high-pressure section and two to three low-pressure sections. Multiple stages of feedwater heating are employed in all designs. Staffing for the turbine side was assumed to be the same for the three single reactor types and slightly augmented for the twin unit ACR-700.

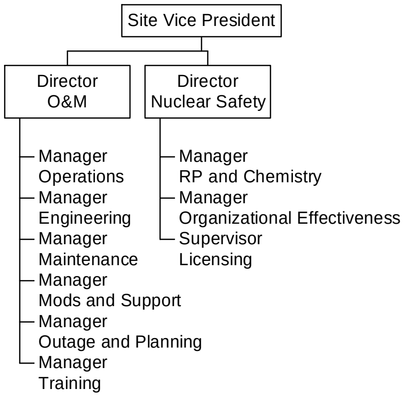
Table 3-2 presents the detailed staffing matrix by title. Table 3-3 is the summary matrix, listing staff by titles identified in the Electric Utility Cost Group (EUCG) staffing standard.

3.2.2 Staff Description By Department

In order to clarify staffing and the differences between technologies, a description of the staff for each department is required. This report will address the typical department staff of Dominion's North Anna Power Station, since that was used to develop the staff matrix. Different power companies may use alternate staff models and relationships, so the following description will be as generic as possible.

A typical site organization is shown in Figure 3-1.

Figure 3-1. Typical Site Organization



3.2.2.1 Operations

The Operations Department typically consists of an on-shift component that handles day-to-day plant operations, and an off-shift support component that performs tasks in support of the overall plant. As stated earlier, the on-shift operations staff was assumed to be on a 5-shift rotation. This on-shift staff is dedicated and not shared with other units on site.

The on-shift operations staff consists of a control room contingent and support contingent of non-licensed operators. Control room staffing is governed by 10 CFR 50.54. 10 CFR 50.54 requires that licensed operators be present in the control room and it prescribes minimum staffing requirements. Specifically, 10 CFR 50.54(m) provides the requirements for minimum control room staffing for up to three units. This staffing table is included in Table 3-4 for information.

The designs evaluated in this study require continuous control room monitoring. In addition, the ABWR, ESBWR, and AP1000 are designed so that each unit has its own independent control room. The ACR-700 is designed to share a common control room between its two units. Therefore, the existing regulations are adequate to determine minimum control room staff.

Regulatory minimum staffing requirements, however, are not the controlling factor for on-shift operations staffing. On-shift operations staff levels must be augmented with allowances for vacation and other time off such as illness or dependent care leave, so that the minimum staff levels can be maintained at all times. Licensed reactor operators will fill some of the non-licensed positions to allow for this contingency. These personnel will rotate into the control room to maintain their proficiency.

Operations staffing per shift for each reactor type is summarized in Table 3-5. Control room staff includes reactor operators and senior reactor operators and shift supervisors, who also have an active senior reactor operator license. Non-licensed operators are used as "eyes and ears" for the control room staff and typically are assigned watch stations, usually by building. To allow for vacation, sickness, and other activities, at least 2 of the non-licensed positions per shift will be filled with licensed reactor operators. Supervisory positions (senior reactor operator licensed staff) cannot be as easily accommodated.

On-shift operations staff differences between the designs evaluated are small. The ABWR and ESBWR each require an additional non-licensed radwaste operator to operate the controls in the radwaste control area. The twin-unit ACR-700 design requires a larger shift operations staff due to its two-unit design and the on-power refueling requirements of the reactor. Based on the simplification and automation of all of these designs, staffing has been reduced from current plants. The need for roaming operators to collect operational data has been reduced, but time still must be allocated for operators to inspect equipment locally. In addition, all plant types are designed for on-line maintenance, and operations support is necessary to support this function. From "fix-it-now" teams to tagging and post-maintenance testing, daily availability of operations staff is necessary.

The ACR-700 is unique in that the reactor is refueled on-power. The on-power refueling design of the ACR-700 does require additional full-time staff positions. Each reactor requires a refueling rate of approximately 22 assemblies per week. Therefore, refueling is a full-time activity and a dedicated staff is required to support it. A senior reactor operator-qualified refueling supervisor heads each refueling crew. This meets the 10 CFR 50.54(m)(iv) requirement of having a dedicated senior reactor operator directly supervise core alterations. In addition, each unit will have a reactor operator and non-licensed operator assigned to support the refueling process. A two-person maintenance team will also support this activity. Refueling will be conducted on a two-shift, five-day a week basis, with fuel movement occurring on four days and the fifth day dedicated to equipment maintenance.

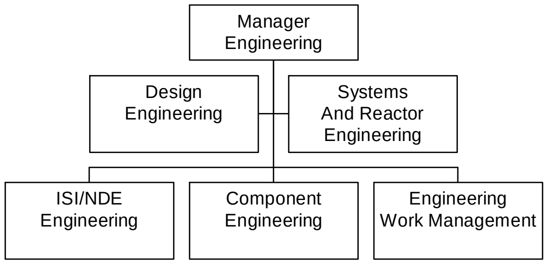
For the addition of a unit at an existing site, little credit was taken for current site staff. Operations training and experience is largely unit-specific and is not easily translated from one unit type to another. Off-shift operations staffing, however, can be used to support additional units. Allowances for off-shift reactor operator and senior reactor operator positions allow use of those individuals for special projects, vacation, and staff augmentation.

In 1979 following the Three Mile Island accident, the NRC established the requirement for a shift technical advisor. The STA position was established to provide additional on-shift technical support and knowledge to the shift supervisors in the areas of operational event evaluation and accident assessment.[3] Some utilities have upgraded the training of the senior reactor operator licensed positions to allow the STA function to be integrated into the senior reactor operator qualification. In order to provide an independent position to fulfill the STA function, additional on-shift senior reactor operator individuals would be required. For this basis of this study, the average salary for an STA was assumed to be the same as that of a senior reactor operator-qualified shift supervisor. Also, the requirement for an independent STA was retained and on-shift positions included in the matrix. Individual utility requirements would allow this to be adjusted as necessary. One STA was assigned to each operating shift (in keeping with a team philosophy) and 3 off-shift positions will provide flexibility in vacation coverage as well as special project support.

3.2.2.2 Engineering

A typical site engineering staff is divided into several major organizations. Some of these organizations are easily shared between an existing unit and a new unit. Others, based on the technological differences between a new unit and any existing units, are not easily shared. A typical engineering organization is shown in Figure 3-2.

Figure 3-2. Engineering Department Organization



Each of the new designs use advanced methods and technology to reduce the burden on the engineering staff. Compared to existing plants, advanced engineering tools will allow rapid and easy access to plant and component data, design

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[3] Taken From NRC IE Circular 81-04, "The Role of Shift Technical Advisors and Importance of Reporting Operational Events," April 30, 1981.

specifications, and calculations. In addition, significant simplification of design reduces the number of systems in the ESBWR, AP1000, and ACR-700.

For both an additional unit on an existing site as well as a single-unit greenfield deployment, the single largest engineering organizational impact is for Systems Engineering. This group is charged with maintaining system reliability and is staffed based on the number of systems and their complexity. For additional units on an existing site, some credit was taken for existing staff since engineering of common site support systems, such as nitrogen, hydrogen, sewage treatment, domestic water, and other shared systems. However, the main plant systems will be significantly different than those already at the site and will require additional system engineers. Credit was taken for the ability of the expected plant technology to improve engineering productivity and effectiveness.

Component (or maintenance) Engineering is usually charged with direct support of maintenance, particularly in solving difficult issues. Current staffs are assigned not by system, but by component type. Since many of the components of these new designs will be largely similar to existing plants (for example pumps, valves, relays, transmitters, etc.), existing staff can assume some of the additional workload. Staff increases in this area are largely to allow more even work distribution, with some specialty areas staffed solely for the newer unit. Examples of this specialty staffing would be the turbine and reactor control systems, which are completely different from those in the current plants.

Other engineering staffing is increased marginally to assume the expected extra work for the new unit. A small contingent of design engineers is needed to perform small-scale plant changes as needed and a small increase in administrative support is allotted.

3.2.2.3 Maintenance

Plant design improvements will greatly affect maintenance staffing and work efficiency. Some designs have eliminated entire plant systems and major components. For example, the ESBWR eliminates most core injection systems as well as reactor vessel recirculation pumps. The ACR-700 has eliminated heavy water from the primary coolant, eliminating most of the systems needed to process and control the heavy water. All the designs have digital systems for protection and control that will reduce the time needed to perform periodic loop and systems calibrations and troubleshooting.

However, these improvements do not result in large sweeping reductions in maintenance staffing. The passive safety plants, which include the AP1000 and the ESBWR, have eliminated the need for many active safety-related emergency systems. These include pump-driven safety injection and spray systems. While some systems have been eliminated, many of the previously designated safety grade systems are still required for investment protection. Safety-related 120V or 250V batteries provide emergency power to the safety systems. These batteries require routine periodic testing and maintenance. In the existing plants, there are approximately 6 batteries, with each battery consisting of 60 individual cells. The new designs that rely on more passive safety have substantially more batteries. For example, the AP1000 has 18 safety-related batteries and 4 nonsafety-related batteries (with 12 associated battery chargers). For this reason, an additional crew of electricians was added to both the ESBWR and the AP1000 staffing.

Maintenance support positions have been minimized to the extent practical. For the addition of a unit at an existing site, one individual was added to assist in obtaining parts to support the maintenance staff. The primary purpose of this position is to assist in obtaining non-stock components and services. The advanced data systems that will be provided as part of the new unit construction will assist in the productivity of this position.

3.2.2.4 Radiation Protection

The Radiation Protection (RP) Department consists of chemists and RP technicians on-shift, as well as an off-shift contingent that focuses on exposure control and dose analysis. Because the new unit will not be contiguous to the existing plants, the on-shift staffing cannot be shared with the existing units. A five-shift rotation was used, with two shifts covering the added day shift workload. For each shift, an RP supervisor and three RP technicians are required for each shift, with two additional technicians on day shift. Additionally, decontamination technicians are available on day and swing shift to support the RP staff. Chemistry technicians are assigned to each shift, with additional technicians on day shift to perform routine sampling and operational support duties.

Off-shift RP staff for the additional unit is minimized, with a few additional technicians to support ALARA planning functions and count room technicians added to support the added work expected for the additional unit.

3.2.2.5 Training

For the addition of a unit to an existing site, much of the existing training organization will be used to support staff training. Some of the specialized department training, however, will have to be tailored specifically for the staff of the new unit.

For operations training, the program and certifications for all operations positions will be plant-specific. This will require instructors dedicated to operations and shift technical advisor initial and requalification training for the additional plant. Engineering training for the additional unit will be combined with the existing plant training program and not be affected. Maintenance training will require some specialized instruction for those systems and components unique to the new unit. Additional instructors are included in the staffing plan to augment the maintenance training staff in these areas.

3.2.2.6 Security

None of the designs studied were sufficiently developed to have a security defense plan. For this reason, estimates of needed additional security staff cannot be based on design specifics. Therefore, a standard simplified staff impact was assumed for all the designs.

The reference site for this study is the North Anna site. The selected area for adding an additional plant on that site is a location that will allow the protected area for the new unit(s) as well as the existing protected area to be included in a single common protected area. This allows a minimal increase of perimeter patrol requirements. The study did not assume the addition of another plant access point. No staff additions were assumed for additional roving patrols.

For those sites where the addition of a new unit cannot be located to allow the protected areas to be combined, the security staffing should be adjusted accordingly.

As final designs are completed, security defensive plans and positions will be developed and staffing will be adjusted as needed. Because of the sensitivity of this issue, it was decided not to spend excessive time on this section.

3.2.2.7 Staff Augmentation

The staff data developed in Tables 3-2 and 3-3 is based on a mature operating plant. A mature operating plant is defined as a plant where construction is complete and all procedures, programs, and plans for all departments are developed and only require periodic review and revision. It is anticipated that this maturity is attained approximately 36 months or approximately two cycles after commercial operation.

Section 3.2.3 discusses staff development during the construction phase of selected departments. Following construction completion however, a significant amount of nonroutine and detail work will remain, requiring significant additional staffing assistance. Additionally, the level of experience of the staff will still require some time before the optimum staff levels are attained. Contract personnel working under the plant owner’s cognizance typically provide this augmentation.

Staff augmentation will vary between departments and even between operating companies. It will be based on the following intangible items:

- Number of open construction-related issues
- Amount of plant cleanup and cosmetic completion remaining at commercial operation
- Completion status of lower-tier procedures
- Plant design changes remaining at commercial operation

It is difficult to estimate total number of contractors that will be needed at commercial operation, but it is expected that almost all these positions would be eliminated within 36-48 months.

3.2.3 Staff Development During Construction

The construction and testing phase of the plant is the ideal time to hire and train staff, as well as to gain valuable knowledge in plant operation. Many of the plant departments will begin staffing during latter stages of plant construction, but some will begin earlier.

Plant ownership by the operating company typically starts during the preoperational test phase of construction. During this phase, systems are accepted from the construction team, readied for operation, and tested to ensure that the installed system and components meet all required design objectives. Following testing, the systems are turned over to the plant owner, who accepts operational and maintenance responsibility.

Staffing of plants is largely a site-specific issue, but some basic guidance can be provided. The construction phase offers a unique opportunity for the permanent plant staff to learn the plant design and layout. Early hiring and integration of the permanent staff may require some additional expense, but has been found to be well worth the cost.

Table 3-6 is a general staff development matrix that is not based on reactor type. Construction period staff development is listed as a percentage of equilibrium staff positions and based on plant construction milestones. Staff augmentation, usually by contractor personnel, will allow the development of department-specific programs and plans as well as the implementing procedures. This augmentation will also allow the experience of the permanent staff to improve, allowing for the eventual elimination of the majority of contractor positions. The effort required to support this development should complete during the 36 months or two cycles of commercial operation.

The data presented is for reference only and will be highly influenced by plant location, contractual arrangements between the plant owner and designer, and other factors. It should be adjusted as necessary as the COL is developed and overall scope is further defined.

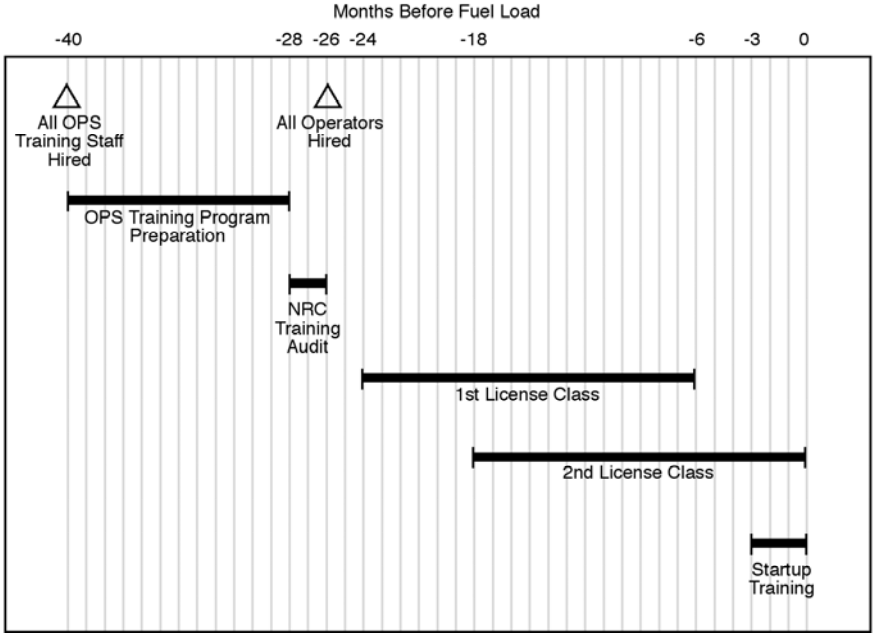
3.2.3.1 Training and Operations

The training of the operations staff has been identified as a significant issue for plant operation. The new reactor designs claim significant reductions in construction time. With shorter construction times, however, come shorter times to qualify station staff, particularly operations staff, to support fuel load and criticality. Current operator training programs, both reactor operator and senior reactor operator, require approximately 18 months of classroom, simulator, and in-plant time to prepare to take an NRC license examination.

For a new unit deployed at either an existing site or a new greenfield site, licensed operators must be on site for fuel receipt, typically starting about 3 months before fuel load, which is 6 months before commercial operation. With a desire to have completed at least two classes of operator training, the simulator must be installed and operational, with all expected plant responses programmed at least 24 months before fuel load. Before this time, lesson plans must be developed and training materials generated. In summary, the training staff for licensed operator training must begin work (and the plant design be sufficiently evolved) approximately 42 months before commercial operation.

At fuel load and for a single-unit deployment, approximately 25-30 licensed positions must be filled. This estimate is based on required control room staff, extra staff per shift for vacations, etc., as well as training positions for management personnel required by regulation to have a license on the unit. To attain this number of licensed individuals and to account for attrition during the class, two training classes will be required to be complete before fuel load. Each class will contain 15-18 people and will run about 6 months apart. This allows one class to complete fundamental theory before the next class starts. Since the ACR-700 is a two-unit design with a year in the construction plan between the units, staff development should be adjusted accordingly.

Based on these estimations, an operations training plan was developed and is summarized as follows:



OPERATIONS TRAINING SUMMARY

Graphics No: MT1677

The training plan times outlined here are based on a typical power company training program and differ from that proposed by the reactor vendors. The staffing data for operations and training is listed in Table 3-6.

3.2.3.2 Maintenance Staff

The point in time where the permanent plant maintenance staff assumes the responsibility for equipment will depend on the specific construction contract for each site. There is no established standard, but for the purpose of this study, it was assumed that the permanent maintenance staff assumes maintenance responsibility as the equipment completes preoperational testing. This milestone is frequently the point at which the Operations Department assumes responsibility for systems operations as well. Ideally, maintenance staffing and training should begin early enough so that qualified individuals are available to maintain systems and components as they turned over following completion of preoperational testing. In reality, permanent site maintenance staffing will begin at some point after the start of preoperational testing. This allows the inventory of systems controlled by the owner to increase to the point where the use of permanent staff is more cost effective. Development of plant procedures to maintain the equipment, however, should begin early in the process, and needs to be largely complete by fuel loading to ensure that plant procedures can be validated by that time. All plant maintenance activities should be the responsibility of the Maintenance Department by fuel load.

3.2.3.3 Engineering Staff

During the preoperational and startup test phases, a unique opportunity is presented to gain large amounts of plant knowledge. These phases usually mark the transition from construction to owner control of systems and components. The preoperational testing phase is an ideal situation that allows permanent staff employees to learn about plant layout, design, and operation. Placing technical staff in the preoperational test group, and later responsible for startup testing, not only allows the plant owner control of these processes, but also exposes individuals to system and component operational modes that may not be repeatable during plant operation.

In past construction evolutions, these testing positions have usually been assigned to plant engineering staff, heavily augmented by experienced contractor personnel. In reality, the technical knowledge required assumes a design as well as operational background, and is ideally suited to plant engineering and operations personnel.

However, as system and component testing is completed, responsibility for the maintenance and upkeep is transferred to the owner and many of these same personnel are required to fulfill permanent staff duties. For this reason, staffing of the preoperational and startup testing organizations cannot consume the entire engineering and off-shift operational staffs. Engineering staffing must support these divergent needs, and additional contractor staffing is allocated such that preoperational and station engineering needs are met.

3.2.3.4 Other Departments

Staff development of other plant departments is needed mainly to support the operation of the plant as opposed to construction activities. For example, some RP personnel are required to be fully trained for fuel receipt and as radioactive sources are deployed for equipment calibration. In addition, staffing of site human resources positions may occur as staff numbers are increased. Implementation of the site security plan will begin on a limited basis on fuel receipt and will be fully in place a few weeks before fuel load (allowing some time to resolve all operational issues for security).

3.3 Operations and Maintenance Cost Development

After a staffing matrix was developed for each unit type, the overall O&M cost data was developed. The reactor vendors provided outage duration and fuel or operating cycle length for each reactor type. A conservative forced outage rate of 4% was assumed and the capacity factors were calculated based on these assumptions. The capacity factors were normalized to a 12-month average. In addition, the reactor vendors provided the power output of the units, in both a gross and a net value. This data was used in calculating the total operating O&M cost as well as the cost per net MWe. The O&M cost calculation, along with the outage durations, forced outage rates, and calculated capacity factors are listed in Table 3-7.

This study did not include investment in capital replacement costs that will be required to replace retired equipment. This allowance would typically include funds for large motor overhauls and replacement, generator rewinds, turbine blade replacement, steam generator replacement, and other items that typically are needed to ensure that the plant operates reliably. These capital cost items are amortized over the expected equipment life and not typically included in an O&M cost calculation.

3.3.1 Staff Cost Development

Development of the staff costs was designed to reflect the relative cost of each staff position. In order to simplify the model slightly, the over 200 staff positions listed in Table 3-2 were reduced to 65 individual pay grades. Each pay grade was assigned to a staff position, with those pay grades used to calculate the staff salary cost. For this study, North Anna pay scales were selected as a basis; the values were averaged from all appropriate pay scales and ranges for each classification. The cost basis uses the detailed staffing quantities by title developed in Table 3-2 to calculate staff cost.

The benefit of this approach is that it allows the staff cost to reflect more accurately the diverse workforce. Adjustments to staffing numbers in any pay group or department will have an appropriate effect on the overall totals. Use of location or company-specific data can be used if desired.

After the salary cost was determined, the additional staff fixed costs were added to Table 3-7. These include overtime costs (based on a percentage of total straight time), retirement and benefits costs, bonus and incentive payments, and payroll taxes. The estimate for overtime was based on a percentage of total salary and increased by 50% to account for premium time. This estimated data is drawn from budget development estimates. These estimates have proven accurate over time. The retirement and benefit calculation was derived from industry estimates developed by EUCG and the bonus and incentive cost was an average value used for budget development purposes. Payroll taxes are self-explanatory. These were applied as appropriate fractions to the overall salary totals.

3.3.2 O&M Cost Items and Estimates

Other cost items included in Table 3-7 are fixed and variable costs and fees associated with plant operations. These include NRC, INPO, and NEI fees, all of which are based on site and reactor design specifics. The values included in Table 3-7 are based on 2003 data and fee structures. Other includes the costs for emergency preparedness fee payments to the federal, state, and local governments and was estimated as a lump-sum value.

After significant discussion, property taxes were excluded from this study. These taxes can be significant, but are highly dependent on local arrangements and agreements. Some localities charge only equipment taxes while others have abated portions of taxes for political reasons, such as job growth. The line entry was included in the spreadsheet to ensure that the values were included when used for individual plant analyses.

Insurance data was estimated for each specific reactor type in the specific location. Since insurance rates are based on plant operating history, these are estimates based on expected values. Included in the insurance estimates are allowances for property and nuclear risk insurance as well as allowances for workmen’s compensation insurance, liability, etc.

For outage costs, it was assumed that the per-cycle outage costs for a 1200 MWe plant with steam generators would be $12M per unit. This is based on slightly below-average industry O&M outage costs for current operational plants. It is anticipated that this value would be representative of future plants as well, since many of the same outage maintenance issues exist, such as turbine maintenance, transformer maintenance, motor and pump refurbishment, etc. The outage cost for each reactor type was adjusted from this basis. The steam generator inspection costs were removed from the ABWR and ESBWR outage costs. The refueling cost was removed from the ACR-700 outage cost since this design is refueled on-power and does not require reactor vessel disassembly to refuel. Since each unit of the ACR-700 is significantly smaller than the other designs, the material costs and labor costs were reduced to reflect the smaller equipment size. The outage costs for each unit were then added to the annualized O&M costs based on the outage frequency and number of units. The outage cost estimation is shown in Table 3-8.

In order to maintain an operating plant, other miscellaneous materials, supplies, and services are needed. In addition, small ongoing modifications to the plant will be required to support operating staff needs and equipment replacements. These ongoing O&M expenses are accounted for with an annual $15M allowance.

Administrative and general cost (A&G) overhead is an allowance for corporate support functions. These can include items financial services to stock distribution and sales. The A&G cost estimate used is based on an average value for Dominion’s Virginia plants. An annual $3M allotment was added to cover these expenses.

The site service cost is the cost of replacement power when the unit is not operating. During maintenance and forced outages, unit power consumption can be significant and is a cost of operating the plant. In order to simplify this calculation, it was assumed that 90% of all outage time would result in a net power consumption. The capacity factor (also calculated in Table 3-7) was used for power production, with outage time assumed as the remaining fraction. A power consumption rate of 4 MWe was used at a cost of $35/MWe.

3.3.3 Total O&M Operating Cost and Cost Per Net MWe

The total O&M operating cost is a sum of all identified costs for each deployment type for each reactor. The outage cost per unit was normalized to a 12-month basis based on the fuel cycle and number of units.

The cost per net MWe is calculated by dividing the total O&M operating cost by the total expected power output adjusted for the expected capacity factor.

3.3.4 Fuel Cost Estimates

This study did not review fuel costs for each design. However, any analysis of operating costs must also consider the cost of the fuel for the plant. Fuel costs for the ABWR, ESBWR, and AP1000 are expected to be in the range of currently operating plants and maybe a small amount lower. For the ACR-700, its fuel assemblies are considerably smaller than those of the other designs and the fuel enrichment, at 2% U235 is significantly less than the 4.5% U235 of the other designs, resulting in a very low cost for each assembly. Therefore, although the ACR-700 would use a larger number of fuel assemblies per unit of electricity generated, the cost per unit of electricity generated is expected to be significantly lower.

3.4 Conclusions

With the forthcoming deployment of new reactor designs, many assumptions have been made that technological advances will significantly reduce plant staffing. Studies have been published that assume that automation will allow plant staffs to be greatly reduced and that the simplicity of their design will allow reduced operating costs. Not all of those assumptions are realistic in the near term.

As stated in the introduction to this section, operators of new plants will use proven methods and processes to ensure safe and reliable operation of their plants. Current plant staffing profiles have proven effective in reducing human error and increasing productivity. Most operating companies have existing union and workforce agreements in place. These existing agreements have proven effective in maintaining a safe and efficient operating environment. Changes to these arrangements are not in the scope of this study. The use of innovative and experimental staffing models on a new design would add an additional element of change that may affect plant operations and might be contemplated at a later date.

This study reviewed the typical staff profile of a top performing plant (North Anna) and used that profile to estimate staffing for four different reactor designs. The technological changes in these new designs did allow the reduction of staffing is some areas, such as operations and engineering. In addition, maintenance staffing was reduced due to the reduction in the number of systems and technological enhancements that resulted in design simplification.

Table 3-9 summarizes the cost study and presents the cost data in both a cost per year basis and cost per net MW-hour. The total staffing difference between the designs is not greatly significant. The AP1000 has the lowest predicted staff levels, followed closely by the ESBWR. Both of these designs use extensive passive safety features to mitigate accidents, but rely heavily on DC electrical power to support equipment in case of a loss of offsite power. This results in a small increase in maintenance staff to compensate for the periodic maintenance required for lead-acid batteries.

The ACR-700, because of its twin-unit design, requires the largest operating staff and the largest operating O&M budget. The twin units require additional staff to operate and maintain and have higher fee structures from those entities that base their fees on number of reactors.

The staff cost was added to the other operating costs of a power station. These costs were determined based on 2003 fee structures and estimates. These other expenses include fees for INPO, NRC, and NEI along with insurance for both nuclear and commercial liability, corporate overhead, site electrical consumption during outages, and other materials and services required for daily plant operations.

A total estimated yearly average operating cost was produced for each reactor type and each siting option. The lowest average annual O&M cost plant ESBWR (additional unit), with the ACR-700 being the highest (either siting option). However, when the plant power ratings are considered, and the costs are expressed as a unit cost of net electrical generation, the lowest cost plant is the ABWR with the AP1000 being the highest.

The most cost-effective implementation model incorporates the addition of a new unit on an existing site. Several studies on this subject exist, most addressing the reduction of construction (capital) costs associated with this deployment model. (See the report "Study of Potential Sites for the Deployment of New Nuclear Plants in the United States," prepared under DOE Cooperative Agreement DE-FC07-02ID14313, September 27, 2002.) The addition of a plant will allow the use of the existing infrastructure and staff that reduce the incremental operational costs.

The O&M cost estimates for the reactors studied are provided in Table 3-9.

Table 3-9. O&M Cost Estimates

Case Studied	O&M Yearly Cost	Number of Units	Total MWe (Net)	Cost per Net MWe
ABWR Additional Unit	$74,590,342	1	1371	$6.71
ESBWR Additional Unit	$74,178,482	1	1340	$6.83
ACR-700 Additional Unit	$88,111,240	2	1406	$7.61
AP1000 Additional Unit	$76,421,310	1	1150	$8.17
ABWR Greenfield	$101,818,008	1	1371	$9.16
ESBWR Greenfield	$101,204,268	1	1340	$9.32
ACR-700 Greenfield	$113,595,502	2	1406	$9.81
AP1000 Greenfield	$103,305,606	1	1150	$11.04

Data was compiled from EUCG on the O&M costs for the reporting nuclear plants in the United States. When sorted by number of reactors per site and then normalized for unit output, the O&M costs for the greenfield deployment of these new reactors were 15% less than that of the top 5 existing single unit plants (sorted by O&M cost). While it is difficult to compare the single unit addition to an existing site with the industry averages, overall the O&M costs are significantly reduced.

Plant staff and cost structures vary widely between power stations, and each plant site must adjust its staff profiles and levels to meet local needs. Each company planning deployment of a new nuclear unit must evaluate staffing based on the model that fits their operational preferences. A staff and cost development spreadsheet was developed to provide the information included in this report. This spreadsheet was provided to DOE as part of this study and can be used as a starting point for those companies interested in developing a site-specific model to more accurately develop the O&M cost model.

Although not part of this study, fuel costs vary widely between the reactor types and should be considered as part of an overall evaluation of new generation.

3.5 References

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24. Staffing Requirements for Future Small and Medium Reactors (SMRs) Based on Operating Experience and Projections, International Atomic Energy Agency IAEA-TECDOC-1193, January 2001.

Table 3-1. Staff Titles by Position

Management
Management - Supervisory
VP
Director O&M
Director Site Safety
Management - Non-Supervisory
Executive Assistant
HR Generalist
Financial Support Services

Operations
Manager Operations
Assistant Manager Operations
Administrative Assistant

Shift Operations
Shift Supervisor
Assistant Shift Supervisor
Licensed Operators (RO)
Non-Licensed Operators
Shift Clerks
Supervisor Shift Operations

Operations Support
Supervisor Operations Support
Refueling Operators/Off-Shift RO
Operations Engineer
Administrative Support
Plant Label Coordinator/Special Projects
Operations Maintenance Advisor
Off-shift SRO - Special Projects

Maintenance
Manager Maintenance
Administrative Assistant

Electrical Maintenance Supervisor
Electrical Foreman
Electricians

Mechanical Maintenance Supervisor
Mechanical Foreman
Mechanics
Welding Foreman
Welders

I&C Supervisor
I&C Foreman
I&C Technicians

Control Operations Supervisor
System Protection Technician

Maintenance Support Supervisor
Maintenance Coordinator
Maintenance Outage Scheduling/Special Projects
Maintenance Human Performance Coordinator
Quality Inspectors
Maintenance/Procurement Interface

Engineering
Engineering Manager
Administrative Assistant

Systems Engineering Supervisor
Systems Engineers
Reactor Engineers

ISI/NDE Supervisor
NDE Technician
ISI Engineers

Component Engineering Supervisor
Component Engineers
Reliability Engineers
Predictive Maintenance Technicians

Site Civil/Mechanical Design Supervisor
Mechanical Design Engineer
Civil Design Engineer

Site I&C and Electrical Design Supervisor
Electrical Design Engineers
I&C Design Engineers

Engineering Work Management Supervisor
Design Control Engineer
Draftsman
Administrative Assistant
Schedule/Cost Engineer

Records Supervisor
Records Clerks

Outage and Planning
Outage and Planning Manager
Administrative Assistant

Nuclear Scheduling Supervisor
Work Week Manager (non-supv)
Electrical Scheduler
Mechanical Scheduler
I&C Scheduler

Nuclear Planning Supervisor
Electrical Planner
Mechanical Planner
PM Planner
I&C Planner

Unit Outage Coordinator
Outage Planner

Supervisor Turbine Maintenance
Turbine Equipment Specialist
Turbine Generator Engineer
Turbine Planner

Table 3-1. Staff Titles by Position

Major Modification and Site Support
Nuclear Support Services Manager
Administrative Assistant

Construction Engineering Supervisor
Quality Inspectors
Construction Engineers
Construction Specialists

Electrical Construction Supervisor
Construction Specialists

Civil/Mechanical Construction Supervisor
Construction Specialists
Scaffolding/Insulation Support

Project Controls Supervisor
Controls Specialists

Facilities Support Supervisor
Vehicle Management
Construction Equipment Management
Labor Supervisor
Labor Support

Construction Craft and Supervision

Organizational Effectiveness
Organizational Effectiveness Manager
Administrative Assistant

Licensing Supervisor
Licensing Engineers

Human Performance Supervisor
Human Performance Coordinator
Self-Assessment Coordinator
OE Coordinator
Benchmarking Coordinator

Nuclear Safety Supervisor
Corrective Action Coordinator
Shift Technical Advisors (on-shift)
STA Office Staff (off-shift)
Root Cause Coordinator
Total Organizational Effectiveness

Nuclear Oversight
Nuclear Oversight Manager
Administrative Assistant
Nuclear Quality Specialists
Nuclear Specialists

Radiation Protection
Radiation Protection Manager
Administrative Assistant

Health Physics Operations Supervisor (on-shift)
HP Coordinator
ALARA Coordinator
ALARA Technicians
HP Shift Supervisor
Shift HP Technicians

Radiation Protection (continued)
Decon Supervisor
Decon Technicians

HP Technical Support Supervisor
Health Physicist
Rad Analysis and Material Control Supervisor
Count Room Technician
Radwaste Technician
Exposure Control & Instrumentation Supervisor
Instrumentation Technician
HP Specialists

Chemistry Supervisor
Asst. Chemistry Supervisor
Chemistry Technicians

Training
Nuclear Training Manager
Administrative Assistant

Ops Initial Training Supervisor
ESP (Engineering) Instructors
License Class Instructors
STA Initial Instructors
Simulator Technician

Ops Continuing Training Supervisor
Licensed Operator Re-Qualification Program Instructor
Shift Supervisor Instructor
STA Continuing Instructor
Non-Licensed Operator Instructor

Maintenance/Rad Protection Training Supervisor
HP Instructor
Chemistry Instructor
New Employee Training Instructor
Electrical Instructor
Mechanical Instructor
I&C Instructor
Nonaccredited Training Instructor

Security
Nuclear Protection Services Manager
Administrative Assistant

Security Operations Supervisor (on-shift)
Security Shift Supervisor
Security Officers
Technical Security Coordinator

Security Training Coordinator
Security Field Team Leader
Fitness-for-Duty Coordinator

Safety and Loss Prevention Supervisor
Loss Prevention Technicians
Environmental
Nurse/Medical

Site Emergency Planning Specialist

Table 3-1. Staff Titles by Position

Supply Chain Management SCM Manager Administrative Assistant Warehouse Supervisor Storekeepers Receiving/Inspection Supervisor Storekeepers Material Verification Specialist Emergent Sourcing Supply Management Coordinator **Telecommunications** IT Business Area Manager Business Analyst Local Area Network Field Services Telecommunications Services - Telephone Telecommunications Services - Servers

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
	MANAGEMENT								
	Management - Supervisory								
OFFTOT	VP	0	1	0	1	0	1	0	1
SSMGMT	Director O&M	0	1	0	1	0	1	0	1
SSMGMT	Director Site Safety	0	1	0	1	0	1	0	1
	Management - Non-Supervisory								
SSADM	Executive Assistant	0	1	0	1	0	1	0	1
SS004	HR Generalist	1	2	1	2	1	2	1	2
SS002	Financial Support Services	1	3	1	3	1	3	1	3
	Total Management	**2**	**9**	**2**	**9**	**2**	**9**	**2**	**9**
	OPERATIONS								
OPMGMT	Manager Operations	0	1	0	1	0	1	0	1
OPMGMT	Assistant Manager Operations	1	0	1	0	1	0	1	0
OPADM	Administrative Assistant	1	1	1	1	1	1	1	1
	Shift Operations								
OPMGMT	Shift Supervisor	5	5	5	5	5	5	5	5
OP001A	Assistant Shift Supervisor	5	5	5	5	5	5	10	10
OP001A	Licensed Operators (RO)	10	10	10	10	10	10	15	15
OP001A	Non-Licensed Operators	30	30	30	30	25	25	40	40
OPADM	Shift Clerks	2	2	2	2	2	2	2	2

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
OPMGMT	Supervisor Shift Operations	1	1	1	1	1	1	1	1
	Operations Support								
OPMGMT	Supervisor Operations Support	1	1	1	1	1	1	1	1
OP001B	Refueling Operators/ Off-Shift Reactor Operator	2	2	2	2	2	2	14	14
OP001B	Operations Engineer	0	1	0	1	0	1	0	1
OPADM	Administrative Support	1	2	1	2	1	2	1	2
OP001B	Plant Label Coordinator/Special Projects	0	1	0	1	0	1	0	1
OP001B	Operations Maintenance Advisor	0	2	0	2	0	2	0	2
OP001A	Off-shift Senior Reactor Operator - Special projects	2	2	2	2	2	2	2	2
	Total Operations	**61**	**66**	**61**	**66**	**56**	**61**	**93**	**98**
	MAINTENANCE								
WMMGMT	Manager Maintenance	0	1	0	1	0	1	1	1
WMADM	Administrative Assistant	2	3	2	3	2	3	3	4
WMMGMT	Electrical Maintenance Supervisor	1	1	1	1	1	1	1	1
WM003B	Electrical Foreman	4	6	5	6	5	6	5	6
WM003B	Electricians	28	35	35	42	35	42	36	42
WMMGMT	Mechanical Maintenance Supervisor	1	1	1	1	1	1	1	1
WM003D	Mechanical Foreman	6	7	5	6	5	6	6	7
WM003D	Mechanics	45	49	40	45	40	45	45	49
WM003D	Welding Foreman	1	1	1	1	1	1	1	1
WM003D	Welders	8	10	6	10	6	10	10	12

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
WMMGMT	I&C Supervisor	0	1	0	1	0	1	1	1
WM003C	I&C Foreman	4	4	4	4	4	4	5	5
WM003C	I&C Technicians	27	27	27	27	27	27	35	35
WM003C	Control Operations Supervisor	0	1	0	1	0	1	1	0
WM003C	System Protection Technician	3	3	3	3	3	3	3	3
WMMGMT	Maintenance Support Supervisor	0	1	0	1	0	1	0	1
WM001B	Maintenance Coordinator	0	1	0	1	0	1	0	1
WM001B	Maintenance Outage Scheduling/Special Projects	0	2	0	2	0	2	0	2
WM001B	Maintenance Human Performance Coordinator	0	1	0	1	0	1	0	1
WM003A	Quality Inspectors	3	4	3	4	3	5	3	4
WM003E	Maintenance/Procurement Interface	1	2	1	2	1	2	1	2
	Total Maintenance	**134**	**161**	**134**	**163**	**134**	**164**	**158**	**179**
	ENGINEERING								
CMMGMT	Engineering Manager	0	1	0	1	0	1	0	1
CMADM	Administrative Assistant	1	3	1	3	1	3	1	3
ERMGMT	Systems Engineering Supervisor	3	4	3	4	3	4	4	4
ER001	Systems Engineers	15	19	14	18	14	18	18	22
CM001B	Reactor Engineers	3	3	3	3	3	3	3	3
ERMGMT	ISI/NDE Supervisor	0	1	0	1	0	1	0	1
ER002	NDE Technician	1	2	1	1	1	1	1	2
ER001	ISI Engineers	2	4	2	2	2	2	2	3

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
ERMGMT	Component Engineering Supervisor	1	1	1	1	1	1	1	1
ER001	Component Engineers	4	8	4	8	4	8	8	10
ER001	Reliability Engineers	2	4	2	4	2	4	3	4
ER001	Predictive Maintenance Technicians	2	2	2	2	2	2	2	2
CMMGMT	Site Civil/Mechanical Design Supervisor	1	1	1	1	1	1	1	1
CM001A	Mechanical Design Engineer	2	3	2	3	2	3	2	3
CM001A	Civil Design Engineer	2	2	2	2	2	2	2	2
CMMGMT	Site I&C and Electrical Design Supervisor	1	1	1	1	1	1	1	1
CM001A	Electrical Design Engineers	2	3	2	3	2	3	2	3
CM001A	I&C Design Engineers	2	2	2	2	2	2	2	2
CMMGMT	Engineering Work Management Supervisor	0	1	0	1	0	1	0	1
CM001A	Design Control Engineer	0	1	0	1	0	1	0	1
CM001A	Draftsman	1	2	1	2	1	2	1	2
CMADM	Administrative Assistant	1	1	1	1	1	1	1	1
CM001A	Schedule/Cost Engineer	0	1	0	1	0	1	0	1
SSMGMT	Records Supervisor	0	1	0	1	0	1	0	1
SS003	Records Clerks	3	5	3	5	3	5	3	5
	Total Engineering	49	76	48	72	48	72	58	80
	OUTAGE AND PLANNING								
WMMGMT	Outage and Planning Manager	0	1	0	1	0	1	0	1
WMADM	Administrative Assistant	1	2	1	2	1	2	1	2
WMMGMT	Nuclear Scheduling Supervisor	0	1	0	1	0	1	0	1

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
WM002B	Work Week Manager (non-supv)	0	1	0	1	0	1	0	1
WM002B	Electrical Scheduler	1	1	1	1	1	1	1	1
WM002B	Mechanical Scheduler	2	2	2	2	2	2	2	2
WM002B	I&C Scheduler	1	1	1	1	1	1	1	1
WMMGMT	Nuclear Planning Supervisor	1	1	1	1	1	1	1	1
WM002A	Electrical Planner	1	2	1	2	1	2	2	2
WM002A	Mechanical Planner	2	2	2	2	2	2	2	2
WM002A	PM Planner	1	1	1	1	1	1	1	1
WM002A	I&C Planner	1	1	1	1	1	1	1	1
WM001A	Unit Outage Coordinator	1	1	1	1	1	1	1	1
WM001A	Outage Planner	1	1	1	1	1	1	1	1
WM003D	Supervisor Turbine Maintenance	0	1	0	1	0	1	0	1
WM003D	Turbine Equipment Specialist	1	1	1	1	1	1	1	1
WM003D	Turbine Generator Engineer	1	1	1	1	1	1	1	1
WM002A	Turbine Planner	0	1	0	1	0	1	0	1
	Total Outage and Planning	15	22	15	22	15	22	16	22
	MAJOR MODIFICATION AND SITE SUPPORT								
WMMGMT	Nuclear Support Services Manager	0	1	0	1	0	1	0	1
WMADM	Administrative Assistant	1	2	1	2	1	2	1	2
WMMGMT	Construction Engineering Supervisor	0	1	0	1	0	1	0	1
WM003A	Quality Inspectors	2	2	2	2	2	2	2	2
WM003E	Construction Engineers	1	2	1	2	1	2	1	2

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
WM001B	Construction Specialists	1	2	1	2	1	2	1	2
WMMGMT	Electrical Construction Supervisor	0	0.5	0	0.5	0	0.5	0	0.5
WM001B	Construction Specialists	1	2	1	2	1	2	1	2
WMMGMT	Civil/Mechanical Construction Supervisor	0	0.5	0	0.5	0	0.5	0	0.5
WM001B	Construction Specialists	1	2	1	2	1	2	1	2
WM003E	Scaffolding/Insulation Support	2	4	2	4	2	4	2	4
WM003E	Project Controls Supervisor	0	1	0	1	0	1	0	1
WM003E	Controls Specialists	1	2	1	2	1	2	1	2
SS005	Facilities Support Supervisor	0	1	0	1	0	1	0	1
SS005	Vehicle Management	0	2	0	2	0	2	0	2
SS005	Construction Equipment Management	0	2	0	2	0	2	0	2
SS005	Labor Supervisor	2	3	2	3	2	3	3	3
SS005	Labor Support	10	15	10	15	10	15	15	20
WM001B	Construction Craft and Supervision								
	Total Major Modification	**22**	**45**	**22**	**45**	**22**	**45**	**28**	**50**
	ORGANIZATIONAL EFFECTIVENESS								
LPMGMT	Organizational Effectiveness Manager	0	1	0	1	0	1	0	1
LPADM	Administrative Assistant	1	1	1	1	1	1	1	1
LPMGMT	Licensing Supervisor	0	1	0	1	0	1	0	1
LP004	Licensing Engineers	3	4	3	4	3	4	3	4
LPMGMT	Human Performance Supervisor	0	0	0	0	0	0	0	0

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
LP002	Human Performance Coordinator	0	0.5	0	0.5	0	0.5	0	0.5
LP002	Self-Assessment Coordinator	0	0.5	0	0.5	0	0.5	0	0.5
LP002	OE Coordinator	0	0.5	0	0.5	0	0.5	0	0.5
LP002	Benchmarking Coordinator	0	0.5	0	0.5	0	0.5	0	0.5
LPMGMT	Nuclear Safety Supervisor	0	1	0	1	0	1	0	1
LP002	Corrective Action Coordinator	0	1	0	1	0	1	0	1
OP001B	Shift Technical Advisors (on-shift)	5	5	5	5	5	5	5	5
OP001B	STA Office Staff (off-shift)	3	3	3	3	3	3	3	3
LP002	Root Cause Coordinator	0	1	0	1	0	1	0	1
	Total Organizational Effectiveness	**12**	**20**	**12**	**20**	**12**	**20**	**12**	**20**
	NUCLEAR OVERSIGHT								
LPMGMT	Nuclear Oversight Manager	0	1	0	1	0	1	0	1
LPADM	Administrative Assistant	0	1	0	1	0	1	0	1
LP002	Nuclear Quality Specialists	2	4	2	4	2	4	2	4
LP002	Nuclear Specialists	2	2	2	2	2	2	2	2
	Total Oversight	**4**	**8**	**4**	**8**	**4**	**8**	**4**	**8**
	RADIATION PROTECTION								
WMMGMT	Radiation Protection Manager	0	1	0	1	0	1	0	1
WMADM	Administrative Assistant	2	3	2	3	2	3	2	3
WMMGMT	Health Physics Operations Supervisor (on-shift)	0	1	0	1	0	1	0	1
WM007	HP Coordinator	0	1	0	1	0	1	0	1
WM007	ALARA Coordinator	0	1	0	1	0	1	0	1

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
WM007	ALARA Technicians	2	2	2	2	2	2	2	2
WM008	HP Shift Supervisor	5	5	5	5	5	5	5	5
WM008	Shift HP Technicians	17	18	17	18	17	18	17	18
WM008	Decon Supervisor	0	2	0	2	0	2	0	2
WM008	Decon Technicians	6	10	6	10	6	10	6	10
WMMGMT	HP Technical Support Supervisor	0	1	0	1	0	1	0	1
WM007	Health Physicist	0	1	0	1	0	1	0	1
WM007	Rad Analysis and Material Control Supervisor	0	0.5	0	0.5	0	0.5	0	0.5
WM007	Count Room Technician	2	2	2	2	2	2	2	2
WM007	Radwaste Technician	2	2	2	2	2	2	2	2
WM007	Exposure Control & Instrumentation Supervisor	0	0.5	0	0.5	0	0.5	0	0.5
WM007	Instrumentation Technician	1	1	1	1	1	1	1	1
WM007	HP Specialists	1	2	1	2	1	2	1	2
OPMGMT	Chemistry Supervisor	0	1	0	1	0	1	0	1
OP003	Asst. Chemistry Supervisor	1	0	1	0	1	0	1	0
OP003	Chemistry Technicians	12	12	12	12	14	14	14	14
	Total RP and Chemistry	**51**	**67**	**51**	**67**	**53**	**69**	**53**	**69**
	TRAINING								
TMGMT	Nuclear Training Manager	0	1	0	1	0	1	0	1
TADM	Administrative Assistant	1	1	3	3	3	3	3	3
TMGMT	Ops Initial Training Supervisor	0	1	0	1	0	1	0	1
T001	ESP (Engineering) Instructors	0	1	0	1	0	1	0	1
T001	License Class Instructors	2	2	2	2	2	2	2	2
T001	STA Initial Instructors	1	2	1	2	1	2	1	2

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
T001	Simulator Technician	1	2	1	2	1	2	1	2
TMGMT	Ops Continuing Training Supervisor	0	1	0	1	0	1	0	1
T001	Licensed Operator Re-Qualification Program Instructor	2	2	2	2	2	2	2	2
T001	Shift Supervisor Instructor	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
T001	STA Continuing Instructor	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
T001	Non-Licensed Operator Instructor	1	1	1	1	1	1	1	1
TMGMT	Maintenance/Rad Protection Training Supervisor	0	1	0	1	0	1	0	1
T001	HP Instructor	0	1	0	1	0	1	0	1
T001	Chemistry Instructor	0	1	0	1	0	1	0	1
T001	New Employee Training Instructor	0	0.5	0	0.5	0	0.5	0	0.5
T001	Electrical Instructor	1	1	1	1	1	1	1	1
T001	Mechanical Instructor	1	1	1	1	1	1	1	1
T001	I&C Instructor	1	1	1	1	1	1	1	1
T001	Nonaccredited Training Instructor	0	0.5	0	0.5	0	0.5	0	0.5
	Total Training	**12**	**22**	**14**	**24**	**14**	**24**	**14**	**24**
	SECURITY								
LPMGMT	Nuclear Protection Services Manager	0	1	0	1	0	1	0	1
LPADM	Administrative Assistant	1	2	1	2	1	2	1	2
LPMGMT	Security Operations Supervisor (on-shift)	0	1	0	1	0	1	0	1

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
LPMGMT	Security Shift Supervisor	5	9	5	9	5	9	5	9
LP001	Security Officers	20	90	20	90	20	90	20	90
LP001	Technical Security Coordinator	0	1	0	1	0	1	0	1
LP001	Security Training Coordinator	0	1	0	1	0	1	0	1
LP001	Security Field Team Leader	2	7	2	7	2	7	2	7
LP003	Fitness-For-Duty Coordinator	0	1	0	1	0	1	0	1
LPMGMT	Safety and Loss Prevention Supervisor	0	1	0	1	0	1	0	1
LP003	Loss Prevention Technicians	1	2	1	2	1	2	1	2
OP002	Environmental	0	1	0	1	0	1	0	1
LP003	Nurse/Medical	0	1	0	1	0	1	0	1
LP005	Site Emergency Planning Specialist	1	2	1	2	1	2	1	2
	Total Security	**30**	**120**	**30**	**120**	**30**	**120**	**30**	**120**
	SUPPLY CHAIN MANAGEMENT								
MSMGMT	SCM Manager	0	1	0	1	0	1	0	1
MSADM	Administrative Assistant	0	1	0	1	0	1	0	1
MSMGMT	Warehouse Supervisor	1	1	1	1	1	1	1	1
MS001	Storekeepers	4	12	4	12	4	12	4	12
MSMGMT	Receiving/Inspection Supervisor	0	1	0	1	0	1	0	1
MS001	Storekeepers	2	4	2	4	2	4	2	4
MS002B	Material Verification Specialist	0	1	0	1	0	1	0	1
MS002A	Emergent Sourcing	0	2	0	2	0	2	0	2
MS001	Supply Management Coordinator	0	1	0	1	0	1	0	1
	Total SCM	**7**	**24**	**7**	**24**	**7**	**24**	**7**	**24**

Table 3-2. Staffing By Title

EUCG	Position	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
	TELECOMMUNICATIONS								
SS001	IT Business Area Manager	0	1	0	1	0	1	0	1
SS001	Business Analyst	2	2	2	2	2	2	2	2
SS001	Local Area Network Field Services	2	3	2	3	2	3	2	3
SS001	Telecommunications Services - Telephone	1	2	1	2	1	2	1	2
SS001	Telecommunications Services - Servers	1	1	1	1	1	1	1	1
	Total IT and Telecommunications	**6**	**9**	**6**	**9**	**6**	**9**	**6**	**9**
	TOTAL PLANT STAFF (ONSITE)	**405**	**649**	**406**	**649**	**403**	**647**	**481**	**712**

Table 3-3. EUCG Staffing

EUCG Account	Description	Current NAPS Staff			ABWR - Single Unit Addition to Existing Site			ABWR - Single Unit New Site			ESBWR - Single Unit Addition to Existing Site			ESBWR - Single Unit New Site			AP1000 - Single Unit Addition to Existing Site			AP1000 - Single Unit New Site			ACR-700 - Twin Unit Addition to Existing Site			ACR-700 - Twin Unit New Site		
		Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr
CM001A	Design/Mods/Technical Engr	25	44		9	8		14	8		9	8		14	8		9	8		14	8		9	8		14	8	
CM001B	Nuclear Fuels/Reactor Engr	3	18		3	9		3	9		3	9		3	9		3	9		3	9		3	9		3	9	
CM002A	Computer Engr	2				2			2			2			2			2			2			2			2	
CM002B	Project Management		19			2			2			2			2			2			2			2			2	
CMADM	Administrative Support	4	8		2	2		4	2		2	2		4	2		2	2		4	2		2	2		4	2	
CMMGMT	Configuration Management (Mgmt)	5	15		2	4		4	4		2	4		4	4		2	4		4	4		2	4		4	4	
CMTOT	**Total - Configuration Management**	**39**	**104**	**0**	**16**	**27**		**25**	**27**		**16**	**27**		**25**	**27**		**16**	**27**		**25**	**27**		**16**	**27**		**25**	**27**	
ER001	Plant Engineering	59			25	0		37	0		24	0		34	0		24	0		34	0		33	0		41	0	
ER002	Nondestructive Exams (NDE)	3			1	0		2	0		1	0		1	0		1	0		1	0		1	0		2	0	
ERADM	Administrative Support	2				0			0			0			0			0			0			0			0	
ERMGMT	Equipment Reliability Management	6			4	0		6	0		4	0		6	0		4	0		6	0		5	0		6	0	
ERTOT	**Total - Equipment Reliability**	**70**	**0**	**0**	**30**	**0**		**45**	**0**		**29**	**0**		**41**	**0**		**29**	**0**		**41**	**0**		**39**	**0**		**49**	**0**	
LP001	Security	103	2		22	1		99	2		22	1		99	2		22	1		99	2		22	1		99	2	
LP002	QA and Corrective Action Program	10	4		4	0		10	0		4	0		10	0		4	0		10	0		4	0		10	0	
LP003	Safety/Health	20	1		1	0		4	0		1	0		4	0		1	0		4	0		1	0		4	0	
LP004	Licensing	5	6		3	2		4	2		3	2		4	2		3	2		4	2		3	2		4	2	
LP005	Emergency Preparedness	2	2		1	1		2	2		1	1		2	2		1	1		2	2		1	1		2	2	
LP006	Fire Protection																											
LPADM	Administrative Support	5	3		2	0		4	0		2	0		4	0		2	0		4	0		2	0		4	0	
LPMGMT	Loss Prevention Management	15	4		5	1		16	2		5	0		16	1		5	0		16	1		5	0		16	1	
LPTOT	**Total - Loss Prevention**	**160**	**22**	**0**	**38**	**5**		**139**	**8**		**38**	**4**		**139**	**7**		**38**	**4**		**139**	**7**		**38**	**4**		**139**	**7**	
MS001	Materials Mgmt/Warehouse	29	7		6	2		17	2		6	2		17	2		6	2		17	2		6	2		17	2	
MS002A	Contracts and Purchasing				0	0		2	0		0	0		2	0		0	0		2	0		0	0		2	0	
MS002B	Procurement Engineering				0	0		1	0		0	0		1	0		0	0		1	0		0	0		1	0	
MSADM	Administrative Support				0	0		1	0		0	0		1	0		0	0		1	0		0	0		1	0	
MSMGMT	Materials and Services Management	3	4		1	0		3	0		1	0		3	0		1	0		3	0		1	0		3	0	
MSTOT	**Total - Materials and Services**	**32**	**11**	**0**	**7**	**2**		**24**	**2**		**7**	**2**		**24**	**2**		**7**	**2**		**24**	**2**		**7**	**2**		**24**	**2**	
OP001A	Operations	48			47	0		47	0		47	0		47	0		42	0		42	0		67	0		67	0	
OP001B	Operations Support	69			10	0		14	0		10	0		14	0		10	0		14	0		22	0		26	0	
OP002	Environmental	1	5		0	0		1	0		0	0		1	0		0	0		1	0		0	0		1	0	
OP003	Chemistry	20			13	0		12	0		13	0		12	0		15	0		14	0		15	0		14	0	
OPADM	Administrative Support	3	1		4	0		5	0		4	0		5	0		4	0		5	0		4	0		5	0	
OPMGMT	Operations Management	17	2		8	0		9	0		8	0		9	0		8	0		9	0		8	0		9	0	
OPTOT	**Total -Operate Plant**	**158**	**8**	**0**	**82**	**0**		**88**	**0**		**82**	**0**		**88**	**0**		**79**	**0**		**85**	**0**		**116**	**0**		**122**	**0**	
SS001	Information Services	14	13		6	4		9	8		6	4		9	8		6	4		9	8		6	4		9	8	
SS002	Financial Services	3	4		1			3			1			3			1			3			1			3		
SS003	Document Control/Records	10			3			5	3		3			5	3		3			5	3		3			5	3	
SS004	Human Resources	2	1		1	0		2	1		1	0		2	1		1	0		2	1		1	0		1	1	
SS005	Facilities	46			12	0		23	0		12	0		23	0		12	0		23	0		18	0		28	0	
SS006	Communications	2				0			0			0			0			0			0			0			0	
SSADM	Administrative Support	4	2		0	1		1	2		0	1		1	2		0	1		1	2		0	1		0	2	

Table 3-3. EUCG Staffing

EUCG Account	Description	Current NAPS Staff			ABWR - Single Unit Addition to Existing Site			ABWR - Single Unit New Site			ESBWR - Single Unit Addition to Existing Site			ESBWR - Single Unit New Site			AP1000 - Single Unit Addition to Existing Site			AP1000 - Single Unit New Site			ACR-700 - Twin Unit Addition to Existing Site			ACR-700 - Twin Unit New Site		
		Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr	Onsite	Offsite	Contr
SSASST	Management Assistance					0			0			0			0			0			0			0			0	
SSMGMT	Support Services Management	11	3		0	0		3	1		0	0		3	1		0	0		3	1		0	0		3	1	
SSTOT	**Total - Management and Support Svs**	**92**	**23**	**0**	**23**	**5**		**46**	**15**		**23**	**5**		**46**	**15**		**23**	**5**		**46**	**15**		**29**	**5**		**49**	**15**	
T001	Training	42	4		11	0		17	0		11	0		17	0		11	0		17	0		11	0		17	0	
TADM	Administrative Support	3			1	0		1	0		3	0		3	0		3	0		3	0		3	0		3	0	
TMGMT	Training Management	4	1		0	0		4	0		0	0		4	0		0	0		4	0		0	0		4	0	
TTOT	**Total - Training**	**49**	**5**	**0**	**12**	**0**		**22**	**0**		**14**	**0**		**24**	**0**		**14**	**0**		**24**	**0**		**14**	**0**		**24**	**0**	
WM001A	Outage Management	4			2	0		2	0		2	0		2	0		2	0		2	0		2	0		2	0	
WM001B	Maintenance/Construction Support	18			3	0		10	0		3	0		10	0		3	0		10	0		3	0		10	0	
WM002A	Planning	21			5	0		7	0		5	0		7	0		5	0		7	0		6	0		7	0	
WM002B	Scheduling	14			4	0		5	0		4	0		5	0		4	0		5	0		4	0		5	0	
WM003A	Quality Control				5	0		6	0		5	0		6	0		5	0		7	0		5	0		6	0	
WM003B	Electrical Maintenance	40			32	0		41	0		40	0		48	0		40	0		48	0		41	0		48	0	
WM003C	I&C Maintenance	39			34	0		35	0		34	0		35	0		34	0		35	0		44	0		43	0	
WM003D	Mechanical Maintenance	87			62	0		70	0		54	0		65	0		54	0		65	0		64	0		72	0	
WM003E	Maintenance/Construction Other				5	0		11	0		5	0		11	0		5	0		11	0		5	0		11	0	
WM007	RP - Support	10			8	0		13	0		8	0		13	0		8	0		13	0		8	0		13	0	
WM008	Radwaste and RP Direct	51			28	0		35	0		28	0		35	0		28	0		35	0		28	0		35	0	
WMADM	Administrative Support	13			6	0		10	0		6	0		10	0		6	0		10	0		7	0		11	0	
WMMGMT	Work Management (Mgmt)	34			3	0		14	0		3	0		14	0		3	0		14	0		5	0		14	0	
WMTOT	**Total - Work Management**	**331**	**0**	**0**	**197**	**0**		**259**	**0**	**0**	**197**	**0**		**261**	**0**		**197**	**0**		**262**	**0**		**222**	**0**		**277**	**0**	
OFFTOT	**Total - Officers/Executives**	**1**	**1**		**0**	**0**		**1**	**0**		**0**	**0**		**1**	**0**		**0**	**0**		**1**	**0**		**0**	**0**		**1**	**0**	
STAFFTOT	**Total - Staffing**	**932**	**174**	**0**	**405**	**39**		**649**	**52**		**406**	**38**		**649**	**51**		**403**	**38**		**647**	**51**		**481**	**38**		**710**	**51**	
	Total Onsite and Offsite Staff			1106			444			701			444			700			441			698			519			761

Table 3-4. 10 CFR 50.54(M) Minimum Requirements Per Shift for Onsite Staffing of Nuclear Power Units by Operators and Senior Operators Licensed Under 10 CFR Part 55 (Notes 1 and 2)

Number of Units Operating	Position	One Unit	Two Units		Three Units	
		One Control Room	One Control Room	Two Control Rooms	Two Control Rooms	Three Control Rooms
None	Senior Operator	1	1	1	1	1
	Operator	1	2	2	3	3
One	Senior Operator	2	2	2	2	2
	Operator	2	3	3	4	4
Two	Senior Operator	—	2	3	3 (Note 3)	3
	Operator	—	3	4	5 (Note 3)	5
Three	Senior Operator	—	—	—	3	4
	Operator	—	—	—	5	6

Notes:

1. Temporary deviations from the numbers required by this table shall be in accordance with criteria established in the unit’s technical specifications.
2. For the purpose of this table, a nuclear power unit is considered to be operating when it is in a mode other than cold shutdown or refueling as defined by the unit's technical specifications.
3. The number of required licensed personnel when the operating nuclear power units are controlled from a common control room is two senior operators and four operators.

Table 3-5. Shift Operations Staffing

Operations Per shift	Single/Add	Operations Per Shift	Twin Unit
ABWR		**ACR-700 (Note 3)**	
Shift Supervisor	1	Shift Supervisor	1
Reactor Operator (MCR)	2	Reactor Operator (MCR)	3
Senior Reactor Operator (MCR)	1	Senior Reactor Operator (MCR)	2
Non-Licensed Operator (Note 1)		Non-Licensed Operator (Note 1)	
Outside	1	Outside	2
Turbine/Auxiliary Building	1	Turbine/Auxiliary Building	1
Radwaste (Note 2)	2	Radwaste (Note 2)	2
Tagging/Other	2	Tagging/Other	3
Total Per Shift	10	Total Per Shift	14
ESBWR		Refueling Operations (Note 4)	
Shift Supervisor	1	Refueling Operators	2
Reactor Operator (MCR)	2	Non-Licensed Operator (Fuel Support)	2
Senior Reactor Operator (MCR)	1	Refueling Supervisor (Senior Reactor Operator)	1
Non-Licensed Operator (Note 1)		Refueling Maintenance Crew	2
Outside	1		
Turbine/Auxiliary Building	1		
Radwaste (Note 2)	2		
Tagging/Other	2		
Total Per Shift	10		
AP1000			
Shift Supervisor	1		
RO (MCR)	2		
SRO (MCR)	1		
Non-Licensed Operator (Note 1)			
Outside	1		
Turbine/Auxiliary Building	1		
Radwaste (Note 2)	1		
Tagging/Other	2		
Total Per Shift	9		

Notes:

1. At least 2 non-licensed operators shall be RO-qualified to allow for vacation/sick.
2. Radwaste operations are part time, requiring perhaps 4 hours per shift. Operators are available for other duties beyond this time.
3. ACR-700 is marketed as a twin unit design only.
4. Refueling operations will be performed on 2 shifts, 4 days per week, with maintenance performed on the 5th day.

Table 3-6. Plant Operational Staff Development During Construction

Position	Start Construction	Start of Preoperational Testing	Fuel Receipt	Fuel Load	Commercial Operation	36 Months Later (Staff Equilibrium)
	(percent of equilibrium staffing)					
Management	0	25	100	100	100	100
Operations						
Shift Operations	0	110	100	100	100	100
Operations Support	0	0	110	125	125	100
Maintenance						
Electrical Maintenance	0	25	100	100	110	100
Mechanical Maintenance	0	25	100	100	110	100
I&C	0	25	110	125	110	100
Control Operations	0	50	100	100	110	100
Maintenance Support	0	10	100	125	150	100
Engineering	0	25	150	150	125	100
Outage and Planning	0	0	50	90	110	100
Major Modification and Site Support	0	0	50	75	100	100
Organizational Effectiveness	0	0	75	90	100	100
Nuclear Oversight	0	0	100	110	110	100
Radiation Protection						
Health Physics Operations	0	0	50	90	110	100
HP Support	0	0	90	125	125	100
Chemistry	0	50	90	125	110	100
Training						
Ops Initial Training	0	300	200	150	125	100
Ops Continuing Training	0	100	125	125	100	100
Maintenance/Rad Protection Training	0	10	100	100	100	100
Security						
Nuclear Protection Services	0	0	30	100	125	100
Safety and Loss Prevention	0	25	75	100	100	100
Site Emergency Planning Specialist	0	0	100	100	100	100
Supply Chain Management	0	0	80	110	100	100
Telecommunications	0	0	75	150	125	100

Table 3-7. O&M Cost Calculation

Cost Component	ABWR Additional Unit	ABWR Greenfield Single Unit	ESBWR Additional Unit	ESBWR Greenfield Single Unit	AP1000 Additional Unit	AP1000 Greenfield Single Unit	ACR-700 Additional Twin Unit	ACR-700 Greenfield Twin Unit
Fuel Cycle (months)	24	24	24	24	18	18	36	36
Outage Duration (days)	25	25	25	25	17	17	21	21
Forced Outage Rate	4%	4%	4%	4%	4%	4%	4%	4%
Capacity Factor (Note 1)	93%	93%	93%	93%	93%	93%	94%	94%
MWe (gross)	1422	1422	1390	1390	1210	1210	1506	1506
MWe (net)	1371	1371	1340	1340	1150	1150	1406	1406
Total Onsite and Offsite Staff	444	701	444	700	441	698	519	761
Site Staff Cost (salaries)	$23,033,504	$36,368,384	$22,908,704	$36,216,544	$22,825,504	$36,191,584	$27,278,784	$39,752,544
Offsite Staff Cost (salaries)	$2,768,480	$3,596,320	$2,697,760	$3,525,600	$2,697,760	$3,525,600	$2,697,760	$3,525,600
Staff Overtime (Note 2) (7.5%)	$1,935,149	$2,997,353	$1,920,485	$2,980,661	$1,914,245	$2,978,789	$2,248,241	$3,245,861
Staff Retirement and Benefits (38.5%)	$9,933,764	$15,386,411	$9,858,489	$15,300,725	$9,826,457	$15,291,116	$11,540,969	$16,662,085
Staff Bonus and Incentives (8%)	$2,064,159	$3,197,176	$2,048,517	$3,179,372	$2,041,861	$3,177,375	$2,398,124	$3,462,252
Staff Payroll Tax (7.7%)	$2,135,759	$3,308,078	$2,119,575	$3,289,656	$2,112,688	$3,287,590	$2,481,308	$3,582,348
NRC Fees (Note 3)	$4,071,000	$4,071,000	$4,071,000	$4,071,000	$4,071,000	$4,071,000	$8,142,000	$8,142,000
INPO Fees (Note 4)	$176,586	$706,344	$176,586	$706,344	$176,586	$706,344	$353,172	$882,930
NEI Fees (Note 5)	$357,647	$357,647	$349,599	$349,599	$304,327	$304,327	$378,774	$378,774
Other Fees (EP, etc.)	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000
Property Taxes								
Insurance (Note 6)	$1,521,000	$5,236,000	$1,457,000	$5,014,000	$1,362,000	$4,683,000	$2,251,000	$5,620,000
Materials, Supplies, Services & Upgrades	$15,000,000	$15,000,000	$15,000,000	$15,000,000	$15,000,000	$15,000,000	$15,000,000	$15,000,000
Administrative & General Cost Overhead	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000
Depreciation Expense Site Service (Outage Electrical) (Note 7)	$82,475	$82,475	$82,475	$82,475	$78,898	$78,898	$65,612	$65,612
Routine O&M Cost	$69,079,523	$96,307,189	$68,690,190	$95,715,976	$68,411,326	$95,295,623	$80,835,745	$106,320,007
Outage O&M Cost Per Unit (Note 8)	$11,021,638	$11,021,638	$10,976,585	$10,976,585	$12,014,975	$12,014,975	$10,913,243	$10,913,243
Total O&M Operating Cost	$74,590,342	$101,818,008	$74,178,482	$101,204,268	$76,421,310	$103,305,606	$88,111,240	$113,595,502
Cost Per Net MWe	$6.71	$9.16	$6.83	$9.32	$8.17	$11.04	$7.61	$9.81

Notes:

1. Capacity factor is a multi-year rolling average based on fuel cycle. The value here is the 12-month average capacity factor.
2. Assumes 5% overtime hours worked at time and a half pay.
3. Base fee $3,251,000 per reactor plus an estimated $320,000 for inspection, NRR, and operator licensing fees per reactor.
4. Based on $529,758 per site plus $176,586 per unit.
5. 2003 fee: $251.51 per gross MWe.
6. Insurance rates are electric power dependent.
7. Cost of replacement power for outages. Normalized to yearly values. Based on $35/MWe and 4 MWe consumption, and 90% of overall outage time.
8. Cost listed is for each outage. Total O&M Cost uses only the average annual cost.

Table 3-8. Outage Cost Estimate

Cost Component	1200 MWe Base Plant	ABWR	ESBWR	AP1000	ACR-700 (per unit)	Comments
Outage Material	$3,000,000	$3,321,638	$3,276,585	$3,014,975	$2,268,243	Based on the ratio of the plant electrical output to the reference plant raised to an exponent of 0.6 (Note 1).
Refueling Costs	2,500,000	2,500,000	2,500,000	2,500,000	0	ACR-700 is refueled on-power.
Labor and Services	6,500,000	5,200,000	5,200,000	6,500,000	8,645,000	Base plant costs include allowance for S/G inspection. This was subtracted for the BWR plants and additional allowance added for ACR-700 calandria tube inspections.
Total Outage O&M Cost	**$12,000,000**	**$11,021,638**	**$10,976,585**	**$12,014,975**	**$10,913,243**	

Notes:

1. Based on a reactor vendor study of material costs and unit size.
2. ACR-700 labor costs reduced by 12% due to smaller equipment size and increased by 7% to account for the longer operating cycle.

4. Decommissioning Costs and Funding Requirements for Advanced Reactor Designs

4.1 Introduction

Decommissioning, in the broadest sense, is the process by which the liabilities associated with a retired nuclear asset are ultimately retired, secured, or resolved. While decommissioning is typically associated with the activities related to the removal of radioactivity, the process can be much more extensive and involve the removal of nonradioactive material, program management, engineering and planning, and the interfacing with numerous regulatory authorities, public agencies, and other policy-setting organizations.

The ultimate objective of the decommissioning process is to reduce the inventory of contaminated and activated material to levels consistent with release criteria, so that the operating license can be terminated. Approved alternatives typically include immediate or prompt remediation, an option whereby the facility is placed into safe-storage with remediation deferred, or a more aggressive encapsulation or entombment of the facility for a long-term or indefinite deferral of remediation.

The cost analysis described in the following sections is based on the prompt decommissioning alterative, or DECON, as defined by the NRC. In this alternative, decommissioning is undertaken shortly after the facility ceases operation. This course of action has the advantage of reducing or eliminating the liability in the shortest time. However, successful execution depends on several factors including sufficient financial resources, the ability to remove or isolate the spent fuel generated during operations, and the capability to dispose of the waste generated in the remediation of the facility. The DECON alternative is also the basis for the NRC funding regulations and the use of the DECON alternative for the advanced reactor designs facilitates the comparison with the agency’s own estimates and financial provisions.

4.2 Background

This report presents estimates of the costs to decommission the advanced reactor designs following a scheduled cessation of plant operations. The analysis, prepared by TLG Services, Inc. (TLG), an Entergy company, is designed to provide potential owners with sufficient information to assess their financial obligations as they pertain to the eventual decommissioning of a nuclear unit. It is not a detailed engineering document, but a financial analysis prepared in advance of the detailed engineering that will be required to carry out the decommissioning.

4.2.1 Regulations and Regulatory Guidance

The NRC's financial requirements for decommissioning are delineated in 10 CFR 50.75. This section establishes the requirements for providing reasonable assurance that adequate funds for performing decommissioning are available at the end of plant operations. Two factors need to be considered in demonstrating assurance: the amount of funds needed, and the method(s) to be used to provide financial assurance.

As discussed later, the NRC requires that licensees establish an initial certification amount or NRC minimum funding amount for decommissioning at the operating license stage. This initial value is adjusted over the operating life, as necessary, using the prescribed escalation formula as delineated in §50.75(c)(2). The licensee has the option of using the NRC's minimum certification amount or a site-specific estimate as the basis for funding; however, the site-specific estimate must at least be equal to the minimum amount identified in §50.75(c).

4.2.2 Regulatory History

The NRC provided initial decommissioning requirements in its rule "General Requirements for Decommissioning Nuclear Facilities," issued in June 1988. This rule set forth financial criteria for decommissioning licensed nuclear power facilities and addressed decommissioning planning needs, timing, funding methods, and environmental review requirements. The intent of the rule was to ensure that decommissioning would be accomplished in a safe and timely manner and that adequate funds would be available for this purpose. Subsequent to the rule, the NRC issued Regulatory Guide 1.159, "Assuring the Availability of Funds for Decommissioning Nuclear Reactors," which provided additional guidance to the licensees of nuclear facilities on the financial methods acceptable to the NRC staff for complying with the requirements of the rule. The regulatory guide addressed the funding requirements and provided guidance on the content and form of the financial assurance mechanisms indicated in the rule.

4.2.3 Decommissioning Alternatives

The 1988 rule identified three decommissioning alternatives as being acceptable to the NRC: DECON, SAFSTOR, and ENTOMB, defined as follows:

- DECON is the method in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for use shortly after cessation of operations.
- SAFSTOR is the method in which the nuclear facility is placed and maintained in a condition that allows the nuclear facility to be safely stored and subsequently decontaminated (deferred decontamination) to levels that permit release of the property.
- ENTOMB is the method in which radioactive contaminants are encased in a structurally long-lived material, such as concrete. The entombed structure is appropriately maintained,

> and continued surveillance is carried out until the radioactivity decays to a level permitting release of the property.

The rule also placed limits on the time allowed to complete the decommissioning process. For SAFSTOR, the process is restricted in overall duration to 60 years, unless it can be shown that a longer duration is necessary to protect public health and safety. The guidelines for ENTOMB are similar, providing the NRC with both sufficient leverage and flexibility to ensure that these deferred options are only used in situations where it is reasonable and consistent with the definition of decommissioning. At the conclusion of a 60-year dormancy period (or longer for ENTOMB if the NRC approves such a case), the site would still require significant remediation to meet the unrestricted release limits for license termination.

The ENTOMB alternative has not been viewed as a viable option for power reactors due to the significant time required to isolate the long-lived radionuclides for decay to permissible levels. However, with recent rulemaking permitting the controlled release of a site, the NRC has re-evaluated this alternative. The resulting feasibility study, based upon an assessment by Pacific Northwest National Laboratory, concluded that the method did have conditional merit for some, if not most reactors. The staff also found that additional rulemaking would be needed before this option could be treated as a generic alternative. The NRC had considered rulemaking to alter the 60-year time for completing decommissioning and to clarify the use of engineered barriers for reactor entombments. However, the staff has recently recommended that rulemaking be deferred, based upon several factors, for example, no licensee has committed to pursuing the entombment option, the unresolved issues associated with the disposition of Greater-Than-Class C material (GTCC), and the NRC's current priorities, at least until after the additional research studies are complete. The Commission has concurred with the staff's recommendation.

In 1996, the NRC published revisions to the general requirements for decommissioning nuclear power plants. When the decommissioning regulations were adopted in 1988, it was assumed that the majority of licensees would decommission at the end of the facility's operating licensed life. Since that time, several licensees permanently and prematurely ceased operations. Exemptions from certain operating requirements were required once the reactor was defueled to facilitate the decommissioning. Each case was handled individually, without clearly defined generic requirements. The NRC amended the decommissioning regulations in 1996 to clarify ambiguities and codify procedures and terminology as a means of enhancing efficiency and uniformity in the decommissioning process. The new amendments allow for greater public participation and better define the transition process from operations to decommissioning.

4.2.4 Regulatory Process

Under the revised regulations, licensees will submit written certification to the NRC within 30 days after the decision to cease operations. Certification will also be required once the fuel is permanently removed from the reactor vessel. Submittal of these notices will entitle the licensee to a fee reduction and eliminate the obligation to follow certain requirements needed only during operation of the reactor. Within two years of submitting notice of permanent cessation of operations, the licensee is required to submit a Post-Shutdown Decommissioning Activities Report (PSDAR) to the NRC. The PSDAR describes the planned decommissioning activities, the associated sequence and schedule, and an estimate of expected costs. Before completing decommissioning, the licensee is required to submit an application to the NRC to terminate the license, which will include a license termination plan (LTP). The LTP contains a final site characterization, dose assessment, identification of the remaining remediation activities and supporting plan, and final survey plan. Submitted as a supplement to the licensee's final safety analysis report (FSAR) or as an equivalent document, it is a requirement for license termination and site release.

4.2.5 Specific Regulations

There are three major areas of regulation that affect the process by which a nuclear unit is decommissioned. The first two establish the requirements for waste management and the third, the method by which the decommissioning process can be completed.

4.2.5.1 Nuclear Waste Policy Acts

Congress passed the Nuclear Waste Policy Act (NWPA) in 1982, assigning the responsibility for disposal of the spent nuclear fuel created by the commercial nuclear generating plants to the U.S. DOE. Two permanent disposal facilities and an interim storage facility were envisioned. To recover the cost, the legislation created a nuclear waste fund through which money is collected from the sale of electricity generated by the power plants.

After pursuing a national site selection process, the NWPA was amended in 1987 to designate Yucca Mountain, Nevada, as the only site to be evaluated for geologic disposal of high-level waste. With several announced delays, the facility is not expected to begin operations until 2010, at the earliest and the DOE has no plans to receive spent fuel from the commercial reactors until the repository is operational. Once operational, fuel acceptance will be prioritized and spent fuel assemblies will need to meet certain acceptance criteria, including heat output. These conditions will require that the fuel discharged upon the cessation of operations be actively cooled and stored for a minimum period at the generating site(s) before transfer (five years as defined in 10 CFR 961 for standard fuel). As such, the NRC requires that licensees establish a program to manage and provide funding for the management of all irradiated fuel at the reactor until title of the fuel is transferred to the Secretary of Energy, pursuant to 10 CFR 50.54(bb). This funding requirement is fulfilled through inclusion of certain cost elements in the decommissioning estimates, for example, associated with the isolation and continued operation of the spent fuel pool.

4.2.5.2 Low-Level Radioactive Waste Policy Acts

The contaminated and activated material generated in the decontamination and dismantling of a commercial nuclear reactor is classified as low-level (radioactive) waste, although not all of the material is suitable for "shallow-land" disposal. Congress passed the "Low-Level Radioactive Waste Policy Act" in 1980, declaring the states as being ultimately responsible for the disposition of low-level radioactive waste generated within their own borders. The federal law encouraged the formation of regional groups or compacts to implement this objective safely, efficiently, and economically, and set a target date of 1986 for implementation. After little progress, the "Low-Level Radioactive Waste Policy Amendments Act of 1985," extended the implementation schedule, with specific milestones and stiff sanctions for noncompliance. However, to date, no new compact facilities have been successfully sited, licensed, and constructed.

Waste generators are currently able to access facilities in Barnwell, South Carolina and in Clive, Utah for the controlled disposal of radioactive waste. However, in June 2000, South Carolina formally joined with Connecticut and New Jersey to form the Atlantic Compact. The legislation allows South Carolina to gradually limit access to the Barnwell facility, with only Atlantic Compact members having access to the facility after mid-year 2008. While it is reasonable to assume that additional disposal capacity will be required to support reactor decommissioning in the future, particularly for the isolation of the more highly radioactive material that is not suitable for disposal elsewhere, for estimating purposes and as a proxy for future disposal facilities, waste disposal costs are generated using available pricing schedules for the currently operating facilities, that is, at Barnwell and at Envirocare’s facility in Utah.

4.2.5.3 Radiological Criteria for License Termination

In 1997, the NRC published Subpart E, "Radiological Criteria for License Termination," amending 10 CFR 20. This subpart provides radiological criteria for releasing a facility for unrestricted use. The regulation states that the site can be released for unrestricted use if radioactivity levels are such that the average member of a critical group would not receive a total effective dose equivalent in excess of 25 millirem per year, and provided that residual radioactivity has been reduced to levels that are ALARA. The decommissioning estimates for the advanced reactor designs assume that the site will be remediated to a residual level consistent with the NRC-prescribed level.

It should be noted that the NRC and the Environmental Protection Agency (EPA) differ on the amount of residual radioactivity considered acceptable in site remediation. The EPA has two limits that apply to radioactive materials. An EPA limit of 15 millirem per year is derived from criteria established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund). An additional limit of 4 millirem per year, as defined in 40 CFR 141.16, is applied to drinking water.

On October 9, 2002, the NRC signed an agreement with the EPA on the radiological decommissioning and decontamination of NRC-licensed sites. The Memorandum of Understanding (MOU) provides that EPA will defer exercise of authority under CERCLA for the majority of facilities decommissioned under NRC authority. The MOU also includes provisions for NRC and EPA consultation for certain sites when, at the time of license termination, (1) groundwater contamination exceeds EPA-permitted levels; (2) NRC contemplates restricted release of the site; and/or (3) residual radioactive soil concentrations exceed levels defined in the MOU.

The MOU does not impose any new requirements on NRC licensees and should reduce the involvement of the EPA with NRC licensees who are decommissioning. Most sites are expected to meet the NRC criteria for unrestricted use, and the NRC believes that only a few sites will have groundwater or soil contamination in excess of the levels specified in the MOU that trigger consultation with the EPA. However, if there are other hazardous materials on the site, the EPA may be involved in the cleanup. As such, the possibility of dual regulation remains for certain licensees.

4.2.6 Content and Format of the Decommissioning Estimates

The NRC is developing guidance on content and format for the reporting of decommissioning cost estimates; this guidance was proposed in Draft Regulatory Guide DG-1085, "Standard Format and Content of Decommissioning Cost Estimates for Nuclear Power Reactors," in November 2001. In general, decommissioning cost estimates are to be provided by major activity and major decommissioning phase or time period. The cost estimate must also account for the entire decommissioning work scope. Items that are outside the scope of the decommissioning process, such as spent fuel management and site restoration, can be included if identified separately.

The NRC identifies specific activities or cost categories for which cost should be provided. The activities include:

- Major radioactive component removal, including the nuclear reactor, associated heat transfer components and piping, and other large components that are radioactive to a comparable degree.
- Radiological decontamination and dismantling, including the removal of the remaining radioactive plant systems and structural materials.
- Management and support (undistributed costs), including the cost of licensee support staff and decommissioning contractor staff, energy costs, regulatory costs, small tools, insurance, and other site carrying costs.
- Waste packaging and transportation, including loading and shipping containers to waste processors and disposal sites.
- Waste conditioning and disposal fees, including processing charges and burial fees.
- Contingency as an allowance for unexpected costs.

The NRC also expects that any cost estimates include the assumptions, references, and bases for the unit costs used in developing the estimates, as well as a description of how inflation is accounted for in the cost estimate.

Financial management of decommissioning liabilities has been facilitated by a standardized cost estimating methodology. The methodology used for a large majority of the cost assessments for

U.S. commercial reactors was originally developed in 1986, in a program sponsored by the Atomic Industrial Forum (now Nuclear Energy Institute). The details of the program were published in a document entitled "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates (AIF/NESP-036). The methodology described in this report, and the associated cost model, has been updated by TLG since the report was first published as experience in decommissioning large reactors became available. However, the core methodology and reporting format, while providing significantly more detail today, has retained much of its original structure. This continuity has made historical comparisons and trending analyses possible.

TLG has codified the AIF/NESP-036 methodology in a proprietary software package called DECCER. The package, consisting of Basic program code and integrated Microsoft Excel worksheets, allows the user to construct a cost model that incorporates a plant’s physical inventory, the performance schedule, a program management organization and specific assumptions relating to the management of low-level and high-level radioactive waste. The cost estimates for the advanced reactor designs are generated using the DECCER model, as are the estimates for a majority of the commercial reactors in North America. The content and format of the estimates also comply with the guidance proposed by the NRC in DG-1085.

4.3 Decommissioning Activities

The following section describes the basic activities associated with the prompt or DECON alternative. Although detailed procedures for each activity identified are not provided, and the actual sequence of work may vary, the activity descriptions provide a basis not only for estimating but also for the expected scope of work, that is, engineering and planning at the time of decommissioning.

The conceptual approach that the NRC has described in its regulations divides decommissioning into three phases. The initial phase commences with the effective date of permanent cessation of operations and involves the transition of both plant and licensee from reactor operations (that is, power production) to facility de-activation and closure. During the first phase, notification is to be provided to the NRC certifying the permanent cessation of operations and the removal of fuel from the reactor vessel. The licensee would then be prohibited from reactor operation.

The second phase encompasses activities during the storage period or during major decommissioning activities, or a combination of the two. The third phase pertains to the activities involved in license termination. The decommissioning estimates developed for the advanced reactor designs are also divided into phases or periods; however, demarcation of the phases is based upon major milestones within the project or significant changes in the projected expenditures.

The DECON alternative, as defined by the NRC, is "the alternative in which the equipment, structures, and portions of a facility and site containing radioactive contaminants are removed or decontaminated to a level that permits the property to be released for unrestricted use shortly after cessation of operations." This study does not address the cost to dispose of the spent fuel residing at the site; such costs are funded through a surcharge on electrical generation. However, the study does estimate the costs incurred with the interim onsite wet storage of the fuel pending shipment by the DOE to an offsite disposal facility. Extended storage of the spent fuel beyond its required cooling period is not considered. The 60-year operating period should provide sufficient time to develop the resources necessary for prompt and expedient disposal of the high-level waste (spent fuel) such that the impact on decommissioning is minimized.

4.3.1 Preparations

In anticipation of the cessation of plant operations, detailed preparations are undertaken to provide a smooth transition from plant operations to site decommissioning. Through implementation of a staffing transition plan, the organization required to manage the intended decommissioning activities is assembled from available plant staff and outside resources. Preparations include the planning for permanent defueling of the reactor, revision of technical specifications applicable to the operating conditions and requirements, a characterization of the facility and major components, and the development of the PSDAR.

4.3.1.1 Engineering and Planning

The PSDAR, required within two years of the notice to cease operations, provides a description of the licensee’s planned decommissioning activities, a timetable, and the associated financial requirements of the intended decommissioning program. Upon receipt of the PSDAR, the NRC will make the document available to the public for comment in a local hearing to be held in the vicinity of the reactor site. Ninety days following submittal and NRC receipt of the PSDAR, the licensee may begin to perform major decommissioning activities under a modified 10 CFR 50.59 procedure, that is, without specific NRC approval. Major activities are defined as any activity that results in permanent removal of major radioactive components, permanently modifies the structure of the containment, or results in dismantling components (for shipment) containing GTCC, as defined by 10 CFR 61. Major components are further defined as comprising the reactor vessel and internals, large bore primary piping, and other large components that are radioactive. The NRC includes the following additional criteria for use of the §50.59 process in decommissioning. The proposed activity must not:

- foreclose release of the site for possible unrestricted use
- significantly increase decommissioning costs
- cause any significant environmental impact
- violate the terms of the licensee’s existing license

Existing operational technical specifications are reviewed and modified to reflect plant conditions and the safety concerns associated with permanent cessation of operations. The environmental impact associated with the planned decommissioning activities is also considered. Typically, a licensee will not be allowed to proceed if the consequences of a particular decommissioning activity are greater than that bounded by previously evaluated environmental assessments or impact statements. In this instance, the licensee would have to submit a license ments or impact statements. In this instance, the licensee would have to submit a license amendment for the specific activity and update the environmental report.

The decommissioning program outlined in the PSDAR will be designed to accomplish the required tasks within the ALARA guidelines (as defined in 10 CFR 20) for protection of personnel from exposure to radiation hazards. It will also address the continued protection of the health and safety of the public and the environment during the dismantling activity. Consequently, with the development of the PSDAR, activity specifications, cost-benefit and safety analyses, work packages and procedures, would be assembled to support the proposed decontamination and dismantling activities.

4.3.1.2 Site Preparations

Following final plant shutdown, and in preparation for actual decommissioning activities, the following activities are initiated:

- Characterization of the site and surrounding environs. This includes radiation surveys of work areas, major components (including the nuclear reactor), coolant piping, and primary shield cores.
- Isolation of the spent fuel storage pool and fuel handling systems, such that decommissioning operations can commence on the balance of the plant. The pool remains operational for a minimum of five years following the cessation operations to meet the minimum heat load requirements (as defined in the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste, 10 CFR 961) for transfer to the DOE.
- Specification of transport and disposal requirements for activated materials and/or hazardous materials, including shielding and waste stabilization.
- Development of procedures for occupational exposure control, control and release of liquid and gaseous effluent, processing of radwaste (including dry-active waste, resins, filter media, metallic and nonmetallic components generated in decommissioning), site security and emergency programs, and industrial safety.

4.3.2 Decommissioning Operations

This period includes the physical decommissioning activities associated with the removal and disposal of contaminated and activated components and structures, including the successful termination of the 10 CFR 50 operating license. Significant decommissioning activities in this phase include:

- Construction of temporary facilities and/or modification of existing facilities to support dismantling activities. This may include a centralized processing area to facilitate equipment removal and component preparations for offsite disposal.

- Reconfiguration and modification of site structures and facilities as needed to support decommissioning operations. This may include the upgrading of roads (on- and offsite) to facilitate hauling and transport. Modifications may be required to the containment structure to facilitate access of large/heavy equipment. Modifications may also be required to the refueling area of the building to support the segmentation of the reactor and component extraction.

- Design and fabrication of temporary and permanent shielding to support removal and transportation activities, construction of contamination control envelopes, and the procurement of specialty tooling.

- Procurement (lease or purchase) of shipping canisters, cask liners, and industrial packages.

- Decontamination of components and piping systems as required to control (minimize) worker exposure.

- Removal of piping and components no longer essential to support decommissioning operations.

- Disassembly, removal, segmentation and packaging of the nuclear reactor and surrounding metallic structures. Segmentation will maximize the loading of the shielded transport casks, that is, by weight and activity. The operations are conducted under water to the extent practical using remotely operated tooling and contamination controls. Components/material removed in-air are transferred to containers that are stored under water, for example, in an isolated area of the refueling canal. Some material is expected to exceed Class C disposal requirements. As such, the segments will be packaged in modified fuel storage canisters for geologic disposal.

- Removal of the activated portions of the concrete biological/sacrificial shield and accessible contaminated concrete surfaces. If dictated by the steam generator and pressurizer removal scenarios (PWRs only), those portions of the associated cubicles necessary for access and component extraction are removed.

- Removal of the steam generators and pressurizer for material recovery and controlled disposal (PWRs only). The generators will be removed and placed onto a multi-wheeled vehicle and transferred to a rail car for transport the disposal facility. The steam generators and pressurizer can serve as their own burial containers provided that all penetrations are properly sealed and the internal contaminants are stabilized, for example, with grout. Steel shielding will be added, as necessary, to those external areas of the package to meet transportation limits and regulations.

At least two years before the anticipated date of license termination, an LTP is required. Submitted as a supplement to the FSAR or its equivalent, the plan must include: a site characterization, description of the remaining dismantling activities, plans for site remediation, procedures for the final radiation survey, designation of the end use of the site, an updated cost estimate to complete the decommissioning, and any associated environmental concerns. The NRC will notice the receipt of the plan, make the plan available for public comment, and schedule a local hearing. LTP approval will be subject to any conditions and limitations as deemed appropriate by the Commission. The licensee may then commence with the final remediation of site facilities and services, including:

- Removal of remaining plant systems and associated components as they become nonessential to the decommissioning program or worker health and safety (for example, waste collection and treatment systems, electrical power and ventilation systems).
- Removal of the steel liners from refueling canal, connected pools (as appropriate) and other freestanding tankage, disposing of the activated and contaminated sections as radioactive waste. Removal of any activated/contaminated concrete and containment steel.
- Surveys of the decontaminated areas of the containment structure.
- Remediation and removal of the contaminated equipment and material from the auxiliary and fuel buildings (as appropriate) and any other contaminated facility. Radiation and contamination controls will be used until residual levels indicate that the structures and equipment can be released for unrestricted access and conventional demolition. This activity may necessitate the dismantling and disposition of most of the systems and components (both clean and contaminated) located within these buildings. This activity facilitates surface decontamination and subsequent verification surveys required before obtaining release for demolition.
- Routing of material removed in the decontamination and dismantling to a central processing area. Material certified to be free of contamination is released for unrestricted disposition, for example, as scrap, recycle, or general disposal. Contaminated material is characterized and segregated for additional offsite processing (disassembly, chemical cleaning, volume reduction, and waste treatment), and/or packaged for controlled disposal at a low-level radioactive waste disposal facility.

Incorporated into the LTP is the Final Survey Plan. This plan identifies the radiological surveys to be performed once the decontamination activities are completed and is developed using the guidance provided in the "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)." This document incorporates the statistical approaches to survey design and data interpretation used by the EPA. It also identifies state-of-the-art, commercially available instrumentation and procedures for conducting radiological surveys. Use of this guidance ensures that the surveys are conducted in a manner that provides a high degree of confidence that applicable NRC criteria are satisfied. Once the survey is complete, the results are provided to the NRC in a format that can be verified. The NRC then reviews and evaluates the information, performs an independent confirmation of radiological site conditions, and makes a determination on final termination of the license.

The NRC will terminate the operating license if it determines that site remediation has been performed in accordance with the LTP, and that the terminal radiation survey and associated documentation demonstrate that the facility is suitable for release.

4.3.3 Site Restoration

Prompt dismantling of site structures is clearly the most appropriate and cost-effective option. It is unreasonable to anticipate that these structures would be repaired and preserved after the radiological contamination is removed. The cost to dismantle site structures with a work force already mobilized on site is more efficient than if the process was deferred. Site facilities quickly degrade without maintenance, adding additional expense and creating potential hazards to the public as well as to future workers. The estimates for the advanced reactor designs do not include this additional activity, that is, the demolition of nonessential site structures and the restoration of the property. This activity is excluded to facilitate comparison with NRC financial guidelines which exclude activities occurring after the §50 license is terminated. However, an allowance has been included for the removal of clean structural material to support the removal of contaminated material, sometime referred to as cascading costs.

4.4 Basis for the Cost Estimates

The cost estimates prepared for decommissioning the advanced reactor designs consider the unique features of the site, including the nuclear steam supply systems, power generation systems, support services, site buildings, and ancillary facilities. The basis of the estimates, including the sources of information relied upon, the estimating methodology employed, site-specific considerations, and other pertinent assumptions, is described in the following sections.

For estimating purposes, the advanced reactors are assumed to be located on a site geographically located between the TVA's Bellefonte nuclear station in northern Alabama and Dominion Generation's North Anna nuclear station in central Virginia. This hypothetical location is used as a basis for determining transportation charges to offsite processing and disposal facilities. A composite craft labor cost and per diem rate were developed by averaging individual costs for the two areas.

4.4.1 Methodology

The methodology used to develop the estimates follows the basic approach originally presented in AIF/NESP-036 and the DOE "Decommissioning Handbook." These documents present a unit cost factor method for estimating decommissioning activity costs, which simplifies the estimating calculations. Unit factors for concrete removal ($/cubic yard), steel removal ($/ton), and cutting costs ($/inch) were developed using local labor rates. The activity-dependent costs were estimated with the item quantities (cubic yards and tons), developed from plant drawings and inventory documents. Removal rates and material costs for the conventional disposition of components and structures relied upon information available in the industry publication, "Building Construction Cost Data," published by R. S. Means. The unit cost factor method provides a demonstrable basis for establishing reliable cost estimates. The detail provided in the unit cost factors, including activity duration, labor costs (by craft), and equipment and consumable costs, ensures that essential elements have not been omitted.

The estimates reflect lessons learned from the TLG's involvement in the Shippingport Station Decommissioning Project, completed in 1989, as well as the decommissioning of the Cintichem reactor, hot cells, and associated facilities, completed in 1997. In addition, the planning and engineering for the Pathfinder, Shoreham, Rancho Seco, Trojan, Yankee Rowe, Big Rock Point, Maine Yankee, Humboldt Bay-3, Oyster Creek, Connecticut Yankee and San Onofre-1 nuclear units have provided additional insight into the process, the regulatory aspects, and the technical challenges of decommissioning commercial nuclear units.

4.4.1.1 Plant Inventory

The basis for any site-specific decommissioning estimate is the plant inventory. The inventory dictates the decontamination, removal, packaging, transport and disposal requirements and the associated performance cost. Material disposition requirements impact the project schedule and are reflected in the level of management needed to support the project. Consequently, it is important to delineate the inventory of material and components to be dealt with during decommissioning, which in most instances is a subset of the total quantity of material placed during construction. In addition, the plant inventory needs to be defined in units that are compatible with the intended removal methods. For example, while sample panels may contain hundreds of subassemblies, the panels are removed in bulk. The disposition cost may be based upon the total weight of the panel and the lifting devices required rather than by disassembly of the individual components. In contrast to plant operations, the most important parameter in decommissioning can be the component's mass or materials of construction and not its design performance.

- **Systems —** System inventories were determined for material and equipment located in major power block structures (reactor building and containment, auxiliary building, fuel building, turbine building, radwaste building and selective other buildings containing contaminated systems). Quantity information provided by each vendor was converted into English units (required by DECCER) and categorized and grouped in accordance with the input requirements of the estimating model.

  Although actual quantities were used whenever provided by the reactor vendor, system inventories were organized differently between vendors and were provided in various levels of detail. Inventory quantities for categories such as small and large bore hangers, length of electrical conduit, length of electrical cable tray, number of small mechanical equipment and number of small HVAC equipment required conversion, scaling and proportioning to support the cost model. Whenever required, these values were calculated in a consistent fashion among all reactor types. Inventory information was assigned to systems based upon reactor vendor provided information, and systems were categorized based upon TLG's judgment regarding the existence and level of interior or exterior radioactive contamination.

The ESBWR's system inventory, due to the limited inventory information provided by the vendor, was based upon the ABWR inventory, particularly for the secondary side systems. Significant large component design differences between the two reactor types were provided by the ESBWR reactor vendor and incorporated into the estimate. Where new ESBWR systems were identified, quantity information was determined based upon information provided on the system P&IDs and technical descriptions. Systems specific to the ABWR design were excluded from the ESBWR inventory.

Costs for the removal of clean systems and materials from the major plant structures were included in all of the estimates to facilitate the final status survey.

Table 4-1 was developed to provide a list of the system quantity information used in the development of the decommissioning study. (Tables 4-1 through 4-17 are located at the end of Section 4.) However, some vendors considered this information proprietary. Therefore, so as not to prejudice any individual design, this table was labeled as proprietary.

- **Structures —** Structure inventory data was obtained from general arrangement drawings for the major power block structures provided by each of the reactor plant vendors. Quantities of materials such as standard concrete, reinforced concrete, freestanding liners, concrete embedded liners, and grating were obtained by scaling information from the drawings. Standard estimating methods and practices were used to correlate inventory information into quantities that are required by the DECCER cost model. Quantity information for contamination/activation categories such as neutron activated concrete, concrete removed by drill and spall, and floor and wall concrete removed by scabbling, were determined using inventory information extracted from the drawings and the TLG's judgment regarding the extent of contamination/activation. A CAD based system was used to scale the quantities from the building drawings. The estimates principally included only those structures that contain contaminated material, although, in accordance with our standard practice, an allowance was included for the cost to remove clean structures in support of the removal of contaminated systems and equipment.

  Costs for the demolition of buildings after license termination (i.e., structural steel and concrete) were not included in these estimates since these costs are not within the scope of the NRC license termination requirements.

  Table 4-2 was developed to provide a list of the structures quantity information used in the development of the decommissioning study. However, some vendors considered this information proprietary. Therefore, so as not to prejudice any individual design, this table was labeled as proprietary.

- **Reactor —** The reactor plant vendors provided the masses of the various components in each reactor. The source terms, in curies per pound, for each of these components were developed from NUREG/CR-3474, "Long-Lived Activation Products in Reactor Materials." The reactor pressure vessel and internal components are segmented for disposal in shielded, reusable transportation casks. Segmentation is performed underwater to the maximum extent possible using robotics. Handling and packaging of the activated material segments is assumed to control the critical path of the activity; that is cutting of the segments requires less time than packaging and loading shipping casks and other containers. The availability and quantity of transportation casks, their specifications, and transportation regulations will dictate the segmentation and packaging methodology. The segmentation costs include funds for specialty tooling for remote handling and manipulation of the highly radioactive components, and assumed that a specialty contractor would perform the work.

AECL provided 60-year decayed curie estimates for the ACR-700 reactor components; this was back calculated using similar 60-year decayed values for the NUREG PWR and adjusted for a prompt decommissioning program with approximately 2.5 years decay.

All reactor component curie estimates are based upon a 60-year lifetime, with a capacity factor of 93% over the life of the plant. Disposal costs of all components from the reactor are developed using Barnwell, S.C. surrogate rates (excluding GTCC).

Intact disposal of reactor vessel shells has been successfully demonstrated at several of the sites currently being decommissioned. Access to navigable waterways has allowed these large packages to be transported to the Barnwell disposal site with minimal overland travel. However, future access to this site will be restricted and, as such, the estimates for the advanced reactor designs assumed segmentation of the reactor vessel, as a bounding condition. With lower levels of activation, the shells can be packaged more efficiently than the curie-limited internal components. This will allow the use of more conventional waste packages rather than shielded casks for transport. Disposal costs are based upon published rates for the Barnwell facility.

The dismantling of the reactor internals will generate radioactive waste considered unsuitable for shallow land disposal, that is, GTCC. This material was assumed to be disposed of at a DOE geological repository at a cost approximately equivalent to the unit cost of spent fuel disposal. The assumed rate is provided in Table 4-3. Information from NUREG/CR-3474 was used to develop curies of the various isotopes of interest to 10 CFR 61 regarding waste classification.

4.4.1.2 Work Difficulty Factors

The estimates follow the principles of ALARA through the use of work duration adjustment factors. These factors address the impact of activities such as radiological protection instruction, mockup training, and the use of respiratory protection and protective clothing. The factors lengthen a task's duration, increasing costs and lengthening the overall schedule. ALARA planning is considered in the costs for engineering and planning, and in the development of activity specifications and detailed procedures. Changes to worker exposure limits may impact the decommissioning cost and project schedule.

Work difficulty adjustment factors account for the inefficiencies in working in a power plant environment and were assigned to each unique set of unit cost factors, commensurate with the inefficiencies associated with working in confined, hazardous environments. The ranges used for the work difficulty factors are as follows:

Access Factor	10% to 15%
Respiratory Protection Factor	10% to 45%
Radiation/ALARA Factor	10% to 33%
Protective Clothing Factor	10% to 30%
Work Break Factor	8.33%

The factors and their associated range of values were developed in conjunction with the AIF/NESP-036 study. The application of the factors is discussed in more detail in that publication.

The work difficulty adjustment factors were reduced from the levels identified in the AIF/NESP-036 study, to reflect improved access, lower contamination levels, and lower area radioactivity levels expected with the new reactor designs. Improved materials selection, reduction of cobalt in reactor system components and improvements in water chemistry will all contribute to reduced radiation levels during operations as well as the decommissioning period. This resulted in lower values being used for the Access, Respiratory Protection and Radiation/ALARA work difficulty factors.

4.4.1.3 Scheduling Program Durations

The unit cost factors, adjusted by the work difficulty adjustment factors as described above, are applied against the inventory of materials to be removed in the radiologically controlled areas or removed from "clean" areas to facilitate the final status survey. The resulting man-hours, or crew-hours, are used in the development of the decommissioning program schedule, using resource loading and event sequencing considerations. The scheduling of conventional removal and dismantling activities are based upon productivity information available from the "Building Construction Cost Data" publication.

An activity duration critical path is used to determine the total decommissioning program schedule. The schedule is relied upon in calculating the carrying costs, which include program management, administration, field engineering, equipment rental, and support services such as quality control and security. This systematic approach for assembling decommissioning estimates ensures a high degree of confidence in the reliability of the result.

4.4.2 Financial Components of the Cost Model

TLG’s proprietary decommissioning cost model, DECCER, produces a number of distinct cost elements. These direct expenditures, however, do not comprise the total cost to accomplish the project goal, that is, license termination and site restoration.

Inherent in any cost estimate that does not rely on historical data is the inability to specify the precise source of costs imposed by factors such as tool breakage, accidents, illnesses, weather delays, and labor stoppages. In the DECCER cost model, contingency fulfills this role. Contingency is added to each line item to account for costs that are difficult or impossible to develop analytically. Such costs are historically inevitable over the duration of a job of this magnitude; therefore, this cost analysis includes funds to cover these types of expenses.

4.4.2.1 Contingency

The activity- and period-dependent costs are combined to develop the total decommissioning cost. A contingency is then applied on a line-item basis, using one or more of the contingency types listed in the AIF/NESP-036 study. "Contingencies" are defined in the American Association of Cost Engineers "Project and Cost Engineers' Handbook" as "specific provision for unforeseeable elements of cost within the defined project scope; particularly important where previous experience relating estimates and actual costs has shown that unforeseeable events which will increase costs are likely to occur." The cost elements in these estimates are based upon ideal conditions and maximum efficiency; therefore, consistent with industry practice, a contingency factor has been applied. In the AIF/NESP-036 study, the types of unforeseeable events that are likely to occur in decommissioning are discussed and guidelines are provided for percentage contingency in each category. It should be noted that contingency, as used in this analysis, does not account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the station.

Contingency funds are an integral part of the total cost to complete the decommissioning process. Exclusion of this component puts at risk a successful completion of the intended tasks and, potentially, subsequent related activities. For this study, TLG examined the major activity-related problems (decontamination, segmentation, equipment handling, packaging, transport, and waste disposal) that necessitate a contingency. Individual activity contingencies ranged from 10% to 75%, depending on the degree of difficulty judged to be appropriate from TLG's actual decommissioning experience. The contingency values used in this study are as follows:

Decontamination	50%
Contaminated Component Removal	25%
Contaminated Component Packaging	10%
Contaminated Component Transport	15%
Low-Level Radioactive Waste Disposal	25%
Reactor Segmentation	75%
NSSS Component Removal	25%
Reactor Waste Packaging	25%
Reactor Waste Transport	25%
Reactor Vessel Component Disposal	50%
GTCC Disposal	15%
Nonradioactive Component Removal	15%
Heavy Equipment and Tooling	15%

Supplies	25%
Engineering	15%
Energy	15%
Characterization and Termination Surveys	30%
Construction	15%
Taxes and Fees	10%
Insurance	10%
Staffing	15%

The overall, composite contingencies, when applied to the appropriate components of the estimates on a line item basis, are identified in the detailed cost tables for the various reactor designs.

4.4.2.2 Financial Risk

In addition to the routine uncertainties addressed by contingency, another cost element that is sometimes necessary to consider when bounding decommissioning costs relates to uncertainty, or risk. Examples can include changes in work scope, pricing, job performance, and other variations that could conceivably, but not necessarily, occur. Consideration is sometimes necessary to generate a level of confidence in the estimate, within a range of probabilities. TLG considers these types of costs under the broad term "financial risk." Included within the category of financial risk are:

- Transition activities and costs: ancillary expenses associated with eliminating 50% to 80% of the site labor force shortly after the cessation of plant operations, added cost for worker separation packages throughout the decommissioning program, national or company-mandated retraining, and retention incentives for key personnel.

- Delays in approval of the decommissioning plan due to intervention, public participation in local community meetings, legal challenges, and national and local hearings.

- Changes in the project work scope from the baseline estimate, involving the discovery of unexpected levels of contaminants, contamination in places not previously expected, contaminated soil or groundwater previously undiscovered (either radioactive or hazardous material contamination), variations in plant inventory or configuration not indicated by the as-built drawings.

- Regulatory changes, for example, affecting worker health and safety, site release criteria, waste transportation, and disposal.

- Policy decisions altering national commitments, for example, in the ability to accommodate certain waste forms for disposition, or in the timetable for such, for example, the start and rate of acceptance of spent fuel by the DOE.

- Pricing changes for basic inputs, such as labor, energy, materials, and disposal. Some of these inputs may vary slightly, for example -10% to +20% for items subject to widespread price competition (such as materials); others such as waste disposal could vary from -50% to +200% or more, particularly for Class B and C material, where Barnwell is the only accessible licensed commercial facility.

It has been TLG's experience that the results of a risk analysis, when compared with the base case estimate for decommissioning, indicate that the chances of the base decommissioning estimate being too high is a low probability, and the chances that the estimate is too low is a higher probability. This is mostly due to the pricing uncertainty for low-level radioactive waste burial, and to a lesser extent due to schedule increases from changes in plant conditions and to pricing variations in the cost of labor (both craft and staff). This cost analysis, however, does not add any additional costs to the estimate for financial risk since there is insufficient historical data from which to project future liabilities. Consequently, the areas of uncertainty or risk should be revisited periodically and addressed through repeated revisions or updates of the base estimate.

4.4.3 Site-Specific Considerations

There are a number of site-specific considerations that affect the method for dismantling and removal of equipment from the site and the degree of restoration required. The cost impact of the considerations identified below is included in the estimates for the advanced reactor designs.

4.4.3.1 Spent Fuel Management

The cost to dispose of the spent fuel generated from plant operations is not reflected within the estimates. However, the NRC requires licensees to establish a program to manage and provide funding for the management of all irradiated fuel at the reactor until title of the fuel is transferred to the Secretary of Energy. This funding requirement is fulfilled through inclusion of certain cost elements within the estimate, for example, spent fuel pool isolation and continued pool operations. For purposes of these estimates it has been assumed that the storage pool(s) will remain operational for approximately 5½ years after the cessation of plant operations. The cost for pool operations over this period as well as the cost of isolating the spent fuel pool systems is included within the estimates.

The DOE was assumed to provide the canisters at no additional cost to the owner for fuel transferred directly from the storage pool to the DOE. Since the inventory of spent fuel in the storage pool following the cessation of plant operations cannot be predicted, loading costs for assemblies have also not been included within the estimates.

4.4.3.2 Nuclear Reactor Components

The NSSS (reactor and reactor coolant/recirculation system components) are assumed to be decontaminated using chemical agents before the start of cutting operations. This type of decontamination could be expected to have a significant ALARA impact in the DECON scenario, since in this scenario the removal work is done within the first few years of shutdown. It should be noted that if the decommissioning work was delayed (alternate scenario selected), chemical decontamination would probably not be scheduled. A decontamination factor (average reduction) of 10 is assumed for the process. Disposal of the decontamination solution effluent is included within the estimates as a "process liquid waste" charge.

The reactor vessel internal components are segmented for disposal in shielded, reusable transportation casks. Segmentation is performed underwater when practical where a remote cutter is installed. Transportation cask specifications and transportation regulations will dictate segmentation and packaging methodology.

The dismantling of the reactor will generate radioactive waste considered unsuitable for shallow land disposal, that is, GTCC. Although the material is not classified as high-level waste, the DOE has indicated it will accept this waste for disposal at the future high-level waste repository. Currently, there are no acceptance criteria or disposition schedule for this material, and numerous questions remain as to the ultimate disposal cost and waste form requirements. As such, for purposes of this study, the GTCC has been packaged and disposed of as high-level waste, at a cost equivalent to that envisioned for the spent fuel. The estimated unit disposal cost is provided in Table 4-3.

Intact disposal of the nuclear reactor components can provide savings in cost and worker exposure by eliminating the complex segmentation requirements, isolation of the GTCC material, and transport/storage of the resulting waste packages. Portland General Electric (PGE) was able to dispose of the Trojan reactor as an intact package. However, its location on the Columbia River simplified the transportation analysis since:

- the reactor package could be secured to the transport vehicle for the entire journey, that is, the package was not lifted during transport
- there were no man-made or natural terrain features between the plant site and the disposal location that could produce a large drop
- transport speeds were very low, limited by the overland transport vehicle and the river barge

As a member of the Northwest Compact, PGE had a site available for disposal of the package - the U.S. Ecology facility in Washington State. The characteristics of this arid site proved favorable in demonstrating compliance with land disposal regulations.

It is not known whether this option will be available in the future. Viability of this option will depend upon the location of the nuclear unit and the disposal site, as well as the disposal site licensee’s ability to accept highly radioactive packages and effectively isolate them from the environment. Consequently, the study assumes the nuclear reactor will require segmentation, as a bounding condition.

4.4.3.3 Primary System Large Components

The following discussion deals with the removal and disposition of the steam generators, but the techniques involved are also applicable to other large radioactively contaminated components, such as heat exchangers, moisture separator-reheaters, feedwater heaters, and the pressurizer. The steam generators' size and weight, their location within the reactor building, as well as the disposal facility waste acceptance criteria, and access to transportation will ultimately determine the removal, transportation, and disposal strategy.

A crane is set up for the removal of the generators. It can also be used to move portions of the steam generator cubicle walls and floor slabs from the reactor building to a location where they can be decontaminated and transported to the material handling area. Interferences within the work area, such as grating, piping, and other components are removed to create sufficient laydown space for processing these large components.

The generators are rigged for removal, disconnected from the surrounding piping and supports, and maneuvered into the open area where they are lowered onto a downending cradle. Each generator is rotated into the horizontal position for extraction from the containment and placed onto a multi-wheeled vehicle for transport to an onsite preparation area.

Disposal costs are based upon the displaced volume and weight of the primary side portions of the steam generators. Each component is then loaded onto a rail car for transport to the disposal facility. The secondary side is assumed to be sent to an offsite waste processor.

Reactor coolant or heat transport piping is cut from the reactor once the water level (used for personnel shielding during dismantling and cutting operations in and around the reactor) is dropped below the elevation of associated nozzle(s). The piping is boxed and transported by shielded van. The reactor coolant/recirculation/heat transport pumps and motors are lifted out intact, packaged, and transported for disposal.

4.4.3.4 Main Turbine and Condenser

The main turbine and condenser of the AP1000 and ACR-700 units are assumed to be radioactively clean. The same components for the ABWR and ESBWR units are assumed to be radioactively contaminated. This results in a significant difference in the assumed waste stream for these components generated in the decommissioning of these units. The removal process is expected to be similar for each of the units. The main turbine will be dismantled using conventional maintenance procedures, with appropriate radiological controls measures. The turbine rotors and shafts will be removed to a laydown area. The lower turbine casings will be removed from their anchors by controlled demolition. The main condensers will also be disassembled and moved to a laydown area. Material that is expected to be contaminated (generated from BWR reactor units) is then prepared for transportation to an offsite waste processor where it will be surveyed and designated for either decontamination or volume reduction, conventional disposal, or controlled disposal. Components will be packaged, and transported in accordance with the requirements for transportation of radioactive materials. Material that is expected to be clean (PWR and ACR units) will be surveyed before releasing the material as scrap steel waste.

4.4.3.5 Transportation Methods

Contaminated piping, components, and structural material other than the highly activated components will qualify as LSA-I, II or III or Surface Contaminated Object, SCO-I or II, as described in Title 49. The contaminated material will be packaged in Industrial Packages (IP I, II, or III, as defined in subpart 173.411) for transport unless demonstrated to qualify as their own shipping containers. The reactor components are expected to be transported in accordance with §71, as Type B. It is conceivable that the reactor, due to its limited specific activity, could qualify as LSA II or III. However, the high radiation levels on the outer surface would require that additional shielding be incorporated within the packaging so as to attenuate the dose to levels acceptable for transport.

It should be noted that as discussed in an earlier section intact disposal of reactor vessel shells and steam generators has been successfully demonstrated at several of the sites currently being decommissioned. Access to acceptable means of transportation in these cases required access to navigable waterways to allow these large components to be transported essentially intact to the Barnwell disposal site. However, since future access to Barnwell will be restricted and the only remaining site is well inland and distant from navigable waterways, the estimates for the advanced reactor designs do not consider the use of barges as a means of transporting waste.

Transport of the highly activated metal, produced in the segmentation of the reactor components, will be by shielded truck cask. Cask shipments may exceed 95,000 pounds, including vessel segment(s), supplementary shielding, cask tie-downs, and tractor-trailer. The maximum level of activity per shipment assumed permissible was based upon the license limits of the available shielded transport casks. The segmentation scheme for the vessel components is designed to meet these limits.

The transport of large intact components, for example, large heat exchangers and other oversized components will be by a combination of truck, rail, and/or multi-wheeled transporter.

The low-level radioactive waste requiring controlled disposal will be sent to one of two currently available burial facilities. Transportation costs are based upon a destination in the western United States, approximately 2,000 miles from the advanced reactor site. A regional site is assumed as the destination for offsite processing. Transportation costs are estimated using published tariffs from Tri-State Motor Transit.

4.4.3.6 Low-Level Radioactive Waste Disposal

To the greatest extent practical, metallic material generated in the decontamination and dismantling processes is processed to reduce the total cost of controlled disposal. Material meeting the regulatory and/or site release criterion, is released as scrap, requiring no further cost consideration. Conditioning (preparing the material to meet the waste acceptance criteria of the disposal site) and recovery of the waste stream is performed offsite at a licensed processing center. Any material leaving the site is subjected to a survey and release charge, at a minimum. Based on TLG's experience, rates were assumed for offsite processing as well as survey and release. These rates are shown in Table 4-3.

The mass of radioactive waste generated during the various decommissioning activities at the site is shown on a line-item basis in the detailed cost tables, and summarized in Table 4-4. The quantified waste summaries shown in these tables are consistent with §61 classifications. Commercially available steel containers are presumed to be used for the disposal of piping, small components, and concrete. Larger components can serve as their own containers, with proper closure of all openings, access ways, and penetrations. The volumes are calculated based on the exterior package dimensions for containerized material or a specific calculation for components serving as their own waste containers.

The more highly activated reactor components will be shipped in reusable, shielded truck casks with disposable liners. In calculating disposal costs, the burial fees are applied against the liner volume, as well as the special handling requirements of the payload. Packaging efficiencies are lower for the highly activated materials (greater than Type A quantity waste), where high concentrations of gamma-emitting radionuclides limit the capacity of the shipping canisters.

Disposal fees are based upon estimated charges, with surcharges added for the highly activated components, for example, generated in the segmentation of the reactor vessel. The cost to dispose of the majority of the material generated from the decontamination and dismantling activities was based upon an assumed rate for the Envirocare facility in Clive, Utah (Envirocare does not publish a waste disposal rate schedule, and requires that rate information be maintained as proprietary information). Rates and surcharges published for the Barnwell facility in South Carolina were used for the higher activity waste. The disposal rates applied to the various waste streams are identified in Tables 4-3.

4.4.3.7 Site Conditions Following Decommissioning

The NRC will terminate (or amend) the site license if it determines that site remediation has been performed in accordance with the license termination plan, and that the terminal radiation survey and associated documentation demonstrate that the facility is suitable for release. The NRC's involvement in the decommissioning process will end at this point. Building codes and environmental regulations will dictate the next step in the decommissioning process, as well as the owner's own future plans for the site.

4.4.3.8 Multi-Unit Site Considerations

The estimates for the ACR-700 include economies of scale for select activities commensurate with decommissioning multi-unit sites. The size of the utility, decommissioning operations contractor (DOC), and security staffs is reduced to recognize savings when performing decommissioning activities for multiple units. Cost savings are also included for: preparation of engineering and planning documents (specifications and procedures), procurement and use of reactor vessel segmentation equipment, planning and performance of the site characterization and final status survey, and design for isolation of the spent fuel pools.

4.4.4 Estimating Assumptions (Economic)

The following are the major economic assumptions made in the development of the estimates for decommissioning the various reactors.

4.4.4.1 Labor Costs

The craft labor required to decontaminate and dismantle the nuclear units will be acquired through standard site contracting practices. Craft labor costs were based upon information from RS Means. A composite set of craft labor rates was developed based upon the RS Means craft labor rates for two locations (northern Alabama and central Virginia). Craft labor costs include applicable overheads and profit, and are provided in Table 4-3. Severance and retention costs are not included in the estimates. Reduction in staff levels will be handled through normal staffing processes.

The licensee will continue to provide site operations support, including decommissioning program management, licensing, radiological protection, and site security. A DOC will provide the supervisory staff needed to oversee the labor subcontractors, consultants, and specialty contractors needed to perform the work required for the decontamination and dismantling effort. The DOC will also provide the engineering services needed to develop activity specifications, detailed procedures, detailed activation analyses, and support field activities such as structural modifications. Staffing levels were also adjusted for the licensee and contractor organizations based upon the craft levels during the active decommissioning periods and to reflect any economies of scale at a two-unit site.

Utility labor costs were provided by Dominion. Average costs were provided by department or work group and included payroll overheads. Decommissioning Operations Contractor (DOC) labor costs were based on utility labor costs with modified markups to account for employee benefits, DOC overhead and profit. Although specific rates were used for each decommissioning position, average utility and DOC costs are provided in Table 4-3. The utility and DOC staffing levels through each of the decommissioning periods is provided in Table 4-5.

4.4.4.2 Overhead Costs

Based upon corporate and site overhead costs provided by Dominion, an administrative and general cost is included. This cost is based on the average annual administrative and general cost per person applied to each of the utility staffing positions (number of utility personnel assigned to the project). The administrative and general cost includes: site overhead costs directly required to support the site decommissioning staff, and corporate costs allocated to the decommissioning project. The annual costs per person are shown in Table 4-3.

4.4.4.3 Emergency Planning Fees

Based upon current emergency planning fees paid to both federal and local jurisdictions (provided by Dominion) an Emergency Planning Fees cost is included. This cost is based on the current annual fees, but is assumed to decrease during the course of the decommissioning project. The cost per reactor is shown in Table 4-3.

4.4.4.4 Spent Fuel Pool Operations and Maintenance

The study assumes that spent fuel will be stored in the spent fuel pool for approximately 5-1/2 years after plant shutdown. It is assumed that there will be incremental costs associated with operating and maintaining the spent fuel pools. The labor cost associated with operating the pool is included within the Utility Staff cost. Materials, equipment, and contracted services associated with operating and maintaining the pool are listed as "Spent Fuel Pool O&M." The annual cost is shown in Table 4-3.

4.4.4.5 NRC Fees

The NRC is statutorily required to recover most of its budget authority through fees assessed to applicants for an NRC license and to holders of NRC licenses, therefore, the study assumes that the NRC collects fees for their cost recovery. Annual fees for reactors in a decommissioning status are provided in 10 CFR 171.15(c)(1). The staff hourly rates are provided in 10 CFR 170.20(a). It is assumed that the annual fee will be accrued throughout the entire decommissioning period. An estimate was made for the number of NRC man-hours charged to the decommissioning project, which was applied to the hourly rate to estimate a cost. The annual cost and hourly rate is shown in Table 4-3.

4.4.4.6 Insurance

Costs for continuing coverage (nuclear liability and property insurance) following cessation of plant operations and during decommissioning are included and based upon current operating premiums. Reductions in premiums, throughout the decommissioning process, are based upon the guidance and the limits for coverage defined in the NRC’s proposed rulemaking "Financial Protection Requirements for Permanently Shutdown Nuclear Power Reactors." The NRC’s financial protection requirements are based on various reactor (and spent fuel) configurations. The estimated annual premium at the start of decommissioning is shown in Table 4-3.

4.4.4.7 Property Taxes

Property tax payments continue throughout the decommissioning process, although at a substantially reduced level. The annual tax cost was provided by Dominion and is shown in Table 4-3. As discussed in the O&M cost development study, taxes can be significant but are highly dependent on local arrangements and agreements.

4.4.4.8 Energy

For estimating purposes, the plant is assumed to be de-energized, with the exception of those facilities associated with spent fuel storage. Replacement power costs are used for the cost of energy consumption during decommissioning for tooling, lighting, ventilation, and essential services.

Cost for energy used during decommissioning is based on electrical consumption for operating tools, lighting, ventilation, and operating necessary plant equipment. Energy consumption is based on TLG’s model, which is based on industry experience. The unit cost of electricity was provided by Dominion and is shown in Table 4-3.

4.4.4.9 Estimating Assumptions (Noneconomic)

The following are the major noneconomic assumptions made in the development of the estimates for decommissioning the various reactors.

4.4.4.10 Design Conditions

Any fuel cladding failure that occurred during the lifetime of the plant is assumed to have released fission products at sufficiently low levels that the buildup of quantities of long-lived isotopes (for example, ^{137}Cs, ^{90}Sr, or transuranics) has been prevented from reaching levels exceeding those that permit the major NSSS components to be shipped under current transportation regulations and disposal requirements.

The masses of the reactor components were provided by the vendors and incorporated in the estimates. In some cases, additional components were included when required to represent the reactor configuration (e.g., BWR control blades). The curie content of the vessel components at final shutdown are derived from those listed in NUREG/CR-3474. Actual estimates are derived from the curie/gram values contained therein and adjusted for the different mass of the components and projected operating life. Additional short-lived isotopes were derived from NUREG/CR-0130 and NUREG/CR-0672, and benchmarked to the long-lived values from CR-3474. AECL provided curie estimates for major calandria components for the ACR-700 after 60 years' decay; these were compared to PWR curie components decayed a similar amount and the approximate two-year decayed values for the same PWR components were used for the calandria components in the cost estimates.

The PWR control elements are disposed of along with the spent fuel, that is, there is no additional cost provided for their disposal. The disposal cost for the BWR control blades removed from the vessel with the final core load is included within the estimates. Disposition of any blades stored in the pools from operations is considered an operating expense and therefore not accounted for in the estimates. Booster fuel assemblies in the ACR-700 are also assumed to be removed with the spent fuel.

Activation of the reactor building structures is confined to the biological/sacrificial shields. More extensive activation (at very low levels) of the interior structures within containment has been detected at several reactors and the owners have elected to dispose of the affected material at a controlled facility rather than reuse the material as fill on site or send it to a landfill. The ultimate disposition of the material removed from the reactor building will depend upon the site release criteria selected, as well as the designated end use for the site.

4.4.4.11 Transition Activities

Existing warehouses will be cleared of nonessential material and remain for use by the owner and its subcontractors. The plant's operating staff will perform the following activities at no additional cost or credit to the project during the transition period:

- Drain and collect fuel oils, lubricating oils, and transformer oils for recycle and/or sale.
- Drain and collect acids, caustics, and other chemical stores for recycle and/or sale.
- Process operating waste inventories, that is, these estimates do not address the disposition of any legacy wastes; the disposal of operating wastes during this initial period is not considered a decommissioning expense.

4.4.4.12 Scrap and Salvage

The existing plant equipment is considered obsolete and suitable for scrap as deadweight quantities only. The owner will make economically reasonable efforts to salvage equipment following final plant shutdown. However, dismantling techniques assumed for equipment in the estimates are not consistent with removal techniques required for salvage (resale) of equipment. Experience has indicated that some buyers wanted equipment stripped down to very specific requirements before they would consider purchase. This required expensive rework after the equipment had been removed from its installed location. Since placing a salvage value on this machinery and equipment would be speculative, and the value would be small in comparison to the overall decommissioning expenses, this analysis does not attempt to quantify the value that an owner may realize based upon those efforts.

It is assumed, for purposes of these estimates, that any value received from the sale of scrap generated in the dismantling process would be more than offset by the onsite processing costs. The dismantling techniques assumed in the decommissioning estimates do not include the additional cost for size reduction and preparation to meet "furnace ready" conditions. With a volatile market, the potential profit margin in scrap recovery is highly speculative, regardless of the ability to free release this material. An allowance has been included for the survey and release of all metallic material released from the site.

Furniture, tools, mobile equipment such as forklifts, trucks, bulldozers, and other property will be removed at no cost or credit to the decommissioning project. Disposition may include relocation to other facilities. Spare parts will also be made available for alternative use.

4.4.4.13 Site Modifications

The perimeter fence and in-plant security barriers will be moved, as appropriate, to conform to the Site Security Plan in force during the various stages of the project.

Integrated earthworks will be left intact and maintained in accordance with the current dam maintenance and inspection program. The onsite dike and earthwork network forming water retention ponds and lagoons will be disabled to relieve ongoing inspection requirements.

4.4.4.14 Survey and Release of Clean Material

Material that is assumed to be clean (free from internal or external contamination) is released as "scrap" after the material has been radiologically surveyed. An allowance for a free-release survey is included for all material designated as scrap. For PWRs this includes the majority of equipment within the turbine building. In BWRs most of the steam and condensate systems within the turbine building are considered potentially contaminated, and therefore the quantity of scrap material is substantially less.

4.5 Cost Estimates Summary

The results of the decommissioning cost analysis are summarized in Table 4-6. Costs are provided for the major decommissioning cost elements for each reactor. A schedule of expenditures for each reactor design is provided in Tables 4-7 through 4-11. Decommissioning costs are reported in the year of projected expenditure; however, the values are provided in thousands of 2003 dollars. Costs are not inflated, escalated, or discounted over the period of expenditure. The annual expenditures are based upon the detailed activity costs reported in Tables 4-12 through 4-16. These tables also provide an estimate of the labor hour expenditures and the radioactive waste quantities by 10 CFR 61 waste classification.

The estimates described in this report are based on numerous fundamental assumptions, including regulatory requirements, project contingencies, and low-level radioactive waste disposal practices. The primary cost contributors are either labor-related or associated with the management and disposition of the radioactive waste. Program management is the largest single contributor to the overall cost. The magnitude of the expense is a function of both the size of the organization required to manage the decommissioning, as well as the duration of the program.

The cost for waste disposal includes only those costs associated with the controlled disposition of the low-level radioactive waste generated from decontamination and dismantling activities, including plant equipment and components, structural material, filters, resins and dry-active waste. A significant portion of the metallic waste is designated for additional processing and treatment at an offsite facility. Processing reduces the volume of material requiring controlled disposal through such techniques and processes as survey and sorting, decontamination, and volume reduction. The material that cannot be unconditionally released is packaged for controlled disposal.

Estimates to decommission nuclear facilities are typically comprised of several cost drivers. Some cost centers are directly related to the physical plant while others are more common to the management of any large remediation project. Based upon the information available, the advanced reactor designs offer comparable power production with fewer and less complex system components than similar, contemporary designs. As such, with comparable operating histories, the costs associated with the disposition of the contaminated physical plant are correspondingly less for the advanced reactors. This savings has been incorporated within the estimates described in Section 4 for the advanced reactor designs and are principally reflected in those cost elements comprised of direct removal labor and materials and radioactive material disposition (processing, disposal or survey and release). Since the disposition of the plant structures was restricted to only the affected areas requiring decontamination and release necessary to support license termination, the physical differences in facility size did not have as much impact on reducing decommissioning costs as facility configuration for the advanced reactors.

The disposition of radioactive material from a nuclear unit, while a contributor to the overall cost of decontamination and dismantling, is only one of the cost drivers in executing a successful decommissioning project. Typically, the largest cost elements in an estimate for a commercial reactor are project management (including engineering, radiation protection and support, and spent fuel operations), site administration, and security. While there are many support and oversight functions that are related to the level of physical activity at a site, many positions in the organization are independent of the field effort. The organizations (owner and contractors) and the associated costs incorporated within the decommissioning estimates for the advance reactor designs are not assumed to be significantly different than managing the sites currently being decommissioned. These organizations are used as a planning basis for most operating commercial reactors. The completion schedule(s) for the decontamination and dismantling of the advanced reactor designs, consistent with those developed for existing reactors, is based, in large part, upon the availability of the wet spent fuel storage facilities for decommissioning. With a common assumption that the spent fuel would require a minimum cooling period of five years before its relocation to a DOE facility or to an independent onsite dry storage facility, physical differences in the advanced reactor designs, as they pertain to the decommissioning schedule, are somewhat mitigated. Additional savings may be available if the disposition of the final core discharge can be accelerated; however, this is unlikely since higher power density cores may require additional active cooling and, correspondingly, a longer wet storage time period.

There are other costs that are also insensitive to the physical plant. Insurance, NRC fees and other "operating" expenses are driven by the overall program duration and housekeeping demands rather than design differences or component inventory. Again, there may be additional savings in schedule-dependent costs with increased scheduling efficiencies.

Overall, with consistent operating and management assumptions, the total decommissioning costs projected for the advanced reactor designs are comparable to those projected for operating reactors with appropriate reductions in costs due to reduced physical plant inventories. It is important to consider, however, that there are many site-specific factors and design variables that can affect the validity of this observation.

4.5.1 Comparison Among Advanced Reactor Designs

The following table summarizes the variations in systems/structures disposition costs among the various advanced reactor designs.

Systems/Structures Decommissioning Cost Summary
(in thousands of 2003 dollars)

Cost Component	ABWR	ACR-700	AP1000	ESBWR
Systems Disposition	$136,221	$70,894	$43,823	$130,668
Reactor/Calandria and Associated Component Disposition	$105,176	$71,741	$85,242	$85,001
Structures Decontamination	$22,197	$13,604	$11,379	$26,014
Total	**$263,594**	**$156,239**	**$140,444**	**$241,683**

The systems/structures decommissioning costs for the ACR-700 and AP1000 designs are the lowest. This is primarily due to the extent of systems containing radioactive material. For both these reactor types, the analysis assumes that the secondary systems do not become contaminated. The clean secondary systems in these designs result in significant avoided costs in systems removal and disposal. The higher systems removal cost for the ACR-700 versus the AP1000 is a result of the larger number of contaminated calandria and moderator circuit systems in the ACR design. From a design perspective, the predominant factor that affects the decommissioning cost of these reactor designs is the reliability of the steam generators and the ability to contain the radioactive material within the primary system boundary throughout the plant life.

The BWR designs (ABWR and ESBWR) have the highest systems/structures decommissioning costs due to the additional cost for removal and disposition of contaminated secondary system components. The structures decontamination cost for the BWRs are significantly higher than the other advanced reactor designs due to the potential for contamination in the turbine building and due to the significantly larger inventory of potentially contaminated embedded steel liner that exists in the reactor and containment structures. Similar to the ACR-700 and AP1000, the integrity and reliability of the components that contain contaminated fluids are important in controlling the decommissioning cost. The estimates assume the long-term reliability and integrity of the many tanks and pools containing contaminated water, therefore precluding the migration of water beyond the designated boundaries. The decommissioning costs are slightly reduced for the ESBWR relative to the ABWR due to the smaller systems inventory and lower reactor internals masses.

4.5.2 Comparison With Contemporary Reactor Designs

In comparing the decommissioning requirements for advanced reactor designs with current contemporary designs, there are four principal cost drivers worth considering:

- Overall program schedule (the duration from shutdown to license termination)
- The quantity of plant equipment necessary to be removed to support license termination
- The level of contamination or activation of plant equipment and structures
- The extent of remaining building contamination required to be remediated to support license termination

Other significant cost drivers include the cost of labor, nuclear liability and property insurance, corporate overheads, regulatory agency fees, and waste processing, survey and release, and disposal unit costs. Although significant to the decommissioning project, these are essentially not affected by the plant design.

4.5.2.1 Overall Program Schedule

The overall program schedule is not expected to vary significantly between contemporary reactors and the advanced reactor designs. The most significant activity that controls the overall decommissioning schedule is the requirement to store spent fuel in a wet storage pool, until it either meets DOE acceptance requirements, or onsite dry storage requirements. Final decommissioning, which includes removing spent fuel storage systems and contaminated structures, can only take place after the spent fuel has been transferred from the storage pool. Since the advanced designs are not expected to result in significant differences in decay heat generation from contemporary designs, the overall decommissioning schedule will continue to be constrained by fuel storage pool operations (currently assumed to be a minimum of 5 years).

4.5.2.2 Quantity of Plant Equipment

The quantity of plant equipment requiring disposition appears to have been reduced in the advanced reactor designs. This reduction will have a noticeable impact on the decommissioning cost, including reduced labor costs associated with removal and radiation protection, reduced decommissioning equipment and material costs, reduced waste processing and disposal costs, as well as reduced equipment survey costs. The reduction in quantity of plant equipment is not expected to have a substantial affect on the program management and support costs, since many of the position requirements are independent of the quantity of material, and are more directly related to the decommissioning program duration. For instance, the operations department responsible for spent fuel will be required to be present for at least 5 years.

There are other factors that need to be considered when comparing the inventories of the advanced reactors with contemporary designs. The operating plant estimates have inventory quantities based on as-installed information, including construction quantities, typically extracted from post-construction reports, or as-installed plant information (e.g., P&ID drawings, or general arrangement drawings). The advanced reactor design information does not necessarily reflect as-installed conditions. It should also be noted that the quantity of plant equipment assumed to be included within the decommissioning program for the AP1000 and ACR-700 units is highly dependent on the physical integrity of the steam generators. This study assumed that steam generator tube leakage was not significant enough to cause a contamination concern for the secondary systems. Significant steam generator tube failures could substantially increase the plant equipment that would be included within the decommissioning inventory. Some contemporary designs with steam generators have included secondary side contamination in their decommissioning estimates due to steam generator tube failures. Notwithstanding these observations, the advanced reactors appear to have reduced installed quantities of material, which will result in a decrease in decommissioning costs compared to contemporary designs.

4.5.2.3 Level of Contamination or Activation

The advanced reactor designs are expected to have improved material selection and water chemistry resulting in reduced radiation levels during plant operations. This will have a direct effect on the working conditions during decommissioning, reducing ALARA-related expenditures. The impact should be measurable, but will not result in significant decommissioning cost reductions since the majority of the radiation protection practices and procedures are used regardless of small changes in dose rates, or contamination levels. Similarly, the cost of waste disposal or processing does not substantially change with small changes in dose rates or contamination levels. The level of contamination, particularly for those components or areas expected to be radiologically clean could increase decommissioning costs as a result of operating events (such as cross-contaminating systems, overflowing tanks containing radioactive material, failure to promptly clean up radioactive spills or leaks, or fuel failures).

Activation of structural materials surrounding the reactor vessel or calandria is expected to occur. This will result in a decommissioning requirement to remove concrete and steel liners in these affected areas. There appears to be no substantial difference in the amount of activation expected between the advanced reactor designs and contemporary designs.

4.5.2.4 Extent of Building Contamination

The level of effort to decontaminate the advanced reactor buildings as part of the decommissioning scope is expected to decrease from contemporary reactor designs, believed to be principally due to plant layout. Although a specific comparison between the advanced reactor and contemporary plant designs was not conducted, the estimating model techniques were similar between the different reactor designs. In comparing the level of effort to decontaminate buildings (using similar modeling techniques), all of the advanced reactor designs had a substantial reduction in man-hours to decontaminate the structures. Possibly contributing to this reduction are considerations such as locating contaminated equipment in common areas (resulting in a reduced area subject to potential contamination), and incorporating steel-lined concrete into the design (easier to decontaminate steel-lined concrete than uncoated concrete). It should be noted that the extent of building contamination is very difficult to predict, since it is highly dependent on plant operations. Assumptions made as part of a decommissioning study could vary substantially from the final building condition.

4.6 Areas of Future Cost Savings

The estimates for the advanced design reactors are based on numerous fundamental assumptions, including current regulatory requirements, existing technology, and present waste disposal practices. The estimates reflect a labor-intensive process and rigorous control of the byproducts from the decontamination and dismantling activities. If the past ten years are indicative, there will be continued advances in technology that will serve to facilitate the decommissioning process. The role of the regulator(s) is less certain. The commercial industry has experience regulatory pressure from federal agencies as well as from state and local interests in remediating contaminated sites. While the cumulative impact was not fully realized by today’s owners until the decommissioning process was underway, future licensees will benefit from a certain level of regulatory precedent in the planning for future projects. Waste disposal prospects are even less certain, particularly with the failure of federal legislation to promote the development of new disposal sites and the pending closure of the Barnwell facility to non-compact generators and with it a certain level of competition. Without the availability of additional disposal sites, future waste generators may be confronted with the monopolistic pricing practices of the past.

4.6.1 Technology

Technology and its impact on future endeavors are highly speculative. While new technology is generally associated with improved productivity and personnel safety, advances in technology do not necessarily translate into cost savings. Higher operating costs can come with greater technical sophistication and while machines can replace skilled labor in many instances, the capital cost and technical support required may not be economical for many applications. While there are many repetitive activities in decommissioning, working conditions can favor brute force rather than technology.

In general, the "technology" incorporated into the design and construction of the advanced reactors will also facilitate decommissioning. Designs that simplify maintenance, including component replacement, also benefit decommissioning. Design features that minimize working area radiation levels or contamination levels can reduce the effort and cost to ultimately remediate components and structural surfaces. Some of the contributors to increasing decommissioning costs are identified in the following narrative. Methods or "technology" to reduce or eliminate these sources will allow the owner to manage the escalation of decommissioning costs.

4.6.1.1 Neutron Streaming

Activation of the structural materials surrounding the reactor is a normal consequence of operation. However, several of the reactors undergoing decommissioning have detected activation in the outlying structures, for example, refueling canal, overhead crane, and/or containment walls. This additional material, while low in level, has required controlled disposal.

4.6.1.2 Boundary Leakage

The cost of decommissioning increases during a reactor's operating life as radiological sources migrate beyond their "design boundaries." For example, steam generator tube leakage provides a mechanism for contamination of the secondary side of the steam plant in a PWR. While the levels of contaminates are low and can be acceptable for operations, their presence during decommissioning can add considerable expense. Containing contaminates can reduce or eliminate the need for material decontamination, processing and/or controlled disposal. At a minimum, suspected systems and components will require additional surveying before their release from the site.

4.6.1.3 Internal Contamination

Contamination is the primary dose contributor to the decommissioning workforce. Located within the corrosion layer of piping and components, hot spots develop around irregularities on the internal surfaces. Passivation of the surfaces before the installation may be able to minimize the accumulation of contaminants during operation and reduce decontamination costs and ALARA concerns during dismantling.

Material selection can also reduce the inventory of radioactive materials by eliminating unnecessary trace elements that can produce long-lived radioisotopes. Plant chemistry can also contribute to material wear and should be controlled in a way to reduce the inventory of radioactive materials. A particular benefit to both operations and decommissioning is the elimination or minimization of fuel cladding failures. These types of failures could result in alpha contamination in the plant, which could substantially increase the radiological control requirements, and produce higher operating and decommissioning costs.

4.6.1.4 External Contamination

The removal of external surface contamination can be labor intensive, particularly where the contamination has penetrated the outer layer and migrated into the material matrix. For example, concrete with a porous finish, or concrete poured in segments can allow contamination to seep into cracks and fissures, following rebar and other pathways. This situation can be minimized by the good operating practice of promptly stopping the source of contamination (repair the source of the leak), and promptly cleaning the affected area to levels consistent with decommissioning release criteria. Covering the area after it has become contaminated, either through the use of coatings (paint) to reduce the extent of surface contamination, or with concrete (in the case of large source terms) may be expedient while operating, but can create substantial amount of additional decommissioning work. This work includes the removal of the coverings, detection of the contamination (identifying the extent of contamination), as well as monitoring the results of the decontamination.

4.6.1.5 Surface Finish

Sealing the surfaces before plant startup can minimize the adhesion of the contaminants and reduce the potential for surface penetration. A sealed surface is easier to maintain during operations and easier to decontaminate during decommissioning. For example, if a surface can be decontaminated without destroying the continuity (smoothness) of the surface, that is, by scarification or spalling, surface surveys are greatly simplified. Very good, durable epoxy coatings are available and will pay dividends for normal operation and decommissioning. While coatings can be very effective in minimizing the expense associated with decommissioning, they must be selected to minimize the expense associated with removal. For instance, the removal of coatings at older plants has uncovered additives with PCB or asbestos constituents, as well as lead-based paints, complicating the cutting and handling of the radioactively contaminated materials. Consequently, finish material selection should consider disposal and handling requirements, particularly to avoid creating a unique waste stream.

4.6.1.6 Transportation

Decommissioning involves the removal and relocation of a large quantity of material. While rail lines and barge slips are used extensively during construction, they are typically not used to support plant operations and may be allowed to fall into disrepair. These facilities, should they be available during decommissioning, can facilitate the bulk removal and transportation of large components and debris. This is particularly beneficial if the waste processor/disposal sites have access to these types of transportation modes and offer price discounts for material received in bulk.

4.6.1.7 Reactor Vessel (with Internals) One-Piece Disposal

One-piece reactor vessel removal, transportation, and disposal has many potential benefits, including reduced worker exposure to hazards, reduced opportunities to disperse contaminants, reduction in total waste produced, and reduced cost. This approach has been proven viable with the Trojan reactor, as well as with numerous U.S. Navy submarine reactor compartments. However, it is generally not compatible with current disposal site waste acceptance criteria.

4.6.1.8 Spent Fuel Storage Systems Design

The design of the spent fuel pool cooling system should consider capability to isolate the spent fuel cooling system from the normal supporting mechanical and electrical systems to support decommissioning.

4.6.2 Regulatory

Regulations, and compliance with regulations, are an important consideration in decommissioning a licensed reactor. Since the shutdown of several large power reactors in the 1990's, the Code of Federal Regulations has been revised, and the NRC has issued guidance to facilitate decommissioning work. Although it can be reasonably assumed that this process of revising regulations will continue, it can also be reasonably assumed that during this process some of these requirements will result in cost savings, while others may increase costs. Therefore even though there may be changes in regulations that may result in decommissioning savings in the future, since there may also be changes that result in increased decommissioning expense, no savings for improved regulations were considered in these estimates.

4.6.3 Waste Disposal

Disposal of low-level radioactive waste is a significant decommissioning project cost. The contribution of waste disposal is approximately 60% of the total project costs based on the current NRC minimum funding formula (with the use of waste processors). While the TLG studies indicate that the contribution from waste disposal is smaller (approximately 24%–35% of the total cost), it is clear that regardless of the method of estimating, the cost of waste disposal (or processing) is a significant contributor to the total cost. Currently there is limited competition for waste disposal, since there are only two licensed disposal facilities able to dispose of commercially generated radioactive waste, Barnwell in South Carolina, and the Envirocare facility in Utah (this excludes generators in the Northwest and Rocky Mountain Compacts, which have access to a disposal facility at the Hanford site). A limited number of competitors generally can be assumed to result in higher prices, since the supplier has more pricing power in the absence of competition.

The operators of Barnwell have announced that they plan to discontinue accepting waste from non-compact generators after 2008 (effectively eliminating Envirocare's competition). This potential for increased prices due to reduced competition has not been reflected in this study, since the waste generators have options if the disposal cost became prohibitive (such as deferring decommissioning). Conversely, the benefits of reduced disposal prices if additional waste disposal facilities are licensed, and authorized to receive commercially generated waste (for example, facilities currently only available to U.S. government generators, or the proposed facility in Texas) have not been factored into this study.

In the process of decommissioning, any material that is not designated for controlled disposal (including offsite processing at a licensed facility) must meet the limits for uncontrolled use. The NRC has been unsuccessful in establishing national threshold levels for the release of solid waste, that is, limits that would define acceptable levels of contaminates. Coupled with advances in detectors and other analytical instrumentation, radioactivity, at some level, can be detected on most materials. Without quantitative guidelines, our burial capacity will be consumed with material no more contaminated than construction debris or household waste. In addition, naturally occurring elements can be the primary contributor in the activity of materials such as concrete, soil and bedrock. The reluctance to differentiate between artificial and man-made sources increases the volume of material requiring controlled disposal that might be avoided with workable guidelines.

4.7 Decommissioning Costs and NRC Funding Requirements

4.7.1 NRC Minimum

NRC financial requirements for decommissioning are intended to prevent funding shortfalls that could adversely affect public health and safety. Requirements for establishing the minimum funding amounts for decommissioning are set out in 10 CFR 50.33(k), 50.75, 50.82(a)(4), 50.82(a)(8), and 50.82(a)(9). An initial certification amount for decommissioning is established at the operating license stage. The certification amount in 10 CFR 50.75(c)(1) acts as a threshold review level and while not necessarily representing the actual cost of decommissioning for specific reactors, provides assurance that licensees are able to demonstrate adequate financial responsibility in that the bulk of the funds necessary for a safe decommissioning are being considered and planned for early in facility life.

The requirements for funding of decommissioning are discussed in more detail in the NRC’s Regulatory Guide 1.159. As stated in the 1.159, "The certification amounts in 10 CFR 50.75(c)(1) act as threshold review levels. While not necessarily representing the actual cost of decommissioning for specific reactors, these certification amounts provide assurance that licensees are able to demonstrate adequate financial responsibility in that the bulk of the funds necessary for a safe decommissioning are being considered and planned for early in facility life, thus providing adequate assurance that the facility will not become a risk to public health and safety when it is decommissioned."

The original certification levels were developed in 1988 in support of the NRC’s "General Requirements for Decommissioning Nuclear Facilities," issued in June of 1988 and were based upon decommissioning cost estimates prepared by Battelle Pacific Northwest Laboratories for two representative nuclear units, one PWR and one BWR. To adjust these initial values over the operating life of a nuclear unit, 10 CFR 50.75(c)(2) contains a formula to account for inflation that has occurred in the labor, energy, and waste burial components of decommissioning costs. While new indices are issued via NUREG-1307 (‘‘Report on Waste Burial Charges"), the base decommissioning costs have not been updated, that is, the original estimates for decommissioning have not been revised since 1988 in Addendum 4 to NUREG/CR-0130 and Addendum 3 to NUREG/CR-0672. Consequently, with one exception, the bases for the certification levels represent practices and methods for decontamination, dismantling, program management, and other required activities necessary to terminate an operating license dating back to the early 1980s.

Power reactor licensees are required to report to the NRC, at least once every two years, on the status of its decommissioning funding. The report must include, at a minimum, the amount of decommissioning funds estimated to be required pursuant to 10 CFR 50.75 (b). As described previously, the NRC publishes updated escalation indices via NUREG-1307. Due to several factors, including the addition of surcharges resulting from the Low-Level Radioactive Waste Policy Amendments Act of 1985, the escalation of waste disposal charges in the mid-1990s produced higher certification values than many comparable site-specific estimates. With many licensees contemplating exemptions, the NRC included (for the first time in Revision 8 of NUREG-1307, published in December of 1998) the option of mitigating these increases by allowing licensees to incorporate current industry trends in waste conditioning and volume reduction. Enabling this option reduced the threshold levels and ensured compliance by the majority of the industry. While producing the desired result, the manipulation of the economic indices did nothing to realign the original modeling assumptions for waste disposal. The same can be said for the other components of the cost estimates that form the bases for the NRC's certification levels. Expenditures at ongoing decommissioning projects are expected to exceed the "threshold" levels established by the NRC, in some instances by a large margin. While differences in scope can be a factor, the disparities are more likely due to the complexities of the decommissioning process, particularly in today's regulatory and risk environment, which were not fully anticipated in the vintage 1980 estimates.

The minimum certification amounts for the four advanced reactor designs were calculated using the formula delineated in 10 CFR 50.75(c)(1) and the escalation indices provided in NUREG-1307, Rev. 10, dated October 2002 (latest revision) for both the waste recycling and waste burial only options. The funding levels for each reactor design are identified in Table 4-17, with and without use of waste vendors. The differences in the values calculated are primarily a function of the thermal power ratings and type of reactor (PWR or BWR), as the geographic region and burial compact are assumed to be identical. This table also provides the corresponding values from the study estimates for the four reactors.

4.7.2 Decommissioning Funding Guidelines

As delineated in 10 CFR 50.75(e)(1), the following methods are acceptable for financing reactor decommissioning. (Italicized text is extracted from Regulatory Guide 1.159, Rev. 1, October 2003.)

> *Prepayment*
>
> *The deposit preceding the start of operation, or the transfer of a license pursuant to 10 CFR 50.80, into an account segregated from licensee assets and outside the administrative control of the licensee and its subsidiaries or affiliates of cash or liquid assets such that the amount of funds would be sufficient to pay decommissioning costs at the time permanent termination of operations is expected. Prepayment may be in the form of a trust, escrow account, government fund, certificate of deposit, deposit of government securities, or other payment acceptable to the NRC.*

> *External Sinking Fund*
>
> *A fund established and maintained by setting funds aside periodically in an account segregated from licensee assets and outside the administrative control of the licensee and its subsidiaries or affiliates in which the total amount of funds would be sufficient to pay decommissioning costs at the time permanent termination of operations is expected. An external sinking fund may be in the form of a trust, escrow account, government fund, certificate of deposit, deposit of government securities, or other payment acceptable to the NRC.*
>
> *Guarantee Method*
>
> *Can be in the form of surety bonds, letters of credit, or insurance; parent company guarantees may be used when a financial test specified in Appendix A to 10 CFR Part 30 is used.*
>
> *Statement of Intent*
>
> *A Statement of Intent by a government agency, if applicable, indicates that funds for decommissioning will be obtained when necessary.*
>
> *Contractual Obligations*
>
> *Obligations on the part of a licensee's customers, the total amount of which over the duration of the contracts will provide the licensee's total share of uncollected funds to be needed for decommissioning pursuant to 10 CFR 50.75(c), 50.75(f), or 50.82.*
>
> *Other Mechanisms*
>
> *Refers to any other mechanism, or combination of mechanisms, that provides assurance of decommissioning funding equivalent to that provided by the mechanisms listed above.*

"For decommissioning funds that are prepaid or in external sinking fund accounts, the regulations in 10 CFR 50.75(e)(i) and (ii) allow a credit for projected earnings of up to a 2 percent annual real rate of return (that is, nominal rate less inflation) from the time of future funds' collection as a factor in calculating the total amount of funds that would be sufficient to pay decommissioning costs."

4.7.3 History and Precedent

In 2001, Exelon Generation (Exelon) met with the NRC's staff to discuss its consideration to pursue a combined license and a design certification for the Pebble Bed Modular Reactor (PBMR). Exelon planned to operate the PBMR as a merchant plant. Exelon submitted a series of white papers on various legal and financial issues and requested an agency response. Included in the white papers were requirements associated with minimum decommissioning costs and funding. The staff's assessment on the white papers is provided in SECY-01-0207, dated November 20, 2001.

Exelon proposed to seek a license as a nonutility. This would, according to current NRC regulations, provide Exelon with several options for funding decommissioning, but not the sinking fund option. According to the NRC, "utilities are licensees that are rate-regulated and may use any of the six methods. Non-rate-regulated licensees, such as merchant plant operators, may not use the sinking fund method, but are allowed to use any of the other methods. The only notable exception to the above is a power reactor licensee that has the full faith and credit backing of the United States Government." Exelon's position was that 100-percent prepayment for new plants might jeopardize the economic viability of any new plant to be operated as a merchant plant because of the higher present worth of the prepayment relative to other funding mechanisms, which allow payments at a later time.

Exelon indicated that it would propose an alternative decommissioning funding method for the PBMR. An alternative method involving a partial payment of the total decommissioning cost estimate and annual contributions over the next 20 years was identified although Exelon also indicated that it had not yet decided on an alternative funding method. The staff's position was that the intent of its financial regulations was to provide assurance that decommissioning funding is available, particularly in the event of a permanent shutdown of the plant before the expiration of the license. Exelon's proposal, in its opinion, was a form of a sinking fund which the staff did not believe would provides the same level of assurance as other funding options available to non-rate-regulated entities. The staff did not believe that Exelon's proposal was consistent with current requirements or that an exemption to use the sinking fund could be justified since Exelon, as a nonutility, would not have a rate base rate of return.

If Exelon used a prepayment option, it could take the 2-percent real earnings credit over the projected operating period. According to the staff, "the present value of even a relatively large decommissioning cost, when discounted back at 2-percent real rate of return, should not be very large and should thus not require an onerous initial deposit."

Table 4.17 also contains prepayment levels, assuming a 2 percent real earning credit over a 40 and a 60-year operating life. Using the NRC's certification values, the range is between $90 and $188 million, depending upon reactor design and assumed operating period. The corresponding calculation for the site-specific estimates produces values between $118 and $251 million. Without a prepayment exemption, the financial guarantees for decommissioning may well factor into the economics of new construction.

Table 4-1. Decommissioning Study — Plant Equipment Inventories

Component	ABWR		ACR-700 (each unit)		AP1000		ESBWR	
	Surveyed and Released as Clean Material	Controlled Disposal	Surveyed and Released as Clean Material	Controlled Disposal	Surveyed and Released as Clean Material	Controlled Disposal	Surveyed and Released as Clean Material	Controlled Disposal
Piping 0.25 to 2 inches diameter, linear foot	(proprietary)		(proprietary)		(proprietary)		(proprietary)	
Piping >2 to 4 inches diameter, linear foot								
Piping >4 to 8 inches diameter, linear foot								
Piping >8 to 14 inches diameter, linear foot								
Piping >14 to 20 inches diameter, linear foot								
Piping >20 to 36 inches diameter, linear foot								
Piping >36 inches diameter, linear foot								
Valves >2 to 4 inches								
Valves >4 to 8 inches								
Valves >8 to 14 inches								
Valves >14 to 20 inches								
Valves >20 to 36 inches								
Valves >36 inches								
Supports for small bore piping								
Supports for large bore piping								
Pump and motor, <300 pound								
Pumps, 300-1000 pound								
Pumps, >1000-10,000 pound								
Pumps, >10,000 pound								
Pump motors, 300-1000 pound								
Pump motors, >1000-10,000 pound								
Pump motors, >10,000 pound								
Turbine-driven pumps, <10,000 pound								
Turbine-driven pumps, >10,000 pound								
Reactor Coolant or Heat Transport Pump and Motor								
Reactor Coolant or Heat Transport Pump and Motor (each), pounds								
Heat exchanger <3000 pound								
Heat exchanger >3000 pound								
Feedwater heater/deaerator								
Moisture separator/reheater								
Steam Generators								
Steam generator, pounds								
Pressurizer, pounds								
Tanks, <300 gallons, filters, and ion exchangers								
Tanks, 300-3000 gallons								

Table 4-1. Decommissioning Study — Plant Equipment Inventories

Component	ABWR		ACR-700 (each unit)		AP1000		ESBWR	
	Surveyed and Released as Clean Material	Controlled Disposal	Surveyed and Released as Clean Material	Controlled Disposal	Surveyed and Released as Clean Material	Controlled Disposal	Surveyed and Released as Clean Material	Controlled Disposal
Tanks, >3000 gallons, square foot surface								
Electrical equipment, <300 pound								
Electrical equipment, 300-1000 pound								
Electrical equipment, 1000-10,000 pound								
Electrical equipment, >10,000 pound								
Electrical cable tray, linear foot								
Electrical conduit, linear foot								
Mechanical equipment, <300 pound								
Mechanical equipment, 300-1000 pound								
Mechanical equipment, 1000-10,000 pound								
Mechanical equipment, >10,000 pound								
HVAC equipment, <300 pound								
HVAC equipment, 300-1000 pound								
HVAC equipment, 1000-10,000 pound								
HVAC equipment, >10,000 pound								
HVAC ductwork, pound								

Table 4-2. Decommissioning Study - Plant Structures Inventories

Item	ABWR Quantities	ACR-700 (each unit) Quantities	AP1000 Quantities	ESBWR Quantities
Clean Concrete Removed (cubic yards)	(proprietary)	(proprietary)	(proprietary)	(proprietary)
Contaminated or Activated Concrete Removed (cubic yards)				
Decontamination of Concrete (square feet)				
Plant Cranes Removed				
Contam. overhead cranes/monorails >10 - 50 ton cap., each				
Polar cranes >50 ton capacity, each				
Gantry cranes >50 ton capacity, each				
Building Steel Removed				
Clean steel floor grating, square foot				
Contaminated steel floor grating, square foot				
Clean free-standing steel liner, square foot				
Contaminated free-standing steel liner, square foot				
Clean concrete anchored steel liner, square foot				
Contaminated concrete anchored steel liner, square foot				
Scaffolding Installed for Access				
Placement of scaffolding in clean areas, square foot				
Placement of scaffolding in contaminated areas, square foot				
General Building Information				
Total buildings floor area, square foot				
Total buildings free volume, cubic foot				
Additional decon of surfaces by washing, square foot				

Table 4-3. DECCER Model Inputs
(all costs in 2003 dollars, unless otherwise noted)

Data Input Description	Value
Labor-Related Costs	
Average Annual Cost (w/benefits) - Utility Staff	97,975
Average Annual Cost (w/benefits, overhead and profit) - DOC Staff	157,970
Average Hourly Rate - Security Officer	42.57
Average Hourly Rate - Contract HP Technician	44.15
Average Hourly Rate - Laborer	34.25
Average Hourly Rate - Craftsman	46.43
Average Hourly Rate - Foreman (Including Laborer Foreman)	45.81
Average Hourly Rate - General Foreman	47.22
Average Hourly Rate - Consultant	85.69
Number of DOC staff eligible for relocation costs	25
Average Annual Site Overhead Cost (cost per utility employee)	3,499
Average Annual Corporate Overhead Cost (cost per utility employee)	14,111
U.S. GSA CONUS local "Standard" per diem rate (combined), $ per day	112.00
Government/Regulatory Agency Fees	
NRC Annual License Fee	319,000
NRC hourly rate (10 CFR 170.20), $ per hour	156
Average Annual Property Tax	20,625
Average Annual Fees to Government Agencies (at time of shutdown) - Emergency Planning	547,750
Spent-Fuel Storage	
Annual Cost Spent Fuel Pool O & M (excluding utility labor)	706,372
Duration Spent Fuel Stored Wet (years)	5.5
Plant Data	
Operating Life (years)	60
Reference Year (e.g., 2001)	2003
Rated electrical generating capacity, MWe - ACR-700 [single unit]	703
Rated electrical generating capacity, MWe - ABWR	1,371
Rated electrical generating capacity, MWe - AP1000	1,150
Rated electrical generating capacity, MWe - ESBWR	1,340
Rated thermal power, MWt - ACR-700 [single unit]	2,032
Rated thermal power, MWt - ABWR	3,926
Rated thermal power, MWt - AP1000	3,415
Rated thermal power, MWt - ESBWR	4,000
Work Schedule	
Hours Worked per Week	40
Hours Worked per Day	8
Holidays per Year	10
Other Costs	
Annual Nuclear Property and Liability Insurance (immediately after shutdown)	1,344,000
Cost of electricity, $/kWhr	0.035
Composite Regional Adjustment Factor (Cost of Materials and Equipment)	0.96
Average Sales Tax (Purchased Materials) (%)	3.8
Shipping	
Cost for std wt LSA truck shipment to burial site, $/trip	4,135
Cost for shielded van shipment to primary burial site, $/trip	8,869
Cost for cask shipment outbound to primary burial site, $/cwt	24.14
Cost for cask shipment return from primary burial site, $/cwt	12.40
Cost for std wt LSA truck shipment to LLRW processor, $/trip	1,057
Rail shipping charges from site to burial site, $/cwt	13.52

Table 4-3. DECCER Model Inputs
(all costs in 2003 dollars, unless otherwise noted)

Data Input Description	Value
Shipping distance from site to burial site, miles	1,999
Railcar for Stm Gen transport rental, $/month	31,481
Rail special train surcharge, $/mile	52.47
Shipping distance from site to LLRW processor, miles	508
Burial/Disposal	
Primary burial site disposal charge, $ per pound	5.17
Tertiary burial site disposal charge, $ per pound	2.00
Primary burial site curie surcharge, $ per millicurie	0.38
Primary burial site class A average waste density, pounds/cubic ft	85
Tertiary burial site class A average waste density, pounds/cubic ft	100
Radioactive waste offsite processing costs, $/lb	2.00
Recycling LLRW average waste density, pounds/cubic ft	45
Disposal rate for dry activated waste, $ per cubic foot	40
Survey and Release of Clean Metallic Material, $ per pound	0.60
Greater-Than-Class-C Disposal Cost ($ per cubic foot)	25,000

Table 4-4. Decommissioning Waste Disposition Summary

Low-Level Waste	Waste Classification	Quantity of Material Weight (pounds)			
		ABWR	ACR-700 (typ - unit)	AP1000	ESBWR
Barnwell[1]					
	A	5,888,589	5,856,479	5,441,940	6,367,116
	B	2,302,804	533,053	1,193,545	2,215,615
	C	124,785	60,314	40,886	105,044
Envirocare[2]					
	A	2,234,875	3,575,642	873,023	2,360,324
Waste Sent to Offsite Processor		27,680,550	9,388,755	5,189,790	27,080,450
Geological Repository					
	GTCC	182,984	77,603	124,964	110,231
Survey and Released		11,193,900	28,020,565	25,505,684	8,080,150
Total		**49,608,487**	**47,512,410**	**38,369,832**	**46,318,930**

Note: 1 – Disposed of at prices equivalent to the Barnwell facility
Note: 2 – Disposed of at prices equivalent to the Envirocare facility

Table 4-5. Decommissioning Staffing Levels

Period	Period Description	Nominal Staffing Levels							
		Utility			DOC			Security	
Period 1a	Shutdown through transition	210		[168]	0			28	[13]
1b	Preparations for DECON	211		[168]	61		[45]	28	[13]
2a	Preparations for DECON	149		[149]	76			35	
2b	Site decontamination (end wet fuel)	143	(90)	[103]	73	(29)	[54]	28	[13]
2c	Decontamination following wet fuel	102		[69]	50		[37]	28	[13]
2d	Delay before license termination			[8]			[0]		[4]
2e	License termination	51		[26]	37		[23]	9	[4]

( ) - indicates values for AP1000 only
[ ] - indicates values for 2nd ACR unit only

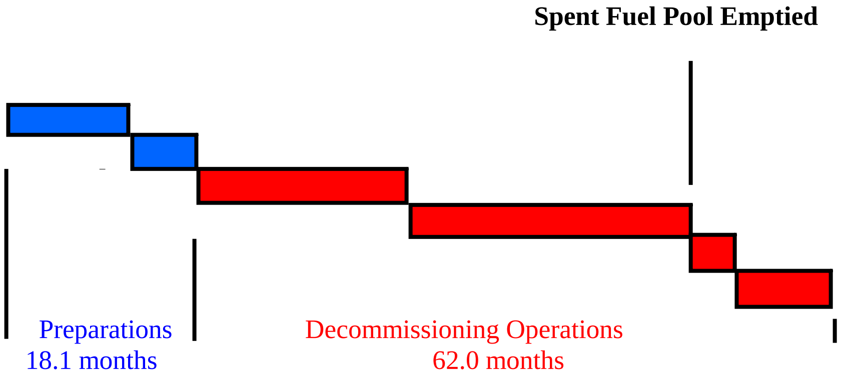
Table 4-6. Summary of Decommissioning Costs
(all values are in thousands of 2003 dollars)

Category	ABWR	ACR-700 Unit 1	ACR-700 Unit 2	AP1000	ESBWR
Decontamination	14,931	6,452	6,452	7,075	15,080
Removal	82,825	60,904	62,427	47,664	79,080
Packaging	15,468	7,262	7,261	9,971	12,866
Transportation	9,396	4,977	4,976	5,050	9,118
Waste Disposal	121,817	70,556	70,551	71,209	106,440
Offsite Waste Processing	63,665	21,950	21,950	12,427	62,285
Program Management (including Engineering and Security)	210,695	172,691	191,710	177,816	210,467
Spent Fuel Pool Isolation	9,269	9,269	6,179	9,269	9,269
Site & Corporate Overhead (A&G)	19,766	17,003	18,453	16,948	19,761
Insurance and Regulatory Fees	8,309	9,096	8,327	8,360	8,318
Energy	5,563	3,544	3,481	4,981	5,529
Characterization and Licensing Surveys	15,367	14,086	14,179	15,728	14,448
Survey & Release of Scrap Material	4,193	14,582	14,582	16,223	4,012
Miscellaneous Equipment & Services	5,925	5,905	5,882	5,895	5,967
Emergency Planning Fees, Spent Fuel O&M	7,802	8,080	7,781	7,796	7,794
Total	**594,991**	**426,358**	**444,191**	**416,412**	**570,433**

Table 4-7. Schedule of Annual Expenditures by Decommissioning Period for the ABWR (thousands, 2003 dollars)

	Decommissioning Activity	Years 1	2	3	4	5	6	7	Total
Period									
1a	Transition and Planning	60,102							60,102
1b	Decommissioning Preparations (DOC Mobilization)		31,417						31,417
2a	Large Component Removal		72,717	147,857	37,166				257,740
2b	BOP Systems Removal				65,490	87,559	43,420		196,469
2c	Building Decontamination (following fuel transfer from pool)						23,438		23,438
2e	License Termination and NRC Review						2,994	22,831	25,825
		60,102	104,134	147,857	102,656	87,559	69,852	22,831	**594,991**

	Decommissioning Activity	**Duration (months)**
Period		
1a	Transition and Planning	12.0
1b	Decommissioning Preparations (DOC Mobilization)	6.1
2a	Large Component Removal	21.0
2b	BOP Systems Removal	26.9
2c	Building Decontamination (following fuel transfer from pool)	5.0
2e	License Termination and NRC Review	9.1

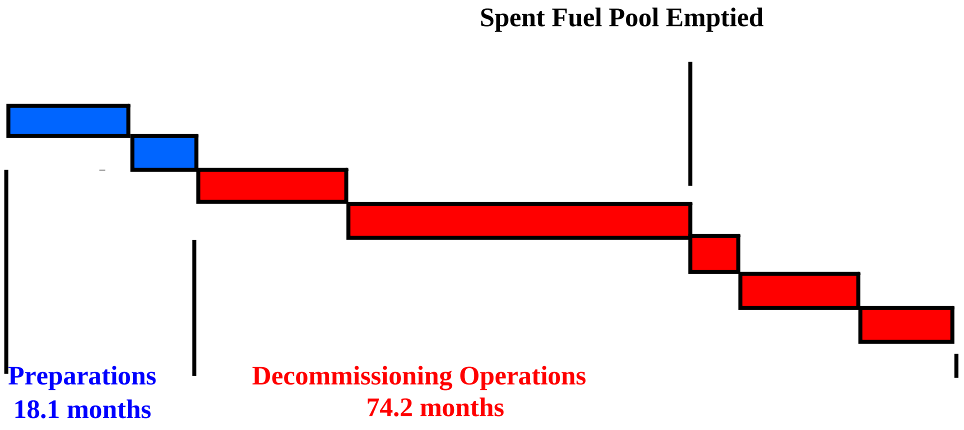


Total Interval Cost (thousands, 2003$) **91,519** **503,471**

Table 4-8. Schedule of Annual Expenditures by Decommissioning Period for the ACR-700, Unit 1
(thousands, 2003 dollars)

		Years								
	Decommissioning Activity	1	2	3	4	5	6	7	8	Total
Period										
1a	Transition and Planning	56,983								56,983
1b	Decommissioning Preparations (DOC Mobilization)		31,738							31,738
2a	Large Component Removal		53,668	80,204						133,873
2b	BOP Systems Removal			15,821	59,534	59,534	29,522			164,412
2c	Building Decontamination (following fuel transfer from pool)						15,997			15,997
2d	Delay Before License Termination						177	2,410		2,587
2e	License Termination and NRC Review							1,957	18,813	20,770
		56,983	85,406	96,026	59,534	59,534	45,696	4,366	18,813	**426,358**

	Decommissioning Activity	**Duration (months)**
Period		
1a	**Transition and Planning**	**12.0**
1b	**Decommissioning Preparations (DOC Mobilization)**	**6.1**
2a	**Large Component Removal**	**14.8**
2b	**BOP Systems Removal**	**33.1**
2c	**Building Decontamination (following fuel transfer from pool)**	**5.2**
2d	**Delay Before License Termination**	**12.0**
2e	**License Termination and NRC Review**	**9.1**

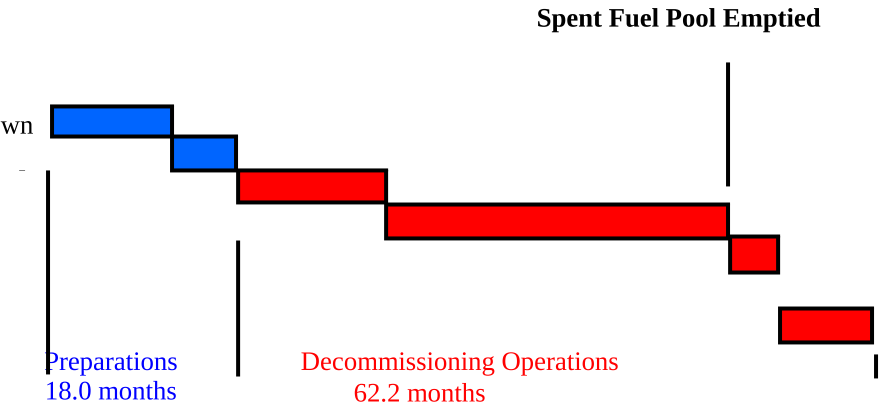


Total Interval Cost (thousands, 2003$)	**88,721**	**337,637**

Table 4-9. Schedule of Annual Expenditures by Decommissioning Period for the ACR-700, Unit 2
(thousands, 2003 dollars)

	Decommissioning Activity	Years 1	2	3	4	5	6	7	8	Total
Period										
1a	Transition and Planning	Shutdown	43,754							43,754
1b	Decommissioning Preparations (DOC Mobilization)	Offset		24,292						24,292
2a	Large Component Removal			54,191	79,797					133,988
2b	BOP Systems Removal				18,844	70,909	70,909	35,357		196,020
2c	Building Decontamination (following fuel transfer from pool)							19,899		19,899
2d	Delay Before License Termination									0
2e	License Termination and NRC Review							2,472	23,767	26,239
			43,754	78,482	98,642	70,909	70,909	57,728	23,767	444,191

	Decommissioning Activity	**Duration (months)**	
Period			
1a	Transition and Planning	12.0	Shutdown
1b	Decommissioning Preparations (DOC Mobilization)	6.0	Offset
2a	Large Component Removal	14.8	
2b	BOP Systems Removal	33.1	
2c	Building Decontamination (following fuel transfer from pool)	5.2	
2d	Delay Before License Termination	0.0	
2e	License Termination and NRC Review	9.1	

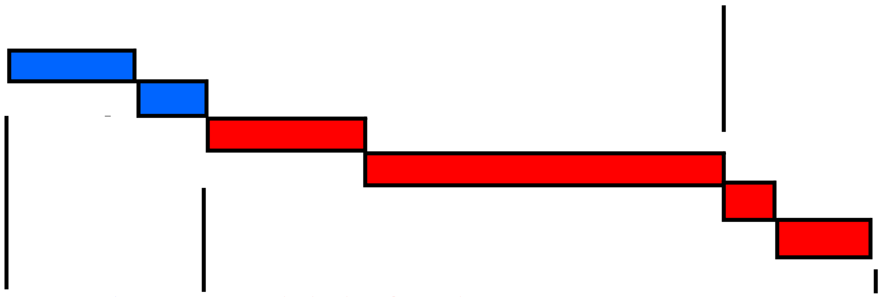


Total Interval Cost (thousands, 2003$) **68,045** **376,145**

Table 4-10. Schedule of Annual Expenditures by Decommissioning Period for the AP1000 (thousands, 2003 dollars)

		Years							
	Decommissioning Activity	1	2	3	4	5	6	7	Total
Period									
1a	Transition and Planning	59,582							59,582
1b	Decommissioning Preparations (DOC Mobilization)		36,170						36,170
2a	Large Component Removal		57,302	94,867					152,168
2b	BOP Systems Removal			8,416	45,176	45,176	22,402		121,170
2c	Building Decontamination (following fuel transfer from pool)						21,077		21,077
2e	License Termination and NRC Review						1,421	24,824	26,245
		59,582	93,472	103,283	45,176	45,176	44,900	24,824	416,412

	Decommissioning Activity	**Duration (months)**
Period		
1a	Transition and Planning	12.0
1b	Decommissioning Preparations (DOC Mobilization)	6.1
2a	Large Component Removal	15.7
2b	BOP Systems Removal	32.2
2c	Building Decontamination (following fuel transfer from pool)	5.6
2e	License Termination and NRC Review	9.1

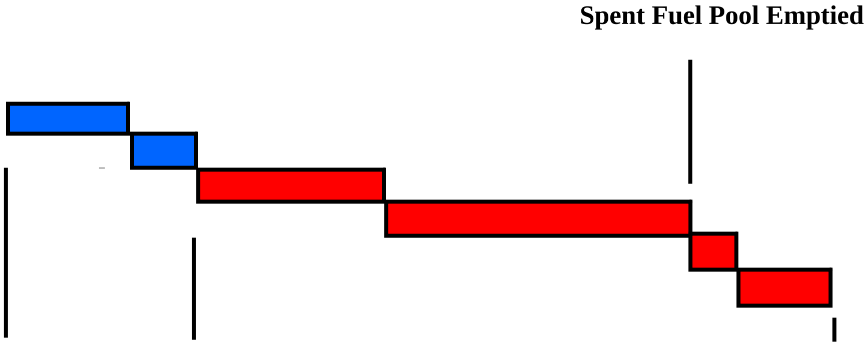


	Preparations 18.1 months	Decommissioning Operations 62.6 months
Total Interval Cost (thousands, 2003$)	**95,752**	**320,660**

Table 4-11. Schedule of Annual Expenditures by Decommissioning Period for the ESBWR
(thousands, 2003 dollars)

	Decommissioning Activity	Years							
		1	2	3	4	5	6	7	Total
Period									
1a	Transition and Planning	60,102							60,102
1b	Decommissioning Preparations (DOC Mobilization)		32,164						32,164
2a	Large Component Removal		72,720	147,865	9,696				230,282
2b	BOP Systems Removal				76,758	82,161	40,743		199,661
2c	Building Decontamination (following fuel transfer from pool)						23,385		23,385
2e	License Termination and NRC Review						2,610	22,229	24,838
		60,102	104,885	147,865	86,454	82,161	66,737	22,229	**570,433**

	Decommissioning Activity	**Duration (months)**
Period		
1a	**Transition and Planning**	**12.0**
1b	**Decommissioning Preparations (DOC Mobilization)**	**6.1**
2a	**Large Component Removal**	**18.7**
2b	**BOP Systems Removal**	**29.1**
2c	**Building Decontamination (following fuel transfer from pool)**	**5.1**
2e	**License Termination and NRC Review**	**9.1**



Preparations
18.1 months

Decommissioning Operations
62.0 months

Total Interval Cost (thousands, 2003$) **92,266** **478,166**

Table 4-12. ABWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
PERIOD 1a Shutdown through Transition																		
Period 1a	Direct Decommissioning Activities																	
1a.1.1	Prepare preliminary decommissioning cost	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.2	Notification of Cessation of Operations	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.3	Remove fuel & source material	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-	-	-
1a.1.4	Notification of Permanent Defueling	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.5	Deactivate plant systems & process waste	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.6	Prepare and submit PSDAR	-	-	-	-	-	-	171	26	197	-	-	-	-	-	-	-	2,000
1a.1.7	Review plant dwgs & specs.	-	-	-	-	-	-	394	59	453	-	-	-	-	-	-	-	4,600
1a.1.8	Perform detailed rad survey	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.9	Estimate by-product inventory	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.10	End product description	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.11	Detailed by-product inventory	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.12	Define major work sequence	-	-	-	-	-	-	643	96	739	-	-	-	-	-	-	-	7,500
1a.1.13	Perform SER and EA	-	-	-	-	-	-	266	40	305	-	-	-	-	-	-	-	3,100
1a.1.14	Perform Site-Specific Cost Study	-	-	-	-	-	-	428	64	493	-	-	-	-	-	-	-	5,000
1a.1.15	Prepare/submit License Termination Plan	-	-	-	-	-	-	351	53	404	-	-	-	-	-	-	-	4,096
1a.1.16	Receive NRC approval of termination plan	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
Activity Specifications																		
1a.1.17	Total	-	-	-	-	-	-	3,614	542	4,156	-	-	-	-	-	-	-	42,174
Planning & Site Preparations																		
1a.1.18	Prepare dismantling sequence	-	-	-	-	-	-	206	31	237	-	-	-	-	-	-	-	2,400
1a.1.19	Plant prep. & temp. svces	-	-	-	-	-	-	2,419	363	2,782	-	-	-	-	-	-	-	-
1a.1.20	Design water clean-up system	-	-	-	-	-	-	120	18	138	-	-	-	-	-	-	-	1,400
1a.1.21	Rigging/Cont. Cntrl Envlps/tooling/etc.	-	-	-	-	-	-	2,048	307	2,355	-	-	-	-	-	-	-	-
1a.1.22	Procure casks/liners & containers	-	-	-	-	-	-	105	16	121	-	-	-	-	-	-	-	1,230

Table 4-12. ABWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
1a.1	Subtotal Period 1a Activity Costs	-	-	-	-	-	-	11,159	1,674	12,833	-	-	-	-	-	-	-	78,100
Period 1a Additional Costs																		
1a.2.1	Spent Fuel Pool Isolation	-	-	-	-	-	-	8,060	1,209	9,269	-	-	-	-	-	-	-	-
1a.2.2	Site Characterization	-	-	-	-	-	-	1,853	556	2,408	-	-	-	-	-	-	-	-
1a.2	Subtotal Period 1a Additional Costs	-	-	-	-	-	-	9,912	1,765	11,677	-	-	-	-	-	-	-	-
Period 1a Collateral Costs																		
1a.3.1	Corporate & Site A&G Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
1a.3	Subtotal Period 1a Collateral Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
Period 1a Period-Dependent Costs																		
1a.4.1	Insurance	-	-	-	-	-	-	1,344	134	1,478	-	-	-	-	-	-	-	-
1a.4.2	Property taxes	-	-	-	-	-	-	21	2	23	-	-	-	-	-	-	-	-
1a.4.3	Health physics supplies	-	229	-	-	-	-	-	57	286	-	-	-	-	-	-	-	-
1a.4.4	Heavy equipment rental	-	292	-	-	-	-	-	44	336	-	-	-	-	-	-	-	-
1a.4.5	Disposal of DAW generated	-	-	5	2	-	16	-	5	28	-	404	-	-	-	8,103	99	-
1a.4.6	Plant energy budget	-	-	-	-	-	-	852	128	980	-	-	-	-	-	-	-	-
1a.4.7	NRC Fees	-	-	-	-	-	-	381	38	419	-	-	-	-	-	-	-	-
1a.4.8	Emergency Planning Fees	-	-	-	-	-	-	547	55	602	-	-	-	-	-	-	-	-
1a.4.9	Spent Fuel Pool O&M	-	-	-	-	-	-	706	106	812	-	-	-	-	-	-	-	-
1a.4.10	Security Staff Cost	-	-	-	-	-	-	2,499	375	2,874	-	-	-	-	-	-	-	58,921
1a.4.11	Utility Staff Cost	-	-	-	-	-	-	20,438	3,066	23,503	-	-	-	-	-	-	-	438,000
1a.4	Subtotal Period 1a Period-Dependent Costs	-	521	5	2	-	16	26,788	4,010	31,342	-	404	-	-	-	8,103	99	496,921
1a.0	TOTAL PERIOD 1a COST	-	521	5	2	-	16	51,555	8,002	60,102	-	404	-	-	-	8,103	99	575,021
PERIOD 1b – Decommissioning Preparations																		
Detailed Work Procedures																		
1b.1.1	Total	-	-	-	-	-	-	2,805	421	3,226	-	-	-	-	-	-	-	32,740
1b.1	Subtotal Period 1b Activity Costs	-	-	-	-	-	-	2,805	421	3,226	-	-	-	-	-	-	-	32,740
Period 1b Collateral Costs																		
1b.3.1	Decon equipment	650	-	-	-	-	-	-	98	748	-	-	-	-	-	-	-	-

Table 4-12. ABWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
1b.3.2	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
1b.3.3	Process liquid waste	92	-	31	151	-	469	-	189	932	-	-	634	-	-	79,871	125	-
1b.3.4	Pipe cutting equipment	-	957	-	-	-	-	-	143	1,100	-	-	-	-	-	-	-	-
1b.3.5	Corporate & Site A&G Costs	-	-	-	-	-	-	1,882	282	2,164	-	-	-	-	-	-	-	-
1b.3	Subtotal Period 1b Collateral Costs	742	957	31	151	-	469	2,819	853	6,022	-	-	634	-	-	79,871	125	-
Period 1b Period-Dependent Costs																		
1b.4.1	Decon supplies	20	-	-	-	-	-	-	5	25	-	-	-	-	-	-	-	-
1b.4.2	Insurance	-	-	-	-	-	-	681	68	749	-	-	-	-	-	-	-	-
1b.4.3	Property taxes	-	-	-	-	-	-	10	1	11	-	-	-	-	-	-	-	-
1b.4.4	Health physics supplies	-	116	-	-	-	-	-	29	146	-	-	-	-	-	-	-	-
1b.4.5	Heavy equipment rental	-	148	-	-	-	-	-	22	170	-	-	-	-	-	-	-	-
1b.4.6	Disposal of DAW generated	-	-	2	1	-	8	-	2	14	-	205	-	-	-	4,107	50	-
1b.4.7	Plant energy budget	-	-	-	-	-	-	864	130	994	-	-	-	-	-	-	-	-
1b.4.8	NRC Fees	-	-	-	-	-	-	193	19	212	-	-	-	-	-	-	-	-
1b.4.9	Emergency Planning Fees	-	-	-	-	-	-	277	28	305	-	-	-	-	-	-	-	-
1b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	358	54	411	-	-	-	-	-	-	-	-
1b.4.11	Security Staff Cost	-	-	-	-	-	-	1,267	190	1,457	-	-	-	-	-	-	-	29,864
1b.4.12	DOC Staff Cost	-	-	-	-	-	-	4,955	743	5,698	-	-	-	-	-	-	-	64,486
1b.4.13	Utility Staff Cost	-	-	-	-	-	-	10,414	1,562	11,976	-	-	-	-	-	-	-	223,057
1b.4	Subtotal Period 1b Period-Dependent Costs	20	265	2	1	-	8	19,019	2,854	22,170	-	205	-	-	-	4,107	50	317,407
1b.0	TOTAL PERIOD 1b COST	762	1,221	33	152	-	477	24,644	4,127	31,418	-	205	634	-	-	83,978	175	350,147
PERIOD 1 TOTALS		762	1,743	38	154	-	493	76,200	12,130	91,519	-	609	634	-	-	92,081	274	925,168
PERIOD 2a – Large Component Removal																		
Nuclear Steam Supply System Removal																		
2a.1.1.3	CRDMs & NIs Removal	194	159	264	152	-	819	-	390	1,977	-	6,404	-	-	-	158,406	7,882	-
2a.1.1.4	Reactor Vessel Internals	22	2,683	6,513	2,540	-	15,133	271	11,996	39,363	-	2,629	2,322	1,492	-	757,741	40,372	1,747
2a.1.1.5	Vessel & Internals GTCC Disposal	-	-	-	-	-	26,724	-	4,009	30,733	-	-	-	-	1,069	182,984	-	-
2a.1.1.6	Reactor Vessel	95	5,159	2,054	1,398	-	12,871	271	11,256	33,103	-	16,704	2,754	-	-	2,105,577	40,372	1,747
2a.1.1	Totals	516	8,001	8,830	4,090	-	55,547	541	27,651	105,176	-	25,737	5,076	1,492	1,069	3,204,709	88,626	3,494

Table 4-12. ABWR DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
Removal of Major Equipment																		
2a.1.2	Main Turbine/Generator	-	459	1,402	253	10,055	-	-	1,801	13,969	59,147	-	-	-	-	5,027,462	10,762	-
2a.1.3	Main Condensers	-	1,431	522	67	5,060	-	-	1,179	8,258	56,222	-	-	-	-	2,530,000	33,860	-
Disposal of Plant Systems																		
2a.1.4.1	Circulating Water	-	99	1	1	87	-	-	38	226	1,068	-	-	-	-	43,364	2,299	-
2a.1.4.2	Condensate Demineralizer	-	707	12	14	1,064	-	-	340	2,137	13,101	-	-	-	-	532,057	16,709	-
2a.1.4.3	Condensate Filter Facility	-	112	1	2	125	-	-	47	287	1,544	-	-	-	-	62,703	2,614	-
2a.1.4.4	Condensate, Feedwater & Air Extraction	-	1,956	88	105	7,917	-	-	1,701	11,766	97,470	-	-	-	-	3,958,327	46,789	-
2a.1.4.5	Extraction Steam	-	536	16	20	1,478	-	-	360	2,410	18,197	-	-	-	-	738,974	12,905	-
2a.1.4.6	Feedwater Heater & Drain	-	1,828	32	38	2,868	-	-	896	5,662	35,312	-	-	-	-	1,434,030	43,188	-
2a.1.4.7	Flammability Control	-	39	1	1	13	40	-	22	116	157	86	-	-	-	14,061	908	-
2a.1.4.8	Generator Cooling	-	13	-	-	-	-	-	2	15	-	-	-	-	-	-	345	-
2a.1.4.9	Generator Sealing Oil	-	13	-	-	-	-	-	2	15	-	-	-	-	-	-	332	-
2a.1.4.10	High Pressure Core Flooder	-	130	11	12	468	291	-	178	1,091	5,768	628	-	-	-	290,537	3,125	-
2a.1.4.11	Hydrogen Gas Cooling	-	28	-	-	-	-	-	4	32	-	-	-	-	-	-	760	-
2A.1.4.12	Makeup Water (condensate)	-	391	7	8	589	-	-	188	1,183	7,256	-	-	-	-	294,667	9,187	-
2a.1.4.13	Moisture Separator/Reheater	-	98	39	46	3,520	-	-	563	4,267	43,339	-	-	-	-	1,760,000	2,481	-
2a.1.4.14	Neutron Monitoring	-	24	2	2	10	85	-	29	152	121	183	-	-	-	21,320	584	-
2a.1.4.15	PCV Pressure & Leak Testing	-	4	0	0	28	-	-	5	38	343	-	-	-	-	13,923	109	-
2a.1.4.16	Reactor Feedwater Pump Driver	-	49	1	1	69	-	-	23	142	847	-	-	-	-	34,416	1,160	-
2a.1.4.17	Reactor Service Water	-	43	2	2	134	-	-	31	212	1,646	-	-	-	-	66,862	1,041	-
2a.1.4.18	Standby Liquid Control	-	32	1	1	54	-	-	16	103	664	-	-	-	-	26,946	730	-
2a.1.4.19	Tank Vent Treatment	-	39	1	1	30	37	-	24	132	373	79	-	-	-	22,220	921	-
2a.1.4.20	Turbine Auxiliary Steam	-	142	2	2	160	-	-	60	367	1,974	-	-	-	-	80,178	3,340	-
2a.1.4.21	Turbine Gland Steam	-	494	6	7	521	-	-	203	1,230	6,412	-	-	-	-	260,411	11,460	-
2a.1.4.22	Turbine Lubricating Oil	-	535	10	11	845	-	-	263	1,664	10,403	-	-	-	-	422,454	12,440	-
2a.1.4.23	Turbine Main Steam	-	292	17	18	556	556	-	300	1,739	6,840	1,198	-	-	-	385,261	7,114	-
2a.1.4.24	Turbine Plant Valves & Supports	-	700	22	26	1,962	-	-	475	3,185	24,151	-	-	-	-	980,802	17,022	-
2a.1.4.25	Turbine Service Water	-	113	4	5	352	-	-	82	556	4,328	-	-	-	-	175,765	2,676	-
2a.1.4.26	Valve Gland Leakage Treatment	-	137	5	3	25	151	-	77	400	313	327	-	-	-	42,016	3,061	-
2a.1.4.27	Zinc Injection	-	11	0	0	2	10	-	6	29	30	22	-	-	-	3,145	249	-
2a.1.4	Totals	-	8,567	280	326	22,876	1,169	-	5,937	39,155	281,657	2,522	-	-	-	11,664,440	203,550	-
2a.1.5	Scaffolding in support of decommissioning	-	3,778	20	4	187	21	-	980	4,990	2,075	104	-	-	-	103,755	44,243	-

Table 4-12. ABWR DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
2a.1	Subtotal period 2a Activity Costs	516	22,235	11,053	4,738	38,178	56,737	541	37,548	171,547	399,101	28,363	5,076	1,492	1,069	22,530,360	381,042	3,494
Period 2a Additional Costs																		
2a.2.1	Curie Surcharge (excluding RPV)	-	-	-	-	-	6,380	-	1,595	7,975	-	-	-	-	-	-	-	-
2a.2	Subtotal Period 2a Additional Costs	-	-	-	-	-	6,380	-	1,595	7,975	-	-	-	-	-	-	-	-
Period 2a Collateral Costs																		
2a.3.1	Process liquid waste	175	-	59	293	-	857	-	352	1,736	-	-	1,229	-	-	154,861	242	-
2a.3.2	Small tool allowance	-	261	-	-	-	-	-	39	300	-	-	-	-	-	-	-	-
2a.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	4,568	685	5,253	-	-	-	-	-	-	-	-
2a.3	Subtotal Period 2a Collateral Costs	175	261	59	293	-	857	4,568	1,076	7,289	-	-	1,229	-	-	154,861	242	-
Period 2a Period-Dependent Costs																		
2a.4.1	Decon supplies	70	-	-	-	-	-	-	17	87	-	-	-	-	-	-	-	-
2a.4.2	Insurance	-	-	-	-	-	-	949	95	1,044	-	-	-	-	-	-	-	-
2a.4.3	Property taxes	-	-	-	-	-	-	36	4	40	-	-	-	-	-	-	-	-
2a.4.4	Health physics supplies	-	1,596	-	-	-	-	-	399	1,995	-	-	-	-	-	-	-	-
2a.4.5	Heavy equipment rental	-	2,764	-	-	-	-	-	415	3,179	-	-	-	-	-	-	-	-
2a.4.6	Disposal of DAW generated	-	-	91	37	-	308	-	92	527	-	7,695	-	-	-	154,203	1,889	-
2a.4.7	Plant energy budget	-	-	-	-	-	-	1,415	212	1,628	-	-	-	-	-	-	-	-
2a.4.8	NRC Fees	-	-	-	-	-	-	775	78	853	-	-	-	-	-	-	-	-
2a.4.9	Emergency Planning Fees	-	-	-	-	-	-	861	86	947	-	-	-	-	-	-	-	-
2a.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	1,234	185	1,419	-	-	-	-	-	-	-	-
2a.4.11	Security Staff Cost	-	-	-	-	-	-	5,451	818	6,269	-	-	-	-	-	-	-	128,511
2a.4.12	DOC Staff Cost	-	-	-	-	-	-	20,737	3,111	23,847	-	-	-	-	-	-	-	277,074
2a.4.13	Utility Staff Cost	-	-	-	-	-	-	25,299	3,795	29,094	-	-	-	-	-	-	-	541,389
2a.4	Subtotal Period 2a Period-Dependent Costs	70	4,360	91	37	-	308	56,758	9,305	70,929	-	7,695	-	-	-	154,203	1,889	946,974
2a.0	TOTAL PERIOD 2a COST	761	26,856	11,203	5,068	38,178	64,281	61,867	49,524	257,740	399,101	36,058	6,305	1,492	1,069	22,839,430	383,173	950,468
PERIOD 2b – Site Decontamination																		
Disposal or Plant Systems																		
2b.1.1.1	Atmospheric Control	-	139	7	6	176	207	-	114	649	2,171	446	-	-	-	128,157	3,293	-
2b.1.1.2	Concentrated Waste	57	67	5	4	37	158	-	91	419	454	410	-	-	-	48,893	2,824	-

Table 4-12. ABWR DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2b.1.1.3	Containment Internal Struct.	-	186	5	5	319	48	-	108	670	3,922	142	-	-	-	168,616	4,413	-
2b.1.1.4	Control Rod Drive	-	720	68	65	304	3,030	-	1,000	5,186	3,738	6,534	-	-	-	737,831	16,769	-
2b.1.1.5	Drywell Cooling	-	39	3	4	236	40	-	56	378	2,908	86	-	-	-	125,791	912	-
2b.1.1.6	Electrical – Primary Containment	-	3,653	33	39	2,396	364	-	1,373	7,857	29,497	785	-	-	-	1,268,325	86,476	-
2b.1.1.7	Electrical – RCA	-	599	7	9	663	-	-	251	1,529	8,162	-	-	-	-	331,448	14,213	-
2b.1.1.8	Electrical – Clean	-	1,141	-	-	-	-	-	171	1,312	-	-	-	-	-	-	28,447	-
2b.1.1.9	Fire Protection	-	106	1	1	78	-	-	38	225	965	-	-	-	-	39,198	2,376	-
2b.1.1.10	High Conductivity waste	703	899	35	32	397	1,320	-	974	4,358	4,885	3,004	-	-	-	453,708	34,616	-
2b.1.1.11	HVAC	-	1,287	24	28	1,564	343	-	649	3,895	19,258	759	-	-	-	848,492	29,002	-
2b.1.1.12	HVAC Emergency Cooling Water	-	51	1	1	64	-	-	23	139	785	-	-	-	-	31,876	1,194	-
2b.1.1.13	HVAC Normal Cooling Water	-	284	4	5	376	-	-	128	797	4,628	-	-	-	-	187,935	6,481	-
2b.1.1.14	Instrument Air	-	316	4	5	374	-	-	136	835	4,600	-	-	-	-	186,803	6,889	-
2b.1.1.15	Laundry Drain	-	38	1	1	9	37	-	20	105	111	79	-	-	-	11,573	875	-
2b.1.1.16	Low Conductivity Waste	384	520	22	19	319	755	-	563	2,582	3,924	1,801	-	-	-	305,406	20,288	-
2b.1.1.17	Nuclear Boiler System	575	517	33	32	161	1,478	-	819	3,615	1,988	3,186	-	-	-	366,543	18,238	-
2b.1.1.18	Off Gas	-	301	16	15	563	393	-	262	1,550	6,931	889	-	-	-	357,570	7,066	-
2b.1.1.19	Plumbing & Drainage	-	1,096	9	10	759	-	-	390	2,263	9,340	-	-	-	-	379,322	25,560	-
2b.1.1.20	Primary Containment Vessel	-	24	3	3	90	86	-	42	248	1,102	186	-	-	-	61,432	583	-
2b.1.1.21	Process & Dust Radiation Monitoring	-	18	1	1	38	37	-	20	115	469	79	-	-	-	26,095	436	-
2b.1.1.22	Radioactive Drain Transfer	220	456	16	15	127	667	-	414	1,916	1,567	1,439	-	-	-	192,700	15,210	
2b.1.1.23	Reactor Building Cooling Water	-	797	13	15	1,145	-	-	375	2,345	14,101	-	-	-	-	572,658	18,216	-
2b.1.1.24	Reactor Core Isolation Cooling	-	91	5	4	32	174	-	72	378	394	375	-	-	-	49,648	2,157	-
2b.1.1.25	Reactor Recirculation	159	115	15	16	88	759	-	315	1,467	1,079	1,636	-	-	-	190,647	2,786	-
2b.1.1.26	Reactor Water Clean-up	193	217	28	26	124	1,220	-	481	2,288	1,524	2,641	-	-	-	297,837	6,713	-
2b.1.1.27	Residual Heat Removal	379	454	51	46	505	1,952	-	879	4,264	6,214	4,210	-	-	-	629,851	13,488	-
2b.1.1.28	Shower Drain	-	155	4	5	250	64	-	94	572	3,079	162	-	-	-	137,455	3,708	-
2b.1.1.29	Solidifying	-	80	5	5	91	183	-	81	445	1,124	427	-	-	-	81,012	1,909	-
2b.1.1.30	Spent Sludge	287	317	23	18	196	767	-	449	2,056	2,410	2,045	-	-	-	246,242	13,480	-
2b.1.1.31	Standby Gas Treatment	-	135	4	5	218	84	-	89	535	2,685	196	-	-	-	125,215	3,230	-
2b.1.1.32	Station Air	-	313	4	4	311	-	-	126	758	3,834	-	-	-	-	155,714	6,891	-
2b.1.1.33	Suppression Pool Cleanup	-	39	1	1	32	41	-	25	139	393	88	-	-	-	23,853	905	-
2b.1.1.34	Turbine Building Cooling Water	-	371	15	17	1,295	-	-	291	1,989	15,944	-	-	-	-	647,494	8,612	-
2b.1.1	Totals	2,957	15,538	468	460	13,335	14,205	-	10,916	57,880	164,186	31,603	-	-	-	9,415,340	408,254	-
2b.1.2	Scaffolding in support of decommissioning	-	4,723	25	4	233	26	-	1,225	6,237	2,594	130	-	-	-	129,694	55,304	-

Table 4-12. ABWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Decontamination of Site Buildings																		
2b.1.3.1	Control	268	157	16	19	93	322	-	272	1,149	1,148	1,624	-	-	-	207,684	9,619	-
2b.1.3.2	Radwaste	325	166	19	23	51	387	-	314	1,283	623	1,941	-	-	-	218,692	11,059	-
2b.1.3.3	Radwaste Runnel	37	16	2	3	2	47	-	35	143	22	236	-	-	-	24,470	1,201	-
2b.1.3.4	Reactor & Containment	1,895	2,127	141	161	763	4,376	-	2,726	12,191	9,391	14,513	-	-	-	1,770,155	90,830	-
2b.1.3.5	Turbine	781	621	50	59	334	972	-	853	3,670	4,112	4,930	-	-	-	653,082	31,577	-
2B.1.3	Totals	3,307	3,088	228	265	1,242	6,105	-	4,200	18,435	15,297	23,245	-	-	-	2,874,082	144,286	-
Demolition of Remaining Site Buildings																		
2b.1.4.1	Reactor & Containment	-	1,021	-	-	-	-	-	153	1,175	-	-	-	-	-	-	-	15,136
2b.1.4.2	Turbine	-	63	-	-	-	-	-	9	73	-	-	-	-	-	-	-	1,062
2b.1.4.3	Remove Rubble	-	1,176	-	-	-	-	-	176	1,353	-	-	-	-	-	-	-	1,885
2b.1.4	Totals	-	2,261	-	-	-	-	-	339	2,600	-	-	-	-	-	-	-	18,083
2b.1	Subtotal Period 2b Activity Costs	6,264	25,609	722	730	14,811	20,336	-	16,681	85,152	182,077	54,978	-	-	-	12,419,116	625,927	-
Period 2b Additional Costs																		
2b.2.1	Survey & Release of Scrap Material	-	-	-	-	-	-	3,646	547	4,193	-	-	-	-	-	-	-	-
2b.2	Subtotal Period 2b Additional Costs	-	-	-	-	-	-	3,646	547	4,193	-	-	-	-	-	-	-	-
Period 2b Collateral Costs																		
2b.3.1	Process liquid waste	303	-	589	1,610	-	6,875	-	2,171	11,547	-	-	8,370	-	-	1,318,891	577	-
2b.3.2	Small tool allowance	-	408	-	-	-	-	-	61	469	-	-	-	-	-	-	-	-
2b.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	5,627	844	6,471	-	-	-	-	-	-	-	-
2b.3	Subtotal Period 2b Collateral Costs	303	408	589	1,610	-	6,875	5,627	3,076	18,487	-	-	8,370	-	-	1,318,891	577	-
Period 2b Period-Dependent Costs																		
2b.4.1	Decon supplies	1,152	-	-	-	-	-	-	288	1,440	-	-	-	-	-	-	-	-
2b.4.2	Insurance	-	-	-	-	-	-	1,218	122	1,340	-	-	-	-	-	-	-	-
2b.4.3	Property taxes	-	-	-	-	-	-	46	5	51	-	-	-	-	-	-	-	-
2b.4.4	Health physics supplies	-	2,422	-	-	-	-	-	606	3,028	-	-	-	-	-	-	-	-
2b.4.5	Heavy equipment rental	-	3,570	-	-	-	-	-	535	4,105	-	-	-	-	-	-	-	-
2b.4.6	Disposal of DAW generated	-	-	118	48	-	399	-	119	683	-	9,985	-	-	-	200,093	2,452	-
2b.4.7	Plant energy budget	-	-	-	-	-	-	1,434	215	1,650	-	-	-	-	-	-	-	-
2b.4.8	NRC Fees	-	-	-	-	-	-	995	100	1,095	-	-	-	-	-	-	-	-

Table 4-12. ABWR DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2b.4.9	Emergency Planning Fees	-	-	-	-	-	-	983	98	1,081	-	-	-	-	-	-	-	-
2b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	1,584	238	1,821	-	-	-	-	-	-	-	-
2b.4.11	Radwaste Processing Equipment/Services	-	-	-	-	-	-	404	61	464	-	-	-	-	-	-	-	-
2b.4.12	Security Staff Cost	-	-	-	-	-	-	5,608	841	6,450	-	-	-	-	-	-	-	132,210
2b.4.13	DOC Staff Cost	-	-	-	-	-	-	25,573	3,836	29,409	-	-	-	-	-	-	-	341,640
2b.4.14	Utility Staff Cost	-	-	-	-	-	-	31,188	4,678	35,866	-	-	-	-	-	-	-	666,900
2b.4	Subtotal Period 2b Period-Dependent Costs	1,152	5,992	118	48	-	399	69,033	11,741	88,483	-	9,985	-	-	-	200,093	2,452	1,140,750
2b.0	TOTAL PERIOD 2b COST	7,719	32,009	1,429	2,387	14,811	27,610	78,306	32,045	196,315	182,077	64,963	8,370	-	-	13,938,099	628,955	1,140,750
PERIOD 2c – Decontamination Following Wet Fuel Storage																		
2c.1.1	Remove spent fuel racks	605	58	75	19	1,434	-	-	543	2,735	15,934	-	-	-	-	717,024	1,497	-
Disposal of Plant Systems																		
2c.1.2.1	Fuel Pool Cooling & Clean-up	-	441	24	22	234	947	-	388	2,057	2,887	2,044	-	-	-	300,508	10,439	-
2c.1.2	Totals	-	441	24	22	234	947	-	388	2,057	2,887	2,044	-	-	-	300,508	10,439	-
Decontamination of Site Buildings																		
2c.1.3.1	Reactor – Spent Fuel Pool	355	381	3	3	116	34	-	289	1,162	1,434	169	-	-	-	75,107	16,400	-
2c.1.3	Totals	355	381	3	3	116	34	-	289	1,162	1,434	169	-	-	-	75,107	16,400	-
2c.1.4	Scaffolding in support of decommissioning	-	945	5	1	47	5	-	245	1,247	519	26	-	-	-	25,939	11,061	-
2c.1	Subtotal Period 2c Activity Costs	940	1,825	107	45	1,832	986	-	1,465	7,201	20,774	2,238	-	-	-	1,118,578	39,397	-
Period 2c Additional Costs																		
2c.2.1	Final Site Survey	-	-	-	-	-	-	1,236	371	1,607	-	-	-	-	-	-	-	12,480
2c.2	Subtotal Period 2c Additional Costs	-	-	-	-	-	-	1,236	371	1,607	-	-	-	-	-	-	-	12,480
Period 2c Collateral Costs																		
2c.3.1	Process liquid waste	87	-	30	150	-	466	-	186	919	-	-	629	-	-	79,344	124	-
2c.3.2	Small tool allowance	-	35	-	-	-	-	-	5	40	-	-	-	-	-	-	-	-

Table 4-12. ABWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2c.3.3.	Decommissioning Equipment Disposition	-	-	58	12	540	60	-	104	774	6,000	300	-	-	-	300,000	735	-
2c.3.4	Corporate & Site A&G Costs	-	-	-	-	-	-	744	112	855	-	-	-	-	-	-	-	-
2c.3	Subtotal Period 2c Collateral Costs	87	35	89	162	540	526	744	406	2,589	6,000	300	629	-	-	379,344	859	-
Period 2c Period-Dependent Costs																		
2c.4.1	Decon supplies	52	-	-	-	-	-	-	13	65	-	-	-	-	-	-	-	-
2c.4.2	Insurance	-	-	-	-	-	-	210	21	231	-	-	-	-	-	-	-	-
2c.4.3	Property taxes	-	-	-	-	-	-	9	1	9	-	-	-	-	-	-	-	-
2c.4.4	Health physics supplies	-	222	-	-	-	-	-	55	277	-	-	-	-	-	-	-	-
2c.4.5	Heavy equipment rental	-	662	-	-	-	-	-	99	762	-	-	-	-	-	-	-	-
2c.4.6	Disposal of DAW generated	-	-	24	10	-	82	-	24	140	-	2,043	-	-	-	40,931	501	-
2c.4.7	Plant energy budget	-	-	-	-	-	-	142	21	163	-	-	-	-	-	-	-	-
2c.4.8	NRC Fees	-	-	-	-	-	-	185	18	203	-	-	-	-	-	-	-	-
2c.4.9	Emergency Planning Fees	-	-	-	-	-	-	160	16	176	-	-	-	-	-	-	-	-
2c.4.10	Radwaste Processing Equipment/Services	-	-	-	-	-	-	150	22	172	-	-	-	-	-	-	-	-
2c.4.11	Security Staff Cost	-	-	-	-	-	-	1,041	156	1,197	-	-	-	-	-	-	-	24,537
2c.4.12	DOC Staff Cost	-	-	-	-	-	-	3,248	487	3,735	-	-	-	-	-	-	-	43,429
2c.4.13	Utility Staff Cost	-	-	-	-	-	-	4,269	640	4,910	-	-	-	-	-	-	-	88,160
2c.4	Subtotal Period 2c Period-Dependent Costs	52	884	24	10	-	82	9,413	1,576	12,041	-	2,043	-	-	-	40,931	501	156,126
2c.0	TOTAL PERIOD 2c COST	1,079	2,744	220	217	2,372	1,594	11,393	3,818	23,438	26,774	4,581	629	-	-	1,538,853	40,757	168,606
PERIOD 2e – License Termination																		
Period 2e Direct Decommissioning Activities																		
2e.1.1	ORISE confirmatory survey	-	-	-	-	-	-	121	36	157	-	-	-	-	-	-	-	-
2e.1.2	Terminate license	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
2e.1.3	Final report to NRC	-	-	-	-	-	-	134	20	154	-	-	-	-	-	-	-	1,560
2e.1	Subtotal Period 2e Activity Costs	-	-	-	-	-	-	254	56	311	-	-	-	-	-	-	-	1,560
Period 2e Additional Costs																		
2e.2.1	Final Site Survey	-	-	-	-	-	-	8,612	2,584	11,195	-	-	-	-	-	-	192,126	6,240
2e.2	Subtotal Period 2e Additional Costs	-	-	-	-	-	-	8,612	2,584	11,195	-	-	-	-	-	-	192,126	6,240

Table 4-12. ABWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	**Activity Description**	**Decon Cost**	**Removal Cost**	**Packaging Costs**	**Transport Costs**	**Offsite Processing Costs**	**LLRW Disposal Costs**	**Other Costs**	**Total Contingency**	**Total Costs**	**Processed Volume Cu. Feet**	**Class A Cu. Feet**	**Class B Cu. Feet**	**Class C Cu. Feet**	**GTCC Cu. Feet**	**Burial/ Processed Wt., Lbs.**	**Craft Manhours**	**Utility and Contractor Manhours**
Period 2e Collateral Costs																		
2e.3.1	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
2e.3.2	Corporate & Site A&G Costs	-	-	-	-	-	-	672	101	773	-	-	-	-	-	-	-	-
2e.3	Subtotal Period 2e Collateral Costs	-	-	-	-	-	-	1,609	241	1,851	-	-	-	-	-	-	-	-
Period 2e Period-Dependent Costs																		
2e.4.1	Insurance	-	-	-	-	-	-	286	29	315	-	-	-	-	-	-	-	-
2e.4.2	Property taxes	-	-	-	-	-	-	16	2	17	-	-	-	-	-	-	-	-
2e.4.3	Health physics supplies	-	776	-	-	-	-	-	194	970	-	-	-	-	-	-	-	-
2e.4.4	Disposal of DAW generated	-	-	4	1	-	12	-	4	21	-	306	-	-	-	6,127	75	-
2e.4.5	Plant energy budget	-	-	-	-	-	-	129	19	148	-	-	-	-	-	-	-	-
2e.4.6	NRC Fees	-	-	-	-	-	-	335	34	369	-	-	-	-	-	-	-	-
2e.4.7	Emergency Planning Fees	-	-	-	-	-	-	207	21	228	-	-	-	-	-	-	-	-
2e.4.8	Security Staff Cost	-	-	-	-	-	-	602	90	692	-	-	-	-	-	-	-	14,194
2e.4.9	DOC Staff Cost	-	-	-	-	-	-	4,416	662	5,078	-	-	-	-	-	-	-	57,566
2e.4.10	Utility Staff Cost-	-	-	-	-	-	-	4,160	624	4,784	-	-	-	-	-	-	-	79,646
2e.4	Subtotal Period 2e Period-Dependent Costs	-	776	4	1	-	12	10,151	1,678	12,622	-	306	-	-	-	6,127	75	151,406
2e.0	TOTAL PERIOD 2e COST	-	776	4	1	-	12	10,151	1,678	12,622	-	306	-	-	-	6,127	192,201	159,206
PERIOD 2 TOTALS		9,559	62,385	12,856	7,674	55,361	93,498	172,193	89,946	503,472	607,951	105,907	15,304	1,492	1,069	38,322,509	1,245,086	2,419,029
TOTAL COST TO DECOMMISSION		10,322	64,128	12,894	7,828	55,361	93,991	248,393	102,076	594,991	607,951	106,516	15,938	1,492	1,069	38,414,590	1,245,360	3,344,198
TOTAL COST TO DECOMMISSION WITH 20.71% CONTINGENCY:								**$594,991 thousands of 2003 dollars**										

End Notes:
n/a – indicates that this activity not charged as decommissioning expense.
a – indicates that this activity performed by decommissioning staff.
0 – indicates that this value is less than 0.5, but is non-zero.
A cell containing " – " indicates a zero value.

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
PERIOD 1a - Shutdown through Transition																		
Period 1a Direct Decommissioning Activities		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1a.1.1	Prepare preliminary decommissioning cost	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.2	Notification of Cessation of Operations	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.3	Remove fuel & source material	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-	-	-
1a.1.4	Notification of Permanent Defueling	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.5	Deactivate plant systems & process waste	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.6	Prepare and submit PSDAR	-	-	-	-	-	-	171	26	197	-	-	-	-	-	-	-	2,000
1a.1.7	Review plant dwgs & specs.	-	-	-	-	-	-	394	59	453	-	-	-	-	-	-	-	4,600
1a.1.8	Perform detailed rad survey	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.9	Estimate by-product inventory	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.10	End product description	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.11	Detailed by-product inventory	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.12	Define major work sequence	-	-	-	-	-	-	643	96	739	-	-	-	-	-	-	-	7,500
1a.1.13	Perform SER and EA	-	-	-	-	-	-	266	40	305	-	-	-	-	-	-	-	3,100
1a.1.14	Perform Site-Specific Cost Study	-	-	-	-	-	-	428	64	493	-	-	-	-	-	-	-	5,000
1a.1.15	Prepare/submit License Termination Plan	-	-	-	-	-	-	351	53	404	-	-	-	-	-	-	-	4,096
1a.1.16	Receive NRC approval of termination plan	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
Activity Specifications																		
1a.1.17	Total	-	-	-	-	-	-	3,241	486	3,728	-	-	-	-	-	-	-	37,827
Planning & Site Preparations																		
1a.1.18	Prepare dismantling sequence	-	-	-	-	-	-	206	31	237	-	-	-	-	-	-	-	2,400
1a.1.19	Plant prep. & temp. svces	-	-	-	-	-	-	2,419	363	2,782	-	-	-	-	-	-	-	-
1a.1.20	Design water cleanup system	-	-	-	-	-	-	120	18	138	-	-	-	-	-	-	-	1,400

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
1a.1.21	Rigging/Cont. Cntrl Envlps/tooling/etc.	-	-	-	-	-	-	2,048	307	2,355	-	-	-	-	-	-	-	-
1a.1.22	Procure casks/liners & containers	-	-	-	-	-	-	105	16	121	-	-	-	-	-	-	-	1,230
1a.1	Subtotal Period 1a Activity Costs	-	-	-	-	-	-	10,787	1,618	12,405	-	-	-	-	-	-	-	73,753
Period 1a Additional Costs																		
1a.2.1	Spent Fuel Pool Isolation	-	-	-	-	-	-	8,060	1,209	9,269	-	-	-	-	-	-	-	-
1a.2.2	Site Characterization	-	-	-	-	-	-	1,251	375	1,626	-	-	-	-	-	-	-	-
1a.2	Subtotal Period 1a Additional Costs	-	-	-	-	-	-	9,310	1,584	10,894	-	-	-	-	-	-	-	-
Period 1a Collateral Costs																		
1a.3.1	Corporate & Site A&G Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
1a.3	Subtotal Period 1a Collateral Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
Period 1a Period-Dependent Costs																		
1a.4.1	Insurance	-	-	-	-	-	-	1,344	134	1,478	-	-	-	-	-	-	-	-
1a.4.2	Property taxes	-	-	-	-	-	-	21	2	23	-	-	-	-	-	-	-	-
1a.4.3	Health physics supplies	-	229	-	-	-	-	-	57	286	-	-	-	-	-	-	-	-
1a.4.4	Heavy equipment rental	-	292	-	-	-	-	-	44	336	-	-	-	-	-	-	-	-
1a.4.5	Disposal of DAW generated	-	-	5	2	-	16	-	5	28	-	404	-	-	-	8,103	99	-
1a.4.6	Plant energy budget	-	-	-	-	-	-	543	81	624	-	-	-	-	-	-	-	-
1a.4.7	NRC Fees	-	-	-	-	-	-	381	38	419	-	-	-	-	-	-	-	-
1a.4.8	Emergency Planning Fees	-	-	-	-	-	-	547	55	602	-	-	-	-	-	-	-	-
1a.4.9	Spent Fuel Pool O&M	-	-	-	-	-	-	706	106	812	-	-	-	-	-	-	-	-
1a.4.10	Security Staff Cost	-	-	-	-	-	-	1,150	173	1,323	-	-	-	-	-	-	-	27,114
1a.4.11	Utility Staff Cost	-	-	-	-	-	-	20,438	3,066	23,503	-	-	-	-	-	-	-	438,000
1a.4	Subtotal Period 1a Period-Dependent Costs	-	521	5	2	-	16	25,129	3,761	29,434	-	404	-	-	-	8,103	99	465,114
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1a.0	TOTAL PERIOD 1a COST	-	521	5	2	-	16	48,922	7,517	56,983	-	404	-	-	-	8,103	99	538,867

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

						Offsite	LLRW				Processed	Burial Volumes				Burial/		Utility and
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Processing Costs	Disposal Costs	Other Costs	Total Contingency	Total Costs	Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Processed Wt., Lbs.	Craft Manhours	Contractor Manhours
PERIOD 1b - Decommissioning Preparations																		
Period 1b Direct Decommissioning Activities																		
Detailed Work Procedures																		
1b.1.1	Total	-	-	-	-	-	-	2,849	427	3,276	-	-	-	-	-	-	-	33,243
1b.1.2	Decon primary loop	199	-	-	-	-	-	-	100	299	-	-	-	-	-	-	1,067	-
1b.1	Subtotal Period 1b Activity Costs	199	-	-	-	-	-	2,849	527	3,575	-	-	-	-	-	-	1,067	33,243
Period 1b Collateral Costs																		
1b.3.1	Decon equipment	650	-	-	-	-	-	-	98	748	-	-	-	-	-	-	-	-
1b.3.2	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
1b.3.3	Process liquid waste	7	-	66	155	-	798	-	233	1,259	-	-	863	-	-	143,541	29	-
1b.3.4	Small tool allowance	-	1	-	-	-	-	-	0	1	-	-	-	-	-	-	-	-
1b.3.5	Pipe cutting equipment	-	957	-	-	-	-	-	143	1,100	-	-	-	-	-	-	-	-
1b.3.6	Corporate & Site A&G Costs	-	-	-	-	-	-	1,882	282	2,164	-	-	-	-	-	-	-	-
1b.3	Subtotal Period 1b Collateral Costs	657	957	66	155	-	798	2,819	897	6,350	-	-	863	-	-	143,541	29	-
Period 1b Period-Dependent Costs																		
1b.4.1	Decon supplies	20	-	-	-	-	-	-	5	25	-	-	-	-	-	-	-	-
1b.4.2	Insurance	-	-	-	-	-	-	681	68	749	-	-	-	-	-	-	-	-
1b.4.3	Property taxes	-	-	-	-	-	-	10	1	11	-	-	-	-	-	-	-	-
1b.4.4	Health physics supplies	-	120	-	-	-	-	-	30	149	-	-	-	-	-	-	-	-
1b.4.5	Heavy equipment rental	-	148	-	-	-	-	-	22	170	-	-	-	-	-	-	-	-
1b.4.6	Disposal of DAW generated	-	-	3	1	-	9	-	3	15	-	221	-	-	-	4,439	54	-
1b.4.7	Plant energy budget	-	-	-	-	-	-	550	83	633	-	-	-	-	-	-	-	-
1b.4.8	NRC Fees	-	-	-	-	-	-	193	19	212	-	-	-	-	-	-	-	-
1b.4.9	Emergency Planning Fees	-	-	-	-	-	-	277	28	305	-	-	-	-	-	-	-	-
1b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	358	54	411	-	-	-	-	-	-	-	-
1b.4.11	Security Staff Cost	-	-	-	-	-	-	1,267	190	1,457	-	-	-	-	-	-	-	29,864
1b.4.12	DOC Staff Cost	-	-	-	-	-	-	4,955	743	5,698	-	-	-	-	-	-	-	64,486

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
1b.4.13	Utility Staff Cost	-	-	-	-	-	-	10,414	1,562	11,976	-	-	-	-	-	-	-	223,057
1b.4	Subtotal Period 1b Period-Dependent Costs	20	268	3	1	-	9	18,705	2,807	21,813	-	221	-	-	-	4,439	54	317,407
1b.0	TOTAL PERIOD 1b COST	876	1,225	69	156	-	807	24,374	4,231	31,738	-	221	863	-	-	147,980	1,150	350,650
PERIOD 1 TOTALS		876	1,746	73	158	-	823	73,295	11,748	88,721	-	626	863	-	-	156,083	1,249	889,517
PERIOD 2a - Large Component Removal																		
Period 2a Direct Decommissioning Activities																		
Nuclear Steam Supply System Removal																		
2a.1.1.1	Heat Transport Piping	715	713	30	101	-	1,637	-	963	4,158	-	3,470	-	-	-	316,546	32,169	-
2a.1.1.2	Pressurizer Relief Tank	27	24	4	9	-	220	-	76	361	-	383	-	-	-	42,533	575	-
2a.1.1.3	Heat Transport Pumps & Motors	148	70	37	80	90	3,014	-	874	4,314	1,993	25,685	-	-	-	628,232	5,231	-
2a.1.1.4	Pressurizer	33	46	5	56	-	2,157	-	576	2,875	-	2,290	-	-	-	417,231	2,779	-
2a.1.1.5	Steam Generators	109	3,503	3,162	1,135	1,546	7,124	-	3,430	20,008	-	8,056	-	-	-	2,742,578	11,613	-
2a.1.1.6	CRDMs/ICIs/Service Structure Removal	33	28	44	25	-	137	-	66	333	-	1,172	-	-	-	26,594	1,354	-
2a.1.1.7	Reactor Vessel Internals	117	1,602	1,125	1,356	-	10,281	151	7,043	21,674	-	8,032	527	517	-	928,521	21,152	978
2a.1.1.8	Vessel & Internals GTCC Disposal	-	-	-	-	-	10,376	-	1,556	11,933	-	-	-	-	415	77,603	-	-
2a.1.1.9	Reactor Vessel	-	2,806	802	-	-	-	151	2,327	6,086	-	-	-	-	-	-	21,152	978
2a.1.1	Totals	1,182	8,791	5,207	2,763	1,637	34,946	303	16,912	71,741	1,993	49,089	527	517	415	5,179,837	96,025	1,956
Removal of Major Equipment																		
2a.1.2	Main Turbine/Generator	-	225	-	-	-	-	-	34	259	-	-	-	-	-	-	5,288	-
2a.1.3	Main Condensers	-	722	-	-	-	-	-	108	831	-	-	-	-	-	-	17,094	-
Disposal of Plant Systems																		
2a.1.4.1	Condensate	-	20	-	-	-	-	-	3	23	-	-	-	-	-	-	492	-
2a.1.4.2	Condensate Purification System	-	4	-	-	-	-	-	1	5	-	-	-	-	-	-	107	-

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
2a.1.4.3	Feedwater	-	31	-	-	-	-	-	5	36	-	-	-	-	-	-	760	-
2a.1.4.4	Feedwater Heater Drain System	-	3	-	-	-	-	-	0	3	-	-	-	-	-	-	70	-
2a.1.4.5	Feedwater Heating System	-	130	-	-	-	-	-	20	150	-	-	-	-	-	-	3,164	-
2a.1.4.6	Gland Sealing	-	2	-	-	-	-	-	0	3	-	-	-	-	-	-	54	-
2a.1.4.7	Jacking Oil Storage	-	1	-	-	-	-	-	0	2	-	-	-	-	-	-	36	-
2a.1.4.8	Liquid Injection Shutdown	-	44	1	1	71	14	-	25	156	869	38	-	-	-	37,915	1,056	-
2a.1.4.9	Moisture Separator	-	36	-	-	-	-	-	5	42	-	-	-	-	-	-	887	-
2a.1.4.10	Oil System	-	16	-	-	-	-	-	2	19	-	-	-	-	-	-	396	-
2a.1.4.11	Process Systems Valves/Pipe In TB	-	1,293	-	-	-	-	-	194	1,486	-	-	-	-	-	-	33,923	-
2a.1.4.12	Reheat	-	9	-	-	-	-	-	1	10	-	-	-	-	-	-	213	-
2a.1.4.13	Steam Generator Blowdown	-	4	0	0	9	-	-	2	16	113	-	-	-	-	4,580	93	-
2a.1.4.14	Turbine And Auxiliary Equipment	-	2	-	-	-	-	-	0	3	-	-	-	-	-	-	57	-
2a.1.4	Totals	-	1,596	1	1	80	14	-	260	1,952	981	38	-	-	-	42,495	41,310	-
2a.1.5	Scaffolding in support of decommissioning	-	2,264	6	1	60	7	-	577	2,915	663	33	-	-	-	33,169	21,221	-
2a.1	Subtotal Period 2a Activity Costs	1,182	13,599	5,215	2,765	1,776	34,966	303	17,892	77,699	3,638	49,159	527	517	415	5,255,502	180,938	1,956
Period 2a Additional Costs																		
2a.2.1	Curie Surcharge (excluding RPV)	-	-	-	-	-	2,500	-	625	3,125	-	-	-	-	-	-	-	-
2a.2	Subtotal Period 2a Additional Costs	-	-	-	-	-	2,500	-	625	3,125	-	-	-	-	-	-	-	-
Period 2a Collateral Costs																		
2a.3.1	Process liquid waste	17	-	6	29	-	135	-	47	234	-	-	121	-	-	15,255	24	-
2a.3.2	Small tool allowance	-	125	-	-	-	-	-	19	143	-	-	-	-	-	-	-	-
2a.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	3,215	482	3,697	-	-	-	-	-	-	-	-
2a.3	Subtotal Period 2a Collateral Costs	17	125	6	29	-	135	3,215	548	4,074	-	-	121	-	-	15,255	24	-
Period 2a Period-Dependent Costs																		

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2a.4.1	Decon supplies	49	-	-	-	-	-	-	12	61	-	-	-	-	-	-	-	-
2a.4.2	Insurance	-	-	-	-	-	-	668	67	735	-	-	-	-	-	-	-	-
2a.4.3	Property taxes	-	-	-	-	-	-	25	3	28	-	-	-	-	-	-	-	-
2a.4.4	Health physics supplies	-	849	-	-	-	-	-	212	1,062	-	-	-	-	-	-	-	-
2a.4.5	Heavy equipment rental	-	1,945	-	-	-	-	-	292	2,237	-	-	-	-	-	-	-	-
2a.4.6	Disposal of DAW generated	-	-	32	13	-	109	-	32	187	-	2,731	-	-	-	54,731	671	-
2a.4.7	Plant energy budget	-	-	-	-	-	-	634	95	729	-	-	-	-	-	-	-	-
2a.4.8	NRC Fees	-	-	-	-	-	-	546	55	600	-	-	-	-	-	-	-	-
2a.4.9	Emergency Planning Fees	-	-	-	-	-	-	606	61	667	-	-	-	-	-	-	-	-
2a.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	868	130	999	-	-	-	-	-	-	-	-
2a.4.11	Security Staff Cost	-	-	-	-	-	-	3,836	575	4,412	-	-	-	-	-	-	-	90,441
2a.4.12	DOC Staff Cost	-	-	-	-	-	-	14,594	2,189	16,783	-	-	-	-	-	-	-	194,994
2a.4.13	Utility Staff Cost	-	-	-	-	-	-	17,805	2,671	20,475	-	-	-	-	-	-	-	381,009
2a.4	Subtotal Period 2a Period-Dependent Costs	49	2,795	32	13	-	109	39,582	6,394	48,974	-	2,731	-	-	-	54,731	671	666,444
2a.0	TOTAL PERIOD 2a COST	1,249	16,518	5,253	2,807	1,776	37,710	43,100	25,459	133,873	3,638	51,890	648	517	415	5,325,488	181,632	668,400
PERIOD 2b - Site Decontamination																		
Period 2b Direct Decommissioning Activities																		
Disposal of Plant Systems																		
2b.1.1.1	Active Drainage Reactor Aux & Service	-	5	0	0	8	1	-	3	18	103	4	-	-	-	4,430	116	-
2b.1.1.2	Active Drainage Reactor Building	-	1	-	-	0	1	-	1	3	4	2	-	-	-	376	31	-
2b.1.1.3	Annulus Gas	-	13	1	1	21	22	-	12	69	262	47	-	-	-	14,842	307	-
2b.1.1.4	Electric - Primary Containment	-	3,855	36	42	2,589	393	-	1,460	8,376	31,870	848	-	-	-	1,370,338	91,108	-
2b.1.1.5	Electrical - RCA	-	2,536	20	24	1,830	-	-	914	5,324	22,528	-	-	-	-	914,871	60,046	-
2b.1.1.6	Electrical - Clean	-	1,784	-	-	-	-	-	268	2,051	-	-	-	-	-	-	44,386	-
2b.1.1.7	Emergency Coolant Injection	-	660	19	20	1,166	226	-	401	2,493	14,355	620	-	-	-	626,703	15,717	-
2b.1.1.8	Fire Protection	-	42	1	1	100	-	-	26	170	1,225	-	-	-	-	49,757	1,008	-
2b.1.1.9	Fuel Changing	-	87	11	12	484	279	-	167	1,040	5,959	604	-	-	-	296,030	2,093	-
2b.1.1.10	H2O Leakage Collection	-	13	0	0	14	-	-	5	33	176	-	-	-	-	7,165	309	-
2b.1.1.11	Heat Transport	2	16	1	1	5	30	-	14	69	58	66	-	-	-	8,225	395	-

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2b.1.1.12	Heat Transport Sys Pressure & Inventory	237	199	38	30	238	1,338	-	547	2,626	2,926	3,178	-	-	-	377,706	8,436	-
2b.1.1.13	Heavy Water Cleanup	-	36	1	1	44	12	-	19	113	545	29	-	-	-	24,460	843	-
2b.1.1.14	Heavy Water Supply	-	56	1	1	80	18	-	31	187	982	48	-	-	-	43,401	1,321	-
2b.1.1.15	Heavy Water Vapor Recovery	-	10	0	0	11	3	-	5	30	138	7	-	-	-	6,151	243	-
2b.1.1.16	Light Water Cleanup	-	2	-	-	3	1	-	1	8	36	2	-	-	-	1,624	55	-
2b.1.1.17	Light Water Supply	-	59	2	2	96	15	-	33	207	1,179	44	-	-	-	50,842	1,400	-
2b.1.1.18	Liquid Waste	1	31	1	1	8	34	-	18	95	103	73	-	-	-	10,695	732	-
2b.1.1.19	Long Term Cooling	-	127	19	20	806	483	-	278	1,734	9,927	1,042	-	-	-	496,547	3,119	-
2b.1.1.20	Main Moderator	95	67	27	23	124	1,055	-	353	1,745	1,531	2,289	-	-	-	266,287	1,868	-
2b.1.1.21	Moderator Cover Gas System	1	23	1	1	4	38	-	17	85	54	82	-	-	-	9,504	557	-
2b.1.1.22	Moderator Deuteration & Dedeuteration	14	23	1	1	17	51	-	28	137	210	132	-	-	-	18,415	817	-
2b.1.1.23	Moderator Heavy Water Collection System	6	9	1	0	6	19	-	11	52	72	52	-	-	-	6,618	339	-
2b.1.1.24	Moderator Liquid Poison Systems	-	9	0	0	5	8	-	5	29	65	18	-	-	-	4,236	219	-
2b.1.1.25	Moderator Purification System	2	17	1	1	7	29	-	14	70	88	62	-	-	-	9,130	392	-
2b.1.1.26	NSP Valves, Pipe & Hangers In RB	-	1,279	64	65	792	2,745	-	1,141	6,087	9,756	5,918	-	-	-	927,104	30,542	-
2b.1.1.27	New Fuel Transfer & Storage	-	26	1	1	91	-	-	20	139	1,116	-	-	-	-	45,324	611	-
2b.1.1.28	Pipe & Hangers In RAB	-	3,557	52	62	4,698	-	-	1,608	9,978	57,845	-	-	-	-	2,349,115	84,492	-
2b.1.1.29	Plant (Service) Air	-	6	-	-	-	-	-	1	7	-	-	-	-	-	-	145	-
2b.1.1.30	RAB Ventilation	-	708	8	9	560	85	-	284	1,653	6,890	183	-	-	-	296,252	15,189	-
2b.1.1.31	Reactor Building Cooling	-	17	2	3	201	-	-	35	258	2,473	-	-	-	-	100,438	426	-
2b.1.1.32	Reactor Building Ventilation	-	130	8	9	286	254	-	141	829	3,527	548	-	-	-	192,385	3,096	-
2b.1.1.33	Recirculated Cooling Water	-	169	15	17	1,282	-	-	238	1,721	15,779	-	-	-	-	640,812	4,062	-
2b.1.1.34	Resin Transfer	6	5	0	0	5	14	-	9	39	58	40	-	-	-	5,002	257	-
2b.1.1.35	Shield Cooling	57	54	5	5	58	233	-	110	522	709	508	-	-	-	73,892	1,440	-
2b.1.1.36	Spent Fuel Transfer And Storage	-	80	11	12	456	312	-	170	1,042	5,619	674	-	-	-	288,569	1,955	-
2b.1.1.37	Spent Resin Handling	-	2	-	-	1	2	-	1	7	7	5	-	-	-	752	54	-
2b.1.1.38	Turbine Building Ventilation	-	78	-	-	-	-	-	12	90	-	-	-	-	-	-	2,082	-
2b.1.1	Totals	421	15,794	350	367	16,096	7,703	-	8,403	49,133	198,176	17,123	-	-	-	9,537,996	380,210	-
2b.1.2	Scaffolding in support of decommissioning	-	2,830	8	1	75	8	-	722	3,644	829	41	-	-	-	41,462	26,527	-

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Decontamination of Site Buildings																		
2b.1.3.1	Maintenance (Shared)	88	36	5	6	-	110	-	82	327	-	551	-	-	-	55,146	2,773	-
2b.1.3.2	Reactor	403	555	101	123	162	2,124	-	924	4,392	1,997	10,653	-	-	-	1,143,314	21,113	-
2b.1.3.3	Concrete Radwaste Tanks	-	85	183	225	-	3,953	-	1,062	5,508	-	19,764	-	-	-	1,976,400	2,389	-
2b.1.3	Totals	491	676	289	353	162	6,187	-	2,068	10,227	1,997	30,968	-	-	-	3,174,860	26,276	-
Demolition of Remaining Site Buildings																		
2b.1.4.1	Reactor	-	777	-	-	-	-	-	117	894	-	-	-	-	-	-	11,280	-
2b.1.4.2	Turbine	-	20	-	-	-	-	-	3	24	-	-	-	-	-	-	491	-
2b.1.4.3	Reactor- Auxiliary	-	63	-	-	-	-	-	9	73	-	-	-	-	-	-	1,062	-
2b.1.4	Totals	-	861	-	-	-	-	-	129	990	-	-	-	-	-	-	12,833	-
2b.1	Subtotal Period 2b Activity Costs	913	20,161	647	721	16,333	13,899	-	11,321	63,995	201,002	48,132	-	-	-	12,754,318	445,845	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Period 2b Additional Costs																		
2b.2.1	Survey & Release of Scrap Material	-	-	-	-	-	-	12,680	1,902	14,582	-	-	-	-	-	-	-	-
2b.2	Subtotal Period 2b Additional Costs	-	-	-	-	-	-	12,680	1,902	14,582	-	-	-	-	-	-	-	-
Period 2b Collateral Costs																		
2b.3.1	Process liquid waste	63	-	115	318	-	1,390	-	438	2,324	-	-	1,644	-	-	258,122	117	-
2b.3.2	Small tool allowance	-	289	-	-	-	-	-	43	333	-	-	-	-	-	-	-	-
2b.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	4,981	747	5,729	-	-	-	-	-	-	-	-
2b.3	Subtotal Period 2b Collateral Costs	63	289	115	318	-	1,390	4,981	1,229	8,385	-	-	1,644	-	-	258,122	117	-
Period 2b Period-Dependent Costs																		
2b.4.1	Decon supplies	337	-	-	-	-	-	-	84	421	-	-	-	-	-	-	-	-
2b.4.2	Insurance	-	-	-	-	-	-	1,499	150	1,649	-	-	-	-	-	-	-	-
2b.4.3	Property taxes	-	-	-	-	-	-	57	6	63	-	-	-	-	-	-	-	-
2b.4.4	Health physics supplies	-	1,991	-	-	-	-	-	498	2,489	-	-	-	-	-	-	-	-
2b.4.5	Heavy equipment rental	-	4,393	-	-	-	-	-	659	5,052	-	-	-	-	-	-	-	-
2b.4.6	Disposal of DAW generated	-	-	84	34	-	285	-	85	488	-	7,124	-	-	-	142,758	1,749	-

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

						Offsite	LLRW				Processed	Burial Volumes				Burial/		Utility and
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Processing Costs	Disposal Costs	Other Costs	Total Contingency	Total Costs	Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Processed Wt., Lbs.	Craft Manhours	Contractor Manhours
2b.4.7	Plant energy budget	-	-	-	-	-	-	1,124	169	1,293	-	-	-	-	-	-	-	-
2b.4.8	NRC Fees	-	-	-	-	-	-	1,225	122	1,347	-	-	-	-	-	-	-	-
2b.4.9	Emergency Planning Fees	-	-	-	-	-	-	1,209	121	1,330	-	-	-	-	-	-	-	-
2b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	1,949	292	2,242	-	-	-	-	-	-	-	-
2b.4.11	Radwaste Processing Equipment/Services	-	-	-	-	-	-	360	54	414	-	-	-	-	-	-	-	-
2b.4.12	Security Staff Cost	-	-	-	-	-	-	3,115	467	3,582	-	-	-	-	-	-	-	73,440
2b.4.13	DOC Staff Cost	-	-	-	-	-	-	22,511	3,377	25,887	-	-	-	-	-	-	-	311,040
2b.4.14	Utility Staff Cost	-	-	-	-	-	-	26,990	4,049	31,039	-	-	-	-	-	-	-	590,400
2b.4	Subtotal Period 2b Period-Dependent Costs	337	6,384	84	34	-	285	60,040	10,132	77,296	-	7,124	-	-	-	142,758	1,749	974,880
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2b.0	TOTAL PERIOD 2b COST	1,312	26,834	846	1,073	16,333	15,574	77,701	24,584	164,258	201,002	55,256	1,644	-	-	13,155,197	447,712	974,880
PERIOD 2c - Decontamination Following Wet Fuel Storage																		
Period 2c Direct Decommissioning Activities																		
2c.1.1	Remove spent fuel racks	197	21	38	3	240	-	-	144	644	2,670	-	-	-	-	120,150	584	-
Disposal of Plant Systems																		
2c.1.2.1	Spent Fuel Bay Cooling & Purification	-	48	5	5	41	199	-	69	367	501	430	-	-	-	58,905	1,153	-
2c.1.2	Totals	-	48	5	5	41	199	-	69	367	501	430	-	-	-	58,905	1,153	-
Decontamination of Site Buildings																		
2c.1.3.1	Reactor- Auxiliary	655	544	21	25	142	407	-	592	2,386	1,746	2,042	-	-	-	274,595	27,263	-
2c.1.3	Totals	655	544	21	25	142	407	-	592	2,386	1,746	2,042	-	-	-	274,595	27,263	-
2c.1.4	Scaffolding in support of decommissioning	-	566	2	0	15	2	-	144	729	166	8	-	-	-	8,292	5,305	-
2c.1	Subtotal Period 2c Activity Costs	852	1,180	66	33	438	608	-	950	4,126	5,082	2,481	-	-	-	461,942	34,305	-
Period 2c Additional Costs																		

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2c.2.1	Final Site Survey	-	-	-	-	-	-	615	184	799	-	-	-	-	-	-	-	6,240
2c.2	Subtotal Period 2c Additional Costs	-	-	-	-	-	-	615	184	799	-	-	-	-	-	-	-	6,240
Period 2c Collateral Costs																		
2c.3.1	Process liquid waste	69	-	24	120	-	383	-	151	747	-	-	502	-	-	63,269	99	-
2c.3.2	Small tool allowance	-	26	-	-	-	-	-	4	30	-	-	-	-	-	-	-	-
2c.3.3	Decommissioning Equipment Disposition	-	-	58	12	540	60	-	104	774	6,000	300	-	-	-	300,000	735	-
2c.3.4	Corporate & Site A&G Costs	-	-	-	-	-	-	525	79	604	-	-	-	-	-	-	-	-
2c.3	Subtotal Period 2c Collateral Costs	69	26	83	132	540	443	525	337	2,155	6,000	300	502	-	-	363,269	834	-
Period 2c Period-Dependent Costs																		
2c.4.1	Decon supplies	195	-	-	-	-	-	-	49	244	-	-	-	-	-	-	-	-
2c.4.2	Insurance	-	-	-	-	-	-	220	22	242	-	-	-	-	-	-	-	-
2c.4.3	Property taxes	-	-	-	-	-	-	9	1	10	-	-	-	-	-	-	-	-
2c.4.4	Health physics supplies	-	210	-	-	-	-	-	52	262	-	-	-	-	-	-	-	-
2c.4.5	Heavy equipment rental	-	693	-	-	-	-	-	104	797	-	-	-	-	-	-	-	-
2c.4.6	Disposal of DAW generated	-	-	13	5	-	43	-	13	74	-	1,084	-	-	-	21,715	266	-
2c.4.7	Plant energy budget	-	-	-	-	-	-	95	14	109	-	-	-	-	-	-	-	-
2c.4.8	NRC Fees	-	-	-	-	-	-	193	19	213	-	-	-	-	-	-	-	-
2c.4.9	Emergency Planning Fees	-	-	-	-	-	-	167	17	184	-	-	-	-	-	-	-	-
2c.4.10	Radwaste Processing Equipment/Services	-	-	-	-	-	-	157	24	180	-	-	-	-	-	-	-	-
2c.4.11	Security Staff Cost	-	-	-	-	-	-	491	74	565	-	-	-	-	-	-	-	11,584
2c.4.12	DOC Staff Cost	-	-	-	-	-	-	2,391	359	2,749	-	-	-	-	-	-	-	33,163
2c.4.13	Utility Staff Cost	-	-	-	-	-	-	2,859	429	3,288	-	-	-	-	-	-	-	62,237
2c.4	Subtotal Period 2c Period-Dependent Costs	195	903	13	5	-	43	6,581	1,176	8,916	-	1,084	-	-	-	21,715	266	106,984
2c.0	TOTAL PERIOD 2c COST	1,116	2,108	162	170	978	1,095	7,721	2,647	15,997	11,082	3,864	502	-	-	846,926	35,405	113,224

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
PERIOD 2d - Delay before License Termination																		
Period 2d Collateral Costs																		
2d.3.1	Corporate & Site A&G Costs	-	-	-	-	-	-	141	21	162	-	-	-	-	-	-	-	-
2d.3	Subtotal Period 2d Collateral Costs	-	-	-	-	-	-	141	21	162	-	-	-	-	-	-	-	-
Period 2d Period-Dependent Costs																		
2d.4.1	Insurance	-	-	-	-	-	-	379	38	417	-	-	-	-	-	-	-	-
2d.4.2	Property taxes	-	-	-	-	-	-	21	2	23	-	-	-	-	-	-	-	-
2d.4.3	Health physics supplies	-	57	-	-	-	-	-	14	72	-	-	-	-	-	-	-	-
2d.4.4	Disposal of DAW generated	-	-	1	0	-	4	-	1	7	-	101	-	-	-	2,026	25	-
2d.4.5	Plant energy budget	-	-	-	-	-	-	54	8	62	-	-	-	-	-	-	-	-
2d.4.6	NRC Fees	-	-	-	-	-	-	319	32	351	-	-	-	-	-	-	-	-
2d.4.7	Emergency Planning Fees	-	-	-	-	-	-	274	27	301	-	-	-	-	-	-	-	-
2d.4.8	Security Staff Cost	-	-	-	-	-	-	332	50	382	-	-	-	-	-	-	-	7,821
2d.4.9	Utility Staff Cost	-	-	-	-	-	-	706	106	811	-	-	-	-	-	-	-	16,686
2d.4	Subtotal Period 2d Period-Dependent Costs	-	57	1	0	-	4	2,083	278	2,425	-	101	-	-	-	2,026	25	24,507
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2d.0	TOTAL PERIOD 2d COST	-	57	1	0	-	4	2,224	300	2,587	-	101	-	-	-	2,026	25	24,507
PERIOD 2e - License Termination																		
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2e.1.1	ORISE confirmatory survey	-	-	-	-	-	-	121	36	157	-	-	-	-	-	-	-	-
2e.1.2	Terminate license	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
2e.1.3	Final report to NRC	-	-	-	-	-	-	134	20	154	-	-	-	-	-	-	-	1,560
2e.1	Subtotal Period 2e Activity Costs	-	-	-	-	-	-	254	56	311	-	-	-	-	-	-	-	1,560
Period 2e Additional Costs																		
2e.2.1	Final Site Survey	-	-	-	-	-	-	8,850	2,655	11,505	-	-	-	-	-	-	207,140	3,120
2e.2	Subtotal Period 2e Additional Costs	-	-	-	-	-	-	8,850	2,655	11,505	-	-	-	-	-	-	207,140	3,120

Table 4-13. ACR-700 Unit 1 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Period 2e Collateral Costs																		
2e.3.1	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
2e.3.2	Corporate & Site A&G Costs	-	-	-	-	-	-	346	52	398	-	-	-	-	-	-	-	-
2e.3	Subtotal Period 2e Collateral Costs	-	-	-	-	-	-	1,283	193	1,476	-	-	-	-	-	-	-	-
Period 2e Period-Dependent Costs																		
2e.4.1	Insurance	-	-	-	-	-	-	286	29	315	-	-	-	-	-	-	-	-
2e.4.2	Property taxes	-	-	-	-	-	-	16	2	17	-	-	-	-	-	-	-	-
2e.4.3	Health physics supplies	-	823	-	-	-	-	-	206	1,029	-	-	-	-	-	-	-	-
2e.4.4	Disposal of DAW generated	-	-	4	1	-	12	-	4	21	-	306	-	-	-	6,127	75	-
2e.4.5	Plant energy budget	-	-	-	-	-	-	82	12	94	-	-	-	-	-	-	-	-
2e.4.6	NRC Fees	-	-	-	-	-	-	335	34	369	-	-	-	-	-	-	-	-
2e.4.7	Emergency Planning Fees	-	-	-	-	-	-	207	21	228	-	-	-	-	-	-	-	-
2e.4.8	Security Staff Cost	-	-	-	-	-	-	251	38	288	-	-	-	-	-	-	-	5,914
2e.4.9	DOC Staff Cost	-	-	-	-	-	-	2,589	388	2,977	-	-	-	-	-	-	-	36,274
2e.4.10	Utility Staff Cost	-	-	-	-	-	-	1,995	299	2,294	-	-	-	-	-	-	-	41,006
2e.4	Subtotal Period 2e Period-Dependent Costs	-	823	4	1	-	12	5,761	1,031	7,632	-	306	-	-	-	6,127	75	83,194
2e.0	TOTAL PERIOD 2e COST	-	823	4	1	-	12	16,148	3,935	20,923	-	306	-	-	-	6,127	207,215	87,874
PERIOD 2 TOTALS		3,677	46,341	6,266	4,052	19,087	54,396	146,894	56,925	337,637	215,722	111,417	2,794	517	415	19,335,764	871,988	1,868,886
TOTAL COST TO DECOMMISSION		4,554	48,088	6,339	4,210	19,087	55,219	220,189	68,673	426,358	215,722	112,043	3,657	517	415	19,491,847	873,237	2,758,403

TOTAL COST TO DECOMMISSION WITH 19.2% CONTINGENCY: **$426,358 thousands of 2003 dollars**

End Notes:
n/a - indicates that this activity not charged as decommissioning expense.
a - indicates that this activity performed by decommissioning staff.
0 - indicates that this value is less than 0. but is non-zero.
a cell containing " - " indicates a zero value

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
PERIOD 1a - Shutdown through Transition																		
Period 1a Direct Decommissioning Activities																		
1a.1.1	Prepare preliminary decommissioning cost	-	-	-	-	-	-	48	7	55	-	-	-	-	-	-	-	556
1a.1.2	Notification of Cessation of Operations	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.3	Remove fuel & source material	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-	-	-
1a.1.4	Notification of Permanent Defueling	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.5	Deactivate plant systems & process waste	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.6	Prepare and submit PSDAR	-	-	-	-	-	-	73	11	84	-	-	-	-	-	-	-	856
1a.1.7	Review plant dwgs & specs.	-	-	-	-	-	-	169	25	194	-	-	-	-	-	-	-	1,969
1a.1.8	Perform detailed rad survey	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.9	Estimate by-product inventory	-	-	-	-	-	-	37	6	42	-	-	-	-	-	-	-	428
1a.1.10	End product description	-	-	-	-	-	-	37	6	42	-	-	-	-	-	-	-	428
1a.1.11	Detailed by-product inventory	-	-	-	-	-	-	48	7	55	-	-	-	-	-	-	-	556
1a.1.12	Define major work sequence	-	-	-	-	-	-	275	41	316	-	-	-	-	-	-	-	3,210
1a.1.13	Perform SER and EA	-	-	-	-	-	-	114	17	131	-	-	-	-	-	-	-	1,327
1a.1.14	Perform Site-Specific Cost Study	-	-	-	-	-	-	183	28	211	-	-	-	-	-	-	-	2,140
1a.1.15	Prepare/submit License Termination Plan	-	-	-	-	-	-	150	23	173	-	-	-	-	-	-	-	1,753
1a.1.16	Receive NRC approval of termination plan	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
Activity Specifications																		
1a.1.17	Total	-	-	-	-	-	-	1,387	208	1,595	-	-	-	-	-	-	-	16,190
Planning & Site Preparations																		
1a.1.18	Prepare dismantling sequence	-	-	-	-	-	-	88	13	101	-	-	-	-	-	-	-	1,027
1a.1.19	Plant prep. & temp. svces	-	-	-	-	-	-	2,419	363	2,782	-	-	-	-	-	-	-	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
1a.1.20	Design water cleanup system	-	-	-	-	-	-	51	8	59	-	-	-	-	-	-	-	599
1a.1.21	Rigging/Cont. Cntrl Envlps/tooling/etc.	-	-	-	-	-	-	2,048	307	2,355	-	-	-	-	-	-	-	-
1a.1.22	Procure casks/liners & containers	-	-	-	-	-	-	45	7	52	-	-	-	-	-	-	-	526
1a.1	Subtotal Period 1a Activity Costs	-	-	-	-	-	-	7,172	1,076	8,248	-	-	-	-	-	-	-	31,566
Period 1a Additional Costs																		
1a.2.1	Spent Fuel Pool Isolation	-	-	-	-	-	-	5,373	806	6,179	-	-	-	-	-	-	-	-
1a.2.2	Site Characterization	-	-	-	-	-	-	1,251	375	1,626	-	-	-	-	-	-	-	-
1a.2	Subtotal Period 1a Additional Costs	-	-	-	-	-	-	6,624	1,181	7,805	-	-	-	-	-	-	-	-
Period 1a Collateral Costs																		
1a.3.1	Corporate & Site A&G Costs	-	-	-	-	-	-	2,956	443	3,400	-	-	-	-	-	-	-	-
1a.3	Subtotal Period 1a Collateral Costs	-	-	-	-	-	-	2,956	443	3,400	-	-	-	-	-	-	-	-
Period 1a Period-Dependent Costs																		
1a.4.1	Insurance	-	-	-	-	-	-	1,344	134	1,478	-	-	-	-	-	-	-	-
1a.4.2	Property taxes	-	-	-	-	-	-	21	2	23	-	-	-	-	-	-	-	-
1a.4.3	Health physics supplies	-	229	-	-	-	-	-	57	286	-	-	-	-	-	-	-	-
1a.4.4	Heavy equipment rental	-	292	-	-	-	-	-	44	336	-	-	-	-	-	-	-	-
1a.4.5	Disposal of DAW generated	-	-	5	2	-	16	-	5	28	-	404	-	-	-	8,103	99	-
1a.4.6	Plant energy budget	-	-	-	-	-	-	543	81	624	-	-	-	-	-	-	-	-
1a.4.7	NRC Fees	-	-	-	-	-	-	381	38	419	-	-	-	-	-	-	-	-
1a.4.8	Emergency Planning Fees	-	-	-	-	-	-	547	55	602	-	-	-	-	-	-	-	-
1a.4.9	Spent Fuel Pool O&M	-	-	-	-	-	-	706	106	812	-	-	-	-	-	-	-	-
1a.4.10	Security Staff Cost	-	-	-	-	-	-	1,150	173	1,323	-	-	-	-	-	-	-	27,114
1a.4.11	Utility Staff Cost	-	-	-	-	-	-	15,975	2,396	18,371	-	-	-	-	-	-	-	350,400
1a.4	Subtotal Period 1a Period-Dependent Costs	-	521	5	2	-	16	20,666	3,091	24,302	-	404	-	-	-	8,103	99	377,514

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
1a.0	TOTAL PERIOD 1a COST	-	521	5	2	-	16	37,418	5,792	43,754	-	404	-	-	-	8,103	99	409,080
PERIOD 1b - Decommissioning Preparations																		
Period 1b Direct Decommissioning Activities																		
Detailed Work Procedures																		
1b.1.1.1	Plant systems	-	-	-	-	-	-	174	26	200	-	-	-	-	-	-	-	2,026
1b.1.1.2	NSSS Decontamination Flush	-	-	-	-	-	-	37	6	42	-	-	-	-	-	-	-	428
1b.1.1.3	Reactor internals	-	-	-	-	-	-	92	14	105	-	-	-	-	-	-	-	1,070
1b.1.1.4	Remaining buildings	-	-	-	-	-	-	50	7	57	-	-	-	-	-	-	-	578
1b.1.1.5	CRD cooling assembly	-	-	-	-	-	-	37	6	42	-	-	-	-	-	-	-	428
1b.1.1.6	CRD housings & ICI tubes	-	-	-	-	-	-	37	6	42	-	-	-	-	-	-	-	428
1b.1.1.7	Incore instrumentation	-	-	-	-	-	-	37	6	42	-	-	-	-	-	-	-	428
1b.1.1.8	Reactor vessel	-	-	-	-	-	-	133	20	153	-	-	-	-	-	-	-	1,554
1b.1.1.9	Facility closeout	-	-	-	-	-	-	44	7	51	-	-	-	-	-	-	-	514
1b.1.1.10	Missile shields	-	-	-	-	-	-	17	2	19	-	-	-	-	-	-	-	193
1b.1.1.11	Biological shield	-	-	-	-	-	-	44	7	51	-	-	-	-	-	-	-	514
1b.1.1.12	Steam generators	-	-	-	-	-	-	169	25	194	-	-	-	-	-	-	-	1,969
1b.1.1.13	Reinforced concrete	-	-	-	-	-	-	37	6	42	-	-	-	-	-	-	-	428
1b.1.1.14	Turbine & condensers	-	-	-	-	-	-	114	17	132	-	-	-	-	-	-	-	1,335
1b.1.1.15	Auxiliary building	-	-	-	-	-	-	100	15	115	-	-	-	-	-	-	-	1,168
1b.1.1.16	Reactor building	-	-	-	-	-	-	100	15	115	-	-	-	-	-	-	-	1,168
1b.1.1	Total	-	-	-	-	-	-	1,219	183	1,402	-	-	-	-	-	-	-	14,228
1b.1.2	Decon primary loop	199	-	-	-	-	-	-	100	299	-	-	-	-	-	-	1,067	-
1b.1	Subtotal Period 1b Activity Costs	199	-	-	-	-	-	1,219	282	1,701	-	-	-	-	-	-	1,067	14,228

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
Period 1b Collateral Costs																		
1b.3.1	Decon equipment	650	-	-	-	-	-	-	98	748	-	-	-	-	-	-	-	-
1b.3.2	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
1b.3.3	Process liquid waste	7	-	66	155	-	798	-	233	1,259	-	-	863	-	-	143,543	29	-
1b.3.4	Small tool allowance	-	1	-	-	-	-	-	0	1	-	-	-	-	-	-	-	-
1b.3.5	Pipe cutting equipment	-	957	-	-	-	-	-	143	1,100	-	-	-	-	-	-	-	-
1b.3.6	Corporate & Site A&G Costs	-	-	-	-	-	-	1,490	224	1,714	-	-	-	-	-	-	-	-
1b.3	Subtotal Period 1b Collateral Costs	657	957	66	155	-	798	2,428	838	5,900	-	-	863	-	-	143,543	29	-
Period 1b Period-Dependent Costs																		
1b.4.1	Decon supplies	20	-	-	-	-	-	-	5	25	-	-	-	-	-	-	-	-
1b.4.2	Insurance	-	-	-	-	-	-	677	68	745	-	-	-	-	-	-	-	-
1b.4.3	Property taxes	-	-	-	-	-	-	10	1	11	-	-	-	-	-	-	-	-
1b.4.4	Health physics supplies	-	119	-	-	-	-	-	30	149	-	-	-	-	-	-	-	-
1b.4.5	Heavy equipment rental	-	147	-	-	-	-	-	22	170	-	-	-	-	-	-	-	-
1b.4.6	Disposal of DAW generated	-	-	3	1	-	9	-	3	15	-	220	-	-	-	4,416	54	-
1b.4.7	Plant energy budget	-	-	-	-	-	-	547	82	629	-	-	-	-	-	-	-	-
1b.4.8	NRC Fees	-	-	-	-	-	-	192	19	211	-	-	-	-	-	-	-	-
1b.4.9	Emergency Planning Fees	-	-	-	-	-	-	276	28	304	-	-	-	-	-	-	-	-
1b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	356	53	409	-	-	-	-	-	-	-	-
1b.4.11	Security Staff Cost	-	-	-	-	-	-	580	87	667	-	-	-	-	-	-	-	13,669
1b.4.12	DOC Staff Cost	-	-	-	-	-	-	3,562	534	4,096	-	-	-	-	-	-	-	47,314
1b.4.13	Utility Staff Cost	-	-	-	-	-	-	8,053	1,208	9,261	-	-	-	-	-	-	-	176,640
1b.4	Subtotal Period 1b Period-Dependent Costs	20	266	3	1	-	9	14,253	2,140	16,691	-	220	-	-	-	4,416	54	237,623
1b.0	TOTAL PERIOD 1b COST	876	1,224	69	156	-	807	17,900	3,260	24,292	-	220	863	-	-	147,959	1,150	251,851
PERIOD 1 TOTALS		876	1,745	73	158	-	823	55,318	9,052	68,045	-	625	863	-	-	156,062	1,249	660,931

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
PERIOD 2a - Large Component Removal																		
Period 2a Direct Decommissioning Activities																		
Nuclear Steam Supply System Removal																		
2a.1.1.1	Heat Transport Piping	715	713	30	101	-	1,637	-	963	4,158	-	3,470	-	-	-	316,546	32,169	-
2a.1.1.2	Pressurizer Relief Tank	27	24	4	9	-	220	-	76	361	-	383	-	-	-	42,533	575	-
2a.1.1.3	Heat Transport Pumps & Motors	148	70	37	80	90	3,014	-	874	4,314	1,993	25,685	-	-	-	628,232	5,231	-
2a.1.1.4	Pressurizer	33	46	5	56	-	2,157	-	576	2,875	-	2,290	-	-	-	417,231	2,779	-
2a.1.1.5	Steam Generators	109	3,503	3,162	1,135	1,546	7,124	-	3,430	20,008	-	8,056	-	-	-	2,742,578	11,613	-
2a.1.1.6	CRDMs/ICIs/Service Structure Removal	33	28	44	25	-	137	-	66	333	-	1,172	-	-	-	26,594	1,354	-
2a.1.1.7	Reactor Vessel Internals	117	1,602	1,125	1,356	-	10,281	151	7,043	21,674	-	8,032	527	517	-	928,521	21,152	978
2a.1.1.8	Vessel & Internals GTCC Disposal	-	-	-	-	-	10,376	-	1,556	11,933	-	-	-	-	415	77,603	-	-
2a.1.1.9	Reactor Vessel	-	2,806	802	-	-	-	151	2,327	6,086	-	-	-	-	-	-	21,152	978
2a.1.1	Totals	1,182	8,791	5,207	2,763	1,637	34,946	303	16,912	71,741	1,993	49,089	527	517	415	5,179,837	96,025	1,956
Removal of Major Equipment																		
2a.1.2	Main Turbine/Generator	-	225	-	-	-	-	-	34	259	-	-	-	-	-	-	5,288	-
2a.1.3	Main Condensers	-	722	-	-	-	-	-	108	831	-	-	-	-	-	-	17,094	-
Disposal of Plant Systems																		
2a.1.4.1	Condensate	-	20	-	-	-	-	-	3	23	-	-	-	-	-	-	492	-
2a.1.4.2	Condensate Purification System	-	4	-	-	-	-	-	1	5	-	-	-	-	-	-	107	-
2a.1.4.3	Feedwater	-	31	-	-	-	-	-	5	36	-	-	-	-	-	-	760	-
2a.1.4.4	Feedwater Heater Drain System	-	3	-	-	-	-	-	0	3	-	-	-	-	-	-	70	-
2a.1.4.5	Feedwater Heating System	-	130	-	-	-	-	-	20	150	-	-	-	-	-	-	3,164	-
2a.1.4.6	Gland Sealing	-	2	-	-	-	-	-	0	3	-	-	-	-	-	-	54	-
2a.1.4.7	Jacking Oil Storage	-	1	-	-	-	-	-	0	2	-	-	-	-	-	-	36	-
2a.1.4.8	Liquid Injection Shutdown	-	44	1	1	71	14	-	25	156	869	38	-	-	-	37,915	1,056	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
2a.1.4.9	Moisture Separator	-	36	-	-	-	-	-	5	42	-	-	-	-	-	-	887	-
2a.1.4.10	Oil System	-	16	-	-	-	-	-	2	19	-	-	-	-	-	-	396	-
2a.1.4.11	Process Systems Valves/Pipe In TB	-	1,293	-	-	-	-	-	194	1,486	-	-	-	-	-	-	33,923	-
2a.1.4.12	Reheat	-	9	-	-	-	-	-	1	10	-	-	-	-	-	-	213	-
2a.1.4.13	Steam Generator Blowdown	-	4	0	0	9	-	-	2	16	113	-	-	-	-	4,580	93	-
2a.1.4.14	Turbine And Auxiliary Equipment	-	2	-	-	-	-	-	0	3	-	-	-	-	-	-	57	-
2a.1.4	Totals	-	1,596	1	1	80	14	-	260	1,952	981	38	-	-	-	42,495	41,310	-
2a.1.5	Scaffolding in support of decommissioning	-	2,264	6	1	60	7	-	577	2,915	663	33	-	-	-	33,169	21,221	-
2a.1	Subtotal Period 2a Activity Costs	1,182	13,599	5,215	2,765	1,776	34,966	303	17,892	77,699	3,638	49,159	527	517	415	5,255,502	180,938	1,956
Period 2a Additional Costs																		
2a.2.1	Curie Surcharge (excluding RPV)	-	-	-	-	-	2,500	-	625	3,125	-	-	-	-	-	-	-	-
2a.2	Subtotal Period 2a Additional Costs	-	-	-	-	-	2,500	-	625	3,125	-	-	-	-	-	-	-	-
Period 2a Collateral Costs																		
2a.3.1	Process liquid waste	17	-	6	29	-	135	-	47	234	-	-	121	-	-	15,255	24	-
2a.3.2	Small tool allowance	-	125	-	-	-	-	-	19	143	-	-	-	-	-	-	-	-
2a.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	3,222	483	3,705	-	-	-	-	-	-	-	-
2a.3	Subtotal Period 2a Collateral Costs	17	125	6	29	-	135	3,222	549	4,083	-	-	121	-	-	15,255	24	-
Period 2a Period-Dependent Costs																		
2a.4.1	Decon supplies	49	-	-	-	-	-	-	12	61	-	-	-	-	-	-	-	-
2a.4.2	Insurance	-	-	-	-	-	-	669	67	736	-	-	-	-	-	-	-	-
2a.4.3	Property taxes	-	-	-	-	-	-	25	3	28	-	-	-	-	-	-	-	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
2a.4.4	Health physics supplies	-	850	-	-	-	-	-	212	1,062	-	-	-	-	-	-	-	-
2a.4.5	Heavy equipment rental	-	1,950	-	-	-	-	-	292	2,242	-	-	-	-	-	-	-	-
2a.4.6	Disposal of DAW generated	-	-	32	13	-	109	-	32	187	-	2,732	-	-	-	54,753	671	-
2a.4.7	Plant energy budget	-	-	-	-	-	-	636	95	731	-	-	-	-	-	-	-	-
2a.4.8	NRC Fees	-	-	-	-	-	-	547	55	601	-	-	-	-	-	-	-	-
2a.4.9	Emergency Planning Fees	-	-	-	-	-	-	607	61	668	-	-	-	-	-	-	-	-
2a.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	870	131	1,001	-	-	-	-	-	-	-	-
2a.4.11	Security Staff Cost	-	-	-	-	-	-	3,845	577	4,421	-	-	-	-	-	-	-	90,643
2a.4.12	DOC Staff Cost	-	-	-	-	-	-	14,626	2,194	16,820	-	-	-	-	-	-	-	195,429
2a.4.13	Utility Staff Cost	-	-	-	-	-	-	17,844	2,677	20,521	-	-	-	-	-	-	-	381,857
2a.4	Subtotal Period 2a Period-Dependent Costs	49	2,800	32	13	-	109	39,670	6,408	49,081	-	2,732	-	-	-	54,753	671	667,929
2a.0	TOTAL PERIOD 2a COST	1,249	16,523	5,253	2,807	1,776	37,710	43,195	25,474	133,988	3,638	51,892	648	517	415	5,325,510	181,632	669,885
PERIOD 2b - Site Decontamination																		
Period 2b Direct Decommissioning Activities																		
Disposal of Plant Systems																		
2b.1.1.1	Active Drainage Reactor Aux & Service	-	5	0	0	8	1	-	3	18	103	4	-	-	-	4,430	116	-
2b.1.1.2	Active Drainage Reactor Building	-	1	-	-	0	1	-	1	3	4	2	-	-	-	376	31	-
2b.1.1.3	Annulus Gas	-	13	1	1	21	22	-	12	69	262	47	-	-	-	14,842	307	-
2b.1.1.4	Electric - Primary Containment	-	3,855	36	42	2,589	393	-	1,460	8,376	31,870	848	-	-	-	1,370,338	91,108	-
2b.1.1.5	Electrical - RCA	-	2,536	20	24	1,830	-	-	914	5,324	22,528	-	-	-	-	914,871	60,046	-
2b.1.1.6	Electrical - Clean	-	1,784	-	-	-	-	-	268	2,051	-	-	-	-	-	-	44,386	-
2b.1.1.7	Emergency Coolant Injection	-	660	19	20	1,166	226	-	401	2,493	14,355	620	-	-	-	626,703	15,717	-
2b.1.1.8	Fire Protection	-	42	1	1	100	-	-	26	170	1,225	-	-	-	-	49,757	1,008	-
2b.1.1.9	Fuel Changing	-	87	11	12	484	279	-	167	1,040	5,959	604	-	-	-	296,030	2,093	-
2b.1.1.10	H2O Leakage Collection	-	13	0	0	14	-	-	5	33	176	-	-	-	-	7,165	309	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2b.1.1.11	Heat Transport	2	16	1	1	5	30	-	14	69	58	66	-	-	-	8,225	395	-
2b.1.1.12	Heat Transport Sys Pressure & Inventory	237	199	38	30	238	1,338	-	547	2,626	2,926	3,178	-	-	-	377,706	8,436	-
2b.1.1.13	Heavy Water Cleanup	-	36	1	1	44	12	-	19	113	545	29	-	-	-	24,460	843	-
2b.1.1.14	Heavy Water Supply	-	56	1	1	80	18	-	31	187	982	48	-	-	-	43,401	1,321	-
2b.1.1.15	Heavy Water Vapor Recovery	-	10	0	0	11	3	-	5	30	138	7	-	-	-	6,151	243	-
2b.1.1.16	Light Water Cleanup	-	2	-	-	3	1	-	1	8	36	2	-	-	-	1,624	55	-
2b.1.1.17	Light Water Supply	-	59	2	2	96	15	-	33	207	1,179	44	-	-	-	50,842	1,400	-
2b.1.1.18	Liquid Waste	1	31	1	1	8	34	-	18	95	103	73	-	-	-	10,695	732	-
2b.1.1.19	Long Term Cooling	-	127	19	20	806	483	-	278	1,734	9,927	1,042	-	-	-	496,547	3,119	-
2b.1.1.20	Main Moderator	95	67	27	23	124	1,055	-	353	1,745	1,531	2,289	-	-	-	266,287	1,868	-
2b.1.1.21	Moderator Cover Gas System	1	23	1	1	4	38	-	17	85	54	82	-	-	-	9,504	557	-
2b.1.1.22	Moderator Deuertation & Dedeuteration	14	23	1	1	17	51	-	28	137	210	132	-	-	-	18,415	817	-
2b.1.1.23	Moderator Heavy Water Collection System	6	9	1	0	6	19	-	11	52	72	52	-	-	-	6,618	339	-
2b.1.1.24	Moderator Liquid Poison Systems	-	9	0	0	5	8	-	5	29	65	18	-	-	-	4,236	219	-
2b.1.1.25	Moderator Purification System	2	17	1	1	7	29	-	14	70	88	62	-	-	-	9,130	392	-
2b.1.1.26	NSP Valves, Pipe & Hangers In RB	-	1,279	64	65	792	2,745	-	1,141	6,087	9,756	5,918	-	-	-	927,104	30,542	-
2b.1.1.27	New Fuel Transfer & Storage	-	26	1	1	91	-	-	20	139	1,116	-	-	-	-	45,324	611	-
2b.1.1.28	Pipe & Hangers In RAB	-	3,557	52	62	4,698	-	-	1,608	9,978	57,845	-	-	-	-	2,349,115	84,492	-
2b.1.1.29	Plant (Service) Air	-	6	-	-	-	-	-	1	7	-	-	-	-	-	-	145	-
2b.1.1.30	RAB Ventilation	-	708	8	9	560	85	-	284	1,653	6,890	183	-	-	-	296,252	15,189	-
2b.1.1.31	Reactor Building Cooling	-	17	2	3	201	-	-	35	258	2,473	-	-	-	-	100,438	426	-
2b.1.1.32	Reactor Building Ventilation	-	130	8	9	286	254	-	141	829	3,527	548	-	-	-	192,385	3,096	-
2b.1.1.33	Recirculated Cooling Water	-	169	15	17	1,282	-	-	238	1,721	15,779	-	-	-	-	640,812	4,062	-
2b.1.1.34	Resin Transfer	6	5	0	0	5	14	-	9	39	58	40	-	-	-	5,002	257	-
2b.1.1.35	Shield Cooling	57	54	5	5	58	233	-	110	522	709	508	-	-	-	73,892	1,440	-
2b.1.1.36	Spent Fuel Transfer And Storage	-	80	11	12	456	312	-	170	1,042	5,619	674	-	-	-	288,569	1,955	-
2b.1.1.37	Spent Resin Handling	-	2	-	-	1	2	-	1	7	7	5	-	-	-	752	54	-
2b.1.1.38	Turbine Building Ventilation	-	78	-	-	-	-	-	12	90	-	-	-	-	-	-	2,082	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2b.1.1	Totals	421	15,794	350	367	16,096	7,703	-	8,403	49,133	198,176	17,123	-	-	-	9,537,996	380,210	-
2b.1.2	Scaffolding in support of decommissioning	-	2,830	8	1	75	8	-	722	3,644	829	41	-	-	-	41,462	26,527	-
Decontamination of Site Buildings																		
2b.1.3.1	Maintenance (Shared)	88	36	5	6	-	110	-	82	327	-	551	-	-	-	55,146	2,773	-
2b.1.3.2	Reactor	403	555	101	123	162	2,124	-	924	4,392	1,997	10,653	-	-	-	1,143,314	21,113	-
2b.1.3.3	Concrete Radwaste Tanks	-	85	183	225	-	3,953	-	1,062	5,508	-	19,764	-	-	-	1,976,400	2,389	-
2b.1.3	Totals	491	676	289	353	162	6,187	-	2,068	10,227	1,997	30,968	-	-	-	3,174,860	26,276	-
Demolition of Remaining Site Buildings																		
2b.1.4.1	Reactor	-	777	-	-	-	-	-	117	894	-	-	-	-	-	-	11,280	-
2b.1.4.2	Turbine	-	20	-	-	-	-	-	3	24	-	-	-	-	-	-	491	-
2b.1.4.3	Reactor- Auxiliary	-	63	-	-	-	-	-	9	73	-	-	-	-	-	-	1,062	-
2b.1.4.4	Remove Rubble	-	1,376	-	-	-	-	-	206	1,582	-	-	-	-	-	-	2,205	-
2b.1.4	Totals	-	2,237	-	-	-	-	-	336	2,573	-	-	-	-	-	-	15,038	-
2b.1	Subtotal Period 2b Activity Costs	913	21,537	647	721	16,333	13,899	-	11,528	65,577	201,002	48,132	-	-	-	12,754,318	448,051	-
Period 2b Additional Costs																		
2b.2.1	Survey & Release of Scrap Material	-	-	-	-	-	-	12,680	1,902	14,582	-	-	-	-	-	-	-	-
2b.2	Subtotal Period 2b Additional Costs	-	-	-	-	-	-	12,680	1,902	14,582	-	-	-	-	-	-	-	-
Period 2b Collateral Costs																		
2b.3.1	Process liquid waste	63	-	115	318	-	1,390	-	438	2,324	-	-	1,644	-	-	258,107	117	-
2b.3.2	Small tool allowance	-	291	-	-	-	-	-	44	334	-	-	-	-	-	-	-	-
2b.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	6,932	1,040	7,972	-	-	-	-	-	-	-	-
2b.3	Subtotal Period 2b Collateral Costs	63	291	115	318	-	1,390	6,932	1,521	10,630	-	-	1,644	-	-	258,107	117	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Period 2b Period-Dependent Costs																		
2b.4.1	Decon supplies	337	-	-	-	-	-	-	84	421	-	-	-	-	-	-	-	-
2b.4.2	Insurance	-	-	-	-	-	-	1,501	150	1,651	-	-	-	-	-	-	-	-
2b.4.3	Property taxes	-	-	-	-	-	-	57	6	63	-	-	-	-	-	-	-	-
2b.4.4	Health physics supplies	-	1,992	-	-	-	-	-	498	2,490	-	-	-	-	-	-	-	-
2b.4.5	Heavy equipment rental	-	4,398	-	-	-	-	-	660	5,057	-	-	-	-	-	-	-	-
2b.4.6	Disposal of DAW generated	-	-	84	34	-	285	-	85	488	-	7,125	-	-	-	142,780	1,749	-
2b.4.7	Plant energy budget	-	-	-	-	-	-	1,125	169	1,294	-	-	-	-	-	-	-	-
2b.4.8	NRC Fees	-	-	-	-	-	-	1,226	123	1,349	-	-	-	-	-	-	-	-
2b.4.9	Emergency Planning Fees	-	-	-	-	-	-	1,211	121	1,332	-	-	-	-	-	-	-	-
2b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	1,951	293	2,244	-	-	-	-	-	-	-	-
2b.4.11	Radwaste Processing Equipment/Services	-	-	-	-	-	-	360	54	414	-	-	-	-	-	-	-	-
2b.4.12	Security Staff Cost	-	-	-	-	-	-	6,909	1,036	7,945	-	-	-	-	-	-	-	162,881
2b.4.13	DOC Staff Cost	-	-	-	-	-	-	31,506	4,726	36,232	-	-	-	-	-	-	-	420,897
2b.4.14	Utility Staff Cost	-	-	-	-	-	-	38,423	5,763	44,186	-	-	-	-	-	-	-	821,614
2b.4	Subtotal Period 2b Period-Dependent Costs	337	6,389	84	34	-	285	84,268	13,767	105,165	-	7,125	-	-	-	142,780	1,749	1,405,393
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2b.0	TOTAL PERIOD 2b COST	1,312	28,217	846	1,073	16,333	15,574	103,881	28,718	195,954	201,002	55,257	1,644	-	-	13,155,205	449,917	1,405,393
PERIOD 2c - Decontamination Following Wet Fuel Storage																		
Period 2c Direct Decommissioning Activities																		
2c.1.1	Remove spent fuel racks	197	21	38	3	240	-	-	144	644	2,670	-	-	-	-	120,150	584	-
Disposal of Plant Systems																		
2c.1.2.1	Spent Fuel Bay Cooling & Purification	-	48	5	5	41	199	-	69	367	501	430	-	-	-	58,905	1,153	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2c.1.2	Totals	-	48	5	5	41	199	-	69	367	501	430	-	-	-	58,905	1,153	-
Decontamination of Site Buildings																		
2c.1.3.1	Reactor- Auxiliary	655	544	21	25	142	407	-	592	2,386	1,746	2,042	-	-	-	274,595	27,263	-
2c.1.3	Totals	655	544	21	25	142	407	-	592	2,386	1,746	2,042	-	-	-	274,595	27,263	-
2c.1.4	Scaffolding in support of decommissioning	-	566	2	0	15	2	-	144	729	166	8	-	-	-	8,292	5,305	-
2c.1	Subtotal Period 2c Activity Costs	852	1,180	66	33	438	608	-	950	4,126	5,082	2,481	-	-	-	461,942	34,305	-
Period 2c Additional Costs																		
2c.2.1	Final Site Survey	-	-	-	-	-	-	615	184	799	-	-	-	-	-	-	-	6,240
2c.2	Subtotal Period 2c Additional Costs	-	-	-	-	-	-	615	184	799	-	-	-	-	-	-	-	6,240
Period 2c Collateral Costs																		
2c.3.1	Process liquid waste	69	-	24	120	-	383	-	151	747	-	-	502	-	-	63,269	99	-
2c.3.2	Small tool allowance	-	26	-	-	-	-	-	4	30	-	-	-	-	-	-	-	-
2c.3.3	Decommissioning Equipment Disposition	-	-	58	12	540	60	-	104	774	6,000	300	-	-	-	300,000	735	-
2c.3.4	Corporate & Site A&G Costs	-	-	-	-	-	-	773	116	889	-	-	-	-	-	-	-	-
2c.3	Subtotal Period 2c Collateral Costs	69	26	83	132	540	443	773	374	2,440	6,000	300	502	-	-	363,269	834	-
Period 2c Period-Dependent Costs																		
2c.4.1	Decon supplies	195	-	-	-	-	-	-	49	244	-	-	-	-	-	-	-	-
2c.4.2	Insurance	-	-	-	-	-	-	219	22	240	-	-	-	-	-	-	-	-
2c.4.3	Property taxes	-	-	-	-	-	-	9	1	10	-	-	-	-	-	-	-	-
2c.4.4	Health physics supplies	-	209	-	-	-	-	-	52	262	-	-	-	-	-	-	-	-
2c.4.5	Heavy equipment rental	-	689	-	-	-	-	-	103	792	-	-	-	-	-	-	-	-
2c.4.6	Disposal of DAW generated	-	-	13	5	-	43	-	13	74	-	1,083	-	-	-	21,693	266	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2c.4.7	Plant energy budget	-	-	-	-	-	-	94	14	108	-	-	-	-	-	-	-	-
2c.4.8	NRC Fees	-	-	-	-	-	-	192	19	211	-	-	-	-	-	-	-	-
2c.4.9	Emergency Planning Fees	-	-	-	-	-	-	166	17	182	-	-	-	-	-	-	-	-
2c.4.10	Radwaste Processing Equipment/Services	-	-	-	-	-	-	156	23	179	-	-	-	-	-	-	-	-
2c.4.11	Security Staff Cost	-	-	-	-	-	-	1,082	162	1,244	-	-	-	-	-	-	-	25,506
2c.4.12	DOC Staff Cost	-	-	-	-	-	-	3,376	506	3,883	-	-	-	-	-	-	-	45,143
2c.4.13	Utility Staff Cost	-	-	-	-	-	-	4,438	666	5,104	-	-	-	-	-	-	-	91,640
2c.4	Subtotal Period 2c Period-Dependent Costs	195	898	13	5	-	43	9,731	1,648	12,533	-	1,083	-	-	-	21,693	266	162,289
2c.0	TOTAL PERIOD 2c COST	1,116	2,103	162	170	978	1,095	11,119	3,156	19,899	11,082	3,863	502	-	-	846,904	35,404	168,529
PERIOD 2e - License Termination																		
Period 2e Direct Decommissioning Activities																		
2e.1.1	ORISE confirmatory survey	-	-	-	-	-	-	121	36	157	-	-	-	-	-	-	-	-
2e.1.2	Terminate license	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
2e.1.3	Final report to NRC	-	-	-	-	-	-	57	9	66	-	-	-	-	-	-	-	668
2e.1	Subtotal Period 2e Activity Costs	-	-	-	-	-	-	178	45	223	-	-	-	-	-	-	-	668
Period 2e Additional Costs																		
2e.2.1	Final Site Survey	-	-	-	-	-	-	8,921	2,676	11,598	-	-	-	-	-	-	208,886	3,120
2e.2	Subtotal Period 2e Additional Costs	-	-	-	-	-	-	8,921	2,676	11,598	-	-	-	-	-	-	208,886	3,120
Period 2e Collateral Costs																		
2e.3.1	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
2e.3.2	Corporate & Site A&G Costs	-	-	-	-	-	-	672	101	773	-	-	-	-	-	-	-	-
2e.3	Subtotal Period 2e Collateral Costs	-	-	-	-	-	-	1,609	241	1,851	-	-	-	-	-	-	-	-

Table 4-14. ACR-700 Unit 2 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
Period 2e Period-Dependent Costs																		
2e.4.1	Insurance	-	-	-	-	-	-	286	29	315	-	-	-	-	-	-	-	-
2e.4.2	Property taxes	-	-	-	-	-	-	16	2	17	-	-	-	-	-	-	-	-
2e.4.3	Health physics supplies	-	828	-	-	-	-	-	207	1,036	-	-	-	-	-	-	-	-
2e.4.4	Disposal of DAW generated	-	-	4	1	-	12	-	4	21	-	306	-	-	-	6,127	75	-
2e.4.5	Plant energy budget	-	-	-	-	-	-	82	12	94	-	-	-	-	-	-	-	-
2e.4.6	NRC Fees	-	-	-	-	-	-	335	34	369	-	-	-	-	-	-	-	-
2e.4.7	Emergency Planning Fees	-	-	-	-	-	-	207	21	228	-	-	-	-	-	-	-	-
2e.4.8	Security Staff Cost	-	-	-	-	-	-	602	90	692	-	-	-	-	-	-	-	14,194
2e.4.9	DOC Staff Cost	-	-	-	-	-	-	4,416	662	5,078	-	-	-	-	-	-	-	57,566
2e.4.10	Utility Staff Cost	-	-	-	-	-	-	4,160	624	4,784	-	-	-	-	-	-	-	79,646
2e.4	Subtotal Period 2e Period-Dependent Costs	-	828	4	1	-	12	10,104	1,684	12,634	-	306	-	-	-	6,127	75	151,406
2e.0	TOTAL PERIOD 2e COST	-	828	4	1	-	12	20,813	4,647	26,305	-	306	-	-	-	6,127	208,961	155,193
PERIOD 2 TOTALS		3,677	47,672	6,264	4,051	19,087	54,392	179,007	61,995	376,145	215,722	111,317	2,794	517	415	19,333,746	875,915	2,399,000
TOTAL COST TO DECOMMISSION		4,553	49,417	6,338	4,209	19,087	55,215	234,325	71,047	444,191	215,722	111,942	3,657	517	415	19,489,808	877,164	3,059,931

TOTAL COST TO DECOMMISSION WITH 19.04% CONTINGENCY: **$444,191 thousands of 2003 dollars**

End Notes:
n/a - indicates that this activity not charged as decommissioning expense.
a - indicates that this activity performed by decommissioning staff.
0 - indicates that this value is less than 0.5 but is non-zero.
a cell containing " - " indicates a zero value

Table 4-15. AP1000 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
PERIOD 1a - Shutdown through Transition																		
1a.1.1	Prepare preliminary decommissioning cost	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.2	Notification of Cessation of Operations	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.3	Remove fuel & source material	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-	-	-
1a.1.4	Notification of Permanent Defueling	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.5	Deactivate plant systems & process waste	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.6	Prepare and submit PSDAR	-	-	-	-	-	-	171	26	197	-	-	-	-	-	-	-	2,000
1a.1.7	Review plant dwgs & specs.	-	-	-	-	-	-	394	59	453	-	-	-	-	-	-	-	4,600
1a.1.8	Perform detailed rad survey	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.9	Estimate by-product inventory	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.10	End product description	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.11	Detailed by-product inventory	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.12	Define major work sequence	-	-	-	-	-	-	643	96	739	-	-	-	-	-	-	-	7,500
1a.1.13	Perform SER and EA	-	-	-	-	-	-	266	40	305	-	-	-	-	-	-	-	3,100
1a.1.14	Perform Site-Specific Cost Study	-	-	-	-	-	-	428	64	493	-	-	-	-	-	-	-	5,000
1a.1.15	Prepare/submit License Termination Plan	-	-	-	-	-	-	351	53	404	-	-	-	-	-	-	-	4,096
1a.1.16	Receive NRC approval of termination plan	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
Activity Specifications																		
1a.1.17	Total							3,241	486	3,728								37,827
Planning & Site Preparations		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1a.1.18	Prepare dismantling sequence	-	-	-	-	-	-	206	31	237	-	-	-	-	-	-	-	2,400
1a.1.19	Plant prep. & temp. svces	-	-	-	-	-	-	2,419	363	2,782	-	-	-	-	-	-	-	-
1a.1.20	Design water cleanup system	-	-	-	-	-	-	120	18	138	-	-	-	-	-	-	-	1,400
1a.1.21	Rigging/Cont. Cntrl Envlps/tooling/etc.	-	-	-	-	-	-	2,048	307	2,355	-	-	-	-	-	-	-	-

Table 4-15. AP1000 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
1a.1.22	Procure casks/liners & containers	-	-	-	-	-	-	105	16	121	-	-	-	-	-	-	-	1,230
1a.1	Subtotal Period 1a Activity Costs	-	-	-	-	-	-	10,787	1,618	12,405	-	-	-	-	-	-	-	73,753
Period 1a Additional Costs																		
1a.2.1	Spent Fuel Pool Isolation	-	-	-	-	-	-	8,060	1,209	9,269	-	-	-	-	-	-	-	-
1a.2.2	Site Characterization	-	-	-	-	-	-	1,853	556	2,408	-	-	-	-	-	-	-	-
1a.2	Subtotal Period 1a Additional Costs	-	-	-	-	-	-	9,912	1,765	11,677	-	-	-	-	-	-	-	-
Period 1a Collateral Costs																		
1a.3.1	Corporate & Site A&G Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
1a.3	Subtotal Period 1a Collateral Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
Period 1a Period-Dependent Costs																		
1a.4.1	Insurance	-	-	-	-	-	-	1,344	134	1,478	-	-	-	-	-	-	-	-
1a.4.2	Property taxes	-	-	-	-	-	-	21	2	23	-	-	-	-	-	-	-	-
1a.4.3	Health physics supplies	-	229	-	-	-	-	-	57	286	-	-	-	-	-	-	-	-
1a.4.4	Heavy equipment rental	-	292	-	-	-	-	-	44	336	-	-	-	-	-	-	-	-
1a.4.5	Disposal of DAW generated	-	-	5	2	-	16	-	5	28	-	404	-	-	-	8,103	99	-
1a.4.6	Plant energy budget	-	-	-	-	-	-	773	116	889	-	-	-	-	-	-	-	-
1a.4.7	NRC Fees	-	-	-	-	-	-	381	38	419	-	-	-	-	-	-	-	-
1a.4.8	Emergency Planning Fees	-	-	-	-	-	-	547	55	602	-	-	-	-	-	-	-	-
1a.4.9	Spent Fuel Pool O&M	-	-	-	-	-	-	706	106	812	-	-	-	-	-	-	-	-
1a.4.10	Security Staff Cost	-	-	-	-	-	-	2,499	375	2,874	-	-	-	-	-	-	-	58,921
1a.4.11	Utility Staff Cost	-	-	-	-	-	-	20,438	3,066	23,503	-	-	-	-	-	-	-	438,000
1a.4	Subtotal Period 1a Period-Dependent Costs	-	521	5	2	-	16	26,709	3,998	31,250	-	404	-	-	-	8,103	99	496,921
1a.0	TOTAL PERIOD 1a COST	-	521	5	2	-	16	51,103	7,935	59,582	-	404	-	-	-	8,103	99	570,674
PERIOD 1b - Decommissioning Preparations																		
Detailed Work Procedures																		
1b.1.1	Total	-	-	-	-	-	-	2,849	427	3,276	-	-	-	-	-	-	-	33,243

Table 4-15. AP1000 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
1b.1.2	Decon primary loop	629	-	-	-	-	-	-	314	943	-	-	-	-	-	-	1,067	-
1b.1	Subtotal Period 1b Activity Costs	629	-	-	-	-	-	2,849	742	4,219	-	-	-	-	-	-	1,067	33,243
Period 1b Collateral Costs																		
1b.3.1	Decon equipment	650	-	-	-	-	-	-	98	748	-	-	-	-	-	-	-	-
1b.3.2	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
1b.3.3	Process liquid waste	40	-	259	619	-	2,977	-	883	4,778	-	-	3,419	-	-	565,063	129	-
1b.3.4	Small tool allowance	-	1	-	-	-	-	-	0	1	-	-	-	-	-	-	-	-
1b.3.5	Pipe cutting equipment	-	957	-	-	-	-	-	143	1,100	-	-	-	-	-	-	-	-
1b.3.6	Corporate & Site A&G Costs	-	-	-	-	-	-	1,882	282	2,164	-	-	-	-	-	-	-	-
1b.3	Subtotal Period 1b Collateral Costs	690	957	259	619	-	2,977	2,819	1,547	9,869	-	-	3,419	-	-	565,063	129	-
Period 1b Period-Dependent Costs																		
1b.4.1	Decon supplies	20	-	-	-	-	-	-	5	25	-	-	-	-	-	-	-	-
1b.4.2	Insurance	-	-	-	-	-	-	681	68	749	-	-	-	-	-	-	-	-
1b.4.3	Property taxes	-	-	-	-	-	-	10	1	11	-	-	-	-	-	-	-	-
1b.4.4	Health physics supplies	-	120	-	-	-	-	-	30	150	-	-	-	-	-	-	-	-
1b.4.5	Heavy equipment rental	-	148	-	-	-	-	-	22	170	-	-	-	-	-	-	-	-
1b.4.6	Disposal of DAW generated	-	-	3	1	-	9	-	3	15	-	221	-	-	-	4,439	54	-
1b.4.7	Plant energy budget	-	-	-	-	-	-	783	117	901	-	-	-	-	-	-	-	-
1b.4.8	NRC Fees	-	-	-	-	-	-	193	19	212	-	-	-	-	-	-	-	-
1b.4.9	Emergency Planning Fees	-	-	-	-	-	-	277	28	305	-	-	-	-	-	-	-	-
1b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	358	54	411	-	-	-	-	-	-	-	-
1b.4.11	Security Staff Cost	-	-	-	-	-	-	1,267	190	1,457	-	-	-	-	-	-	-	29,864
1b.4.12	DOC Staff Cost	-	-	-	-	-	-	4,955	743	5,698	-	-	-	-	-	-	-	64,486
1b.4.13	Utility Staff Cost	-	-	-	-	-	-	10,414	1,562	11,976	-	-	-	-	-	-	-	223,057
1b.4	Subtotal Period 1b Period-Dependent Costs	20	268	3	1	-	9	18,939	2,843	22,082	-	221	-	-	-	4,439	54	317,407
1b.0	TOTAL PERIOD 1b COST	1,339	1,225	262	620	-	2,986	24,607	5,131	36,170	-	221	3,419	-	-	569,502	1,250	350,650
PERIOD 1 TOTALS		1,339	1,747	267	622	-	3,002	75,710	13,066	95,752	-	626	3,419	-	-	577,605	1,349	921,324

Table 4-15. AP1000 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
PERIOD 2a - Large Component Removal																		
Nuclear Steam Supply System Removal																		
2a.1.1.1	Reactor Coolant Piping	42	45	5	18	-	287	-	107	505	-	611	-	-	-	55,606	1,994	-
2a.1.1.2	Pressurizer Relief Tank	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2a.1.1.3	Reactor Coolant Pumps & Motors	61	70	37	103	117	3,895	-	1,058	5,341	223	2,879	-	-	-	811,800	3,325	-
2a.1.1.4	Pressurizer	41	46	5	48	-	1,819	-	495	2,454	-	3,020	-	-	-	351,891	2,948	-
2a.1.1.5	Steam Generators	125	3,503	3,251	1,194	2,132	8,086	-	3,784	22,076	-	14,721	-	-	-	3,367,022	11,613	-
2a.1.1.6	CRDMs/ICIs/Service Structure Removal	124	84	104	58	-	483	-	223	1,077	-	3,742	-	-	-	93,425	4,607	-
2a.1.1.7	Reactor Vessel Internals	61	2,025	3,163	683	-	3,388	165	4,230	13,715	-	1,002	344	402	-	204,412	23,263	1,063
2a.1.1.8	Vessel & Internals GTCC Disposal	-	-	-	-	-	16,979	-	2,547	19,526	-	-	-	-	679	124,964	-	-
2a.1.1.9	Reactor Vessel	66	4,315	1,077	748	-	6,951	165	7,226	20,548	-	6,320	2,128	-	-	924,813	23,263	1,063
2a.1.1	Totals	521	10,090	7,643	2,852	2,249	41,889	329	19,670	85,242	223	32,294	2,473	402	679	5,933,933	71,012	2,125
Removal of Major Equipment																		
2a.1.2	Main Turbine/Generator	-	383	-	-	-	-	-	57	440	-	-	-	-	-	-	8,978	-
2a.1.3	Main Condensers	-	1,244	-	-	-	-	-	187	1,431	-	-	-	-	-	-	29,453	-
Disposal of Plant Systems																		
2a.1.4.1	Auxiliary Steam Supply	-	42	-	-	-	-	-	6	48	-	-	-	-	-	-	1,061	-
2a.1.4.2	Circulating Water	-	33	-	-	-	-	-	5	38	-	-	-	-	-	-	839	-
2a.1.4.3	Condensate	-	150	-	-	-	-	-	22	172	-	-	-	-	-	-	3,765	-
2a.1.4.4	Condensate Polishing	-	9	-	-	-	-	-	1	10	-	-	-	-	-	-	231	-
2a.1.4.5	Condenser Air Removal	-	16	-	-	-	-	-	2	18	-	-	-	-	-	-	392	-
2a.1.4.6	Containment Hydrogen Control	-	38	0	0	12	12	-	14	78	150	25	-	-	-	8,344	943	-
2a.1.4.7	Containment Leak Rate Test	-	3	-	0	8	-	-	2	13	96	-	-	-	-	3,911	75	-
2a.1.4.8	Gland Seal	-	19	-	-	-	-	-	3	21	-	-	-	-	-	-	475	-
2a.1.4.9	Heater Drain	-	57	-	-	-	-	-	9	66	-	-	-	-	-	-	1,483	-
2a.1.4.10	Hydrogen Seal Oil	-	11	-	-	-	-	-	2	12	-	-	-	-	-	-	267	-
2a.1.4.11	Main Steam	-	83	-	-	-	-	-	12	96	-	-	-	-	-	-	2,121	-
2a.1.4.12	Main Turbine and Generator Lube Oil	-	50	-	-	-	-	-	8	58	-	-	-	-	-	-	1,245	-
2a.1.4.13	Main and Startup Feedwater	-	92	-	-	-	-	-	14	106	-	-	-	-	-	-	2,349	-

Table 4-15. AP1000 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2a.1.4.14	Steam Generator	-	243	10	11	343	326	-	197	1,130	4,222	704	-	-	-	234,595	5,961	-
2a.1.4	Totals	-	845	11	12	363	338	-	297	1,866	4,468	729	-	-	-	246,850	21,210	-
2a.1.5	Scaffolding in support of decommissioning	-	1,746	5	1	47	5	-	445	2,250	527	26	-	-	-	26,344	16,502	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2a.1	Subtotal Period 2a Activity Costs	521	14,307	7,658	2,865	2,659	42,232	329	20,656	91,228	5,218	33,049	2,473	402	679	6,207,128	147,155	2,125
Period 2a Additional Costs																		
2a.2.1	Curie Surcharge (excluding RPV)	-	-	-	-	-	3,205	-	801	4,006	-	-	-	-	-	-	-	-
2a.2	Subtotal Period 2a Additional Costs	-	-	-	-	-	3,205	-	801	4,006	-	-	-	-	-	-	-	-
Period 2a Collateral Costs																		
2a.3.1	Process liquid waste	56	-	19	94	-	312	-	122	603	-	-	393	-	-	49,531	77	-
2a.3.2	Small tool allowance	-	103	-	-	-	-	-	16	119	-	-	-	-	-	-	-	-
2a.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	3,422	513	3,936	-	-	-	-	-	-	-	-
2a.3	Subtotal Period 2a Collateral Costs	56	103	19	94	-	312	3,422	651	4,658	-	-	393	-	-	49,531	77	-
Period 2a Period-Dependent Costs																		
2a.4.1	Decon supplies	52	-	-	-	-	-	-	13	65	-	-	-	-	-	-	-	-
2a.4.2	Insurance	-	-	-	-	-	-	711	71	782	-	-	-	-	-	-	-	-
2a.4.3	Property taxes	-	-	-	-	-	-	27	3	30	-	-	-	-	-	-	-	-
2a.4.4	Health physics supplies	-	762	-	-	-	-	-	190	952	-	-	-	-	-	-	-	-
2a.4.5	Heavy equipment rental	-	2,071	-	-	-	-	-	311	2,382	-	-	-	-	-	-	-	-
2a.4.6	Disposal of DAW generated	-	-	32	13	-	109	-	32	187	-	2,732	-	-	-	54,746	671	-
2a.4.7	Plant energy budget	-	-	-	-	-	-	961	144	1,105	-	-	-	-	-	-	-	-
2a.4.8	NRC Fees	-	-	-	-	-	-	581	58	639	-	-	-	-	-	-	-	-
2a.4.9	Emergency Planning Fees	-	-	-	-	-	-	645	65	710	-	-	-	-	-	-	-	-
2a.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	924	139	1,063	-	-	-	-	-	-	-	-
2a.4.11	Security Staff Cost	-	-	-	-	-	-	4,084	613	4,697	-	-	-	-	-	-	-	96,283
2a.4.12	DOC Staff Cost	-	-	-	-	-	-	15,536	2,330	17,867	-	-	-	-	-	-	-	207,589
2a.4.13	Utility Staff Cost	-	-	-	-	-	-	18,955	2,843	21,798	-	-	-	-	-	-	-	405,617
2a.4	Subtotal Period 2a Period-Dependent Costs	52	2,833	32	13	-	109	42,425	6,812	52,276	-	2,732	-	-	-	54,746	671	709,489

Table 4-15. AP1000 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2a.0	TOTAL PERIOD 2a COST	629	17,244	7,710	2,972	2,659	45,859	46,177	28,921	152,169	5,218	35,781	2,866	402	679	6,311,405	147,903	711,614
PERIOD 2b - Site Decontamination																		
Disposal of Plant Systems																		
2b.1.1.1	Annex/Aux Building Nonradioactive Vent.	-	84	2	2	117	27	-	46	277	1,439	57	-	-	-	63,575	2,021	-
2b.1.1.2	Central Chilled Water	-	460	6	7	530	-	-	196	1,199	6,528	-	-	-	-	265,104	10,564	-
2b.1.1.3	Chemical and Volume Control	101	167	8	8	47	355	-	190	877	582	777	-	-	-	92,350	5,409	-
2b.1.1.4	Component Cooling Water	-	338	6	7	513	-	-	163	1,026	6,310	-	-	-	-	256,270	8,033	-
2b.1.1.5	Compressed and Instrument Air	-	205	3	3	218	-	-	85	513	2,688	-	-	-	-	109,154	4,589	-
2b.1.1.6	Containment Air Filtration	-	42	1	2	72	28	-	29	173	883	61	-	-	-	41,278	1,012	-
2b.1.1.7	Containment Main Steam & Feedwater	-	40	2	2	177	-	-	37	258	2,176	-	-	-	-	88,364	946	-
2b.1.1.8	Containment Recirculation Cooling	-	23	1	1	45	20	-	18	108	559	44	-	-	-	26,591	539	-
2b.1.1.9	Demineralized Water Transfer and Storage	-	56	-	-	-	-	-	8	64	-	-	-	-	-	-	1,492	-
2b.1.1.10	Demineralized Water Treatment	-	27	-	-	-	-	-	4	31	-	-	-	-	-	-	668	-
2b.1.1.11	Electrical - Primary Containment	-	271	4	4	261	40	-	118	697	3,208	85	-	-	-	137,937	6,421	-
2b.1.1.12	Electrical - RCA	-	1,088	11	13	994	-	-	424	2,531	12,243	-	-	-	-	497,196	25,861	-
2b.1.1.13	Electrical - Clean	-	313	-	-	-	-	-	47	360	-	-	-	-	-	-	7,752	-
2b.1.1.14	Fire Protection	-	317	6	7	548	-	-	163	1,042	6,750	-	-	-	-	274,113	7,313	-
2b.1.1.15	Fuel Handling and Refueling	-	18	1	1	55	-	-	13	86	672	-	-	-	-	27,280	423	-
2b.1.1.16	Gaseous Radwaste	-	25	1	1	30	11	-	14	81	367	25	-	-	-	16,959	610	-
2b.1.1.17	Health Physics and Hot Machine Shop HVAC	-	10	0	0	22	-	-	6	38	267	-	-	-	-	10,830	242	-
2b.1.1.18	Liquid Radwaste	342	375	17	14	315	476	-	435	1,973	3,880	1,233	-	-	-	249,599	16,275	-
2b.1.1.19	Main Turbine	-	11	-	-	-	-	-	2	13	-	-	-	-	-	-	289	-
2b.1.1.20	Mechanical Handling	-	2	-	-	2	-	-	1	4	22	-	-	-	-	894	45	-
2b.1.1.21	Normal Residual Heat Removal	81	125	8	7	72	308	-	161	761	882	664	-	-	-	95,306	3,659	-
2b.1.1.22	Nuclear Island Nonradioactive Vent.	-	72	1	2	114	-	-	36	225	1,408	-	-	-	-	57,172	1,745	-

Table 4-15. AP1000 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2b.1.1.23	Passive Containment Cooling	-	468	8	10	757	-	-	233	1,476	9,317	-	-	-	-	378,350	11,115	-
2b.1.1.24	Passive Core Cooling	-	218	12	10	167	389	-	179	976	2,062	921	-	-	-	158,948	5,201	-
2b.1.1.25	Primary Sampling	-	32	0	1	25	10	-	14	82	306	21	-	-	-	14,346	752	-
2b.1.1.26	Radiation Monitoring	-	8	-	-	2	2	-	3	16	30	5	-	-	-	1,695	192	-
2b.1.1.27	Radioactive Waste Drain	-	83	3	3	19	125	-	56	288	235	270	-	-	-	33,757	1,897	-
2b.1.1.28	Radiologically Controlled Area Vent.	-	307	3	4	243	43	-	125	725	2,986	92	-	-	-	129,577	6,604	-
2b.1.1.29	Radwaste Building HVAC	-	194	2	3	168	28	-	81	476	2,067	59	-	-	-	89,248	4,160	-
2b.1.1.30	Reactor Coolant	60	143	4	4	63	134	-	110	517	777	288	-	-	-	57,429	4,144	-
2b.1.1.31	Service Water	-	129	9	10	768	-	-	150	1,067	9,457	-	-	-	-	384,059	3,061	-
2b.1.1.32	Solid Radwaste	-	23	1	1	15	29	-	15	84	181	72	-	-	-	12,999	529	-
2b.1.1.33	Steam Generator Blowdown	-	66	2	2	171	-	-	43	284	2,103	-	-	-	-	85,404	1,544	-
2b.1.1.34	Turbine Building Closed Cooling Water	-	59	-	-	-	-	-	9	68	-	-	-	-	-	-	1,519	-
2b.1.1.35	Turbine Building Vent.	-	102	-	-	-	-	-	15	118	-	-	-	-	-	-	2,808	-
2b.1.1.36	Turbine Island Vents, Drains and Relief	-	18	-	-	-	-	-	3	21	-	-	-	-	-	-	470	-
2b.1.1	Totals	583	5,918	123	127	6,529	2,023	-	3,229	18,533	80,383	4,674	-	-	-	3,655,783	149,904	-
2b.1.2	Scaffolding in support of decommissioning	-	2,182	6	1	59	7	-	557	2,812	659	33	-	-	-	32,930	20,627	-
Decontamination of Site Buildings																		
2b.1.3.1	Annex	102	52	6	7	15	125	-	99	406	183	630	-	-	-	69,942	3,457	-
2b.1.3.2	Radwaste	64	33	4	5	13	80	-	63	261	159	403	-	-	-	46,421	2,179	-
2b.1.3.3	Reactor & Containment	873	1,081	86	96	540	2,861	-	1,526	7,063	6,653	8,777	-	-	-	1,098,329	44,520	-
2b.1.3	Totals	1,039	1,165	96	108	568	3,066	-	1,688	7,730	6,995	9,810	-	-	-	1,214,693	50,156	-
Demolition of Remaining Site Buildings																		
2b.1.4	Reactor & Containment	-	661	-	-	-	-	-	99	760	-	-	-	-	-	-	11,667	-
2b.1.4.1	Turbine	-	20	-	-	-	-	-	3	24	-	-	-	-	-	-	491	-
2b.1.4.2	Auxiliary	-	63	-	-	-	-	-	9	73	-	-	-	-	-	-	1,062	-
2b.1.4.3	Remove Rubble	-	658	-	-	-	-	-	99	757	-	-	-	-	-	-	1,055	-
2b.1.4	Totals	-	1,403	-	-	-	-	-	210	1,614	-	-	-	-	-	-	14,275	-
2b.1	Subtotal Period 2b Activity Costs	1,622	10,669	225	236	7,156	5,096	-	5,685	30,688	88,036	14,517	-	-	-	4,903,406	234,962	-

Table 4-15. AP1000 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
Period 2b Additional Costs																		
2b.2.1	Survey & Release of Scrap Material	-	-	-	-	-	-	14,107	2,116	16,223	-	-	-	-	-	-	-	-
2b.2	Subtotal Period 2b Additional Costs	-	-	-	-	-	-	14,107	2,116	16,223	-	-	-	-	-	-	-	-
Period 2b Collateral Costs																		
2b.3.1	Process liquid waste	98	-	95	306	-	1,198	-	404	2,101	-	-	1,488	-	-	220,952	157	-
2b.3.2	Small tool allowance	-	154	-	-	-	-	-	23	177	-	-	-	-	-	-	-	-
2b.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	4,236	635	4,871	-	-	-	-	-	-	-	-
2b.3	Subtotal Period 2b Collateral Costs	98	154	95	306	-	1,198	4,236	1,062	7,150	-	-	1,488	-	-	220,952	157	-
Period 2b Period-Dependent Costs																		
2b.4.1	Decon supplies	407	-	-	-	-	-	-	102	508	-	-	-	-	-	-	-	-
2b.4.2	Insurance	-	-	-	-	-	-	1,456	146	1,602	-	-	-	-	-	-	-	-
2b.4.3	Property taxes	-	-	-	-	-	-	55	6	61	-	-	-	-	-	-	-	-
2b.4.4	Health physics supplies	-	1,307	-	-	-	-	-	327	1,634	-	-	-	-	-	-	-	-
2b.4.5	Heavy equipment rental	-	2,351	-	-	-	-	-	353	2,703	-	-	-	-	-	-	-	-
2b.4.6	Disposal of DAW generated	-	-	50	20	-	169	-	50	290	-	4,232	-	-	-	84,800	1,039	-
2b.4.7	Plant energy budget	-	-	-	-	-	-	1,554	233	1,787	-	-	-	-	-	-	-	-
2b.4.8	NRC Fees	-	-	-	-	-	-	1,190	119	1,308	-	-	-	-	-	-	-	-
2b.4.9	Emergency Planning Fees	-	-	-	-	-	-	1,175	117	1,292	-	-	-	-	-	-	-	-
2b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	1,893	284	2,177	-	-	-	-	-	-	-	-
2b.4.11	Radwaste Processing Equipment/Services	-	-	-	-	-	-	360	54	414	-	-	-	-	-	-	-	-
2b.4.12	Security Staff Cost	-	-	-	-	-	-	6,704	1,006	7,710	-	-	-	-	-	-	-	158,039
2b.4.13	DOC Staff Cost	-	-	-	-	-	-	15,115	2,267	17,382	-	-	-	-	-	-	-	162,066
2b.4.14	Utility Staff Cost	-	-	-	-	-	-	24,423	3,663	28,087	-	-	-	-	-	-	-	502,031
2b.4	Subtotal Period 2b Period-Dependent Costs	407	3,657	50	20	-	169	53,925	8,726	66,955	-	4,232	-	-	-	84,800	1,039	822,136
2b.0	TOTAL PERIOD 2b COST	2,127	14,480	370	562	7,156	6,463	72,268	17,589	121,016	88,036	18,749	1,488	-	-	5,209,158	236,158	822,136
PERIOD 2c - Decontamination Following Wet Fuel Storage																		

Table 4-15. AP1000 DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Period 2c Direct Decommissioning Activities																		
2c.1.1	Remove spent fuel racks	152	16	30	2	186	-	-	111	498	2,063	-	-	-	-	92,850	451	-
Disposal of Plant Systems																		
2c.1.2.1	Spent Fuel Pool Cooling	-	167	9	8	69	364	-	145	762	851	786	-	-	-	105,052	3,957	-
2c.1.2.2	Waste Water	-	56	-	-	-	-	-	8	64	-	-	-	-	-	-	1,458	-
2c.1.2	Totals	-	223	9	8	69	364	-	154	827	851	786	-	-	-	105,052	5,415	-
Decontamination of Site Buildings																		
2c.1.3.1	Auxiliary	555	555	12	14	184	214	-	501	2,036	2,267	1,081	-	-	-	199,301	25,334	-
2c.1.3	Totals	555	555	12	14	184	214	-	501	2,036	2,267	1,081	-	-	-	199,301	25,334	-
2c.1.4	Scaffolding in support of decommissioning	-	436	1	0	12	1	-	111	562	132	7	-	-	-	6,586	4,125	-
2c.1	Subtotal Period 2c Activity Costs	707	1,230	52	25	451	580	-	877	3,922	5,313	1,873	-	-	-	403,788	35,325	-
Period 2c Additional Costs																		
2c.2.1	Final Site Survey	-	-	-	-	-	-	1,236	371	1,607	-	-	-	-	-	-	-	12,480
2c.2	Subtotal Period 2c Additional Costs	-	-	-	-	-	-	1,236	371	1,607	-	-	-	-	-	-	-	12,480
Period 2c Collateral Costs																		
2c.3.1	Process liquid waste	39	-	14	68	-	241	-	91	453	-	-	284	-	-	35,763	56	-
2c.3.2	Small tool allowance	-	26	-	-	-	-	-	4	30	-	-	-	-	-	-	-	-
2c.3.3	Decommissioning Equipment Disposition	-	-	58	12	540	60	-	104	774	6,000	300	-	-	-	300,000	735	-
2c.3.4	Corporate & Site A&G Costs	-	-	-	-	-	-	827	124	951	-	-	-	-	-	-	-	-
2c.3	Subtotal Period 2c Collateral Costs	39	26	72	80	540	301	827	323	2,208	6,000	300	284	-	-	335,763	791	-
Period 2c Period-Dependent Costs																		
2c.4.1	Decon supplies	130	-	-	-	-	-	-	32	162	-	-	-	-	-	-	-	-
2c.4.2	Insurance	-	-	-	-	-	-	234	23	257	-	-	-	-	-	-	-	-
2c.4.3	Property taxes	-	-	-	-	-	-	10	1	10	-	-	-	-	-	-	-	-
2c.4.4	Health physics supplies	-	219	-	-	-	-	-	55	274	-	-	-	-	-	-	-	-

Table 4-15. AP1000 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

						Offsite	LLRW				Processed	Burial Volumes				Burial/		Utility and
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Processing Costs	Disposal Costs	Other Costs	Total Contingency	Total Costs	Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Processed Wt., Lbs.	Craft Manhours	Contractor Manhours
2c.4.5	Heavy equipment rental	-	737	-	-	-	-	-	110	847	-	-	-	-	-	-	-	-
2c.4.6	Disposal of DAW generated	-	-	12	5	-	40	-	12	69	-	1,012	-	-	-	20,280	248	-
2c.4.7	Plant energy budget	-	-	-	-	-	-	143	21	165	-	-	-	-	-	-	-	-
2c.4.8	NRC Fees	-	-	-	-	-	-	205	21	226	-	-	-	-	-	-	-	-
2c.4.9	Emergency Planning Fees	-	-	-	-	-	-	177	18	195	-	-	-	-	-	-	-	-
2c.4.10	Radwaste Processing Equipment/Services	-	-	-	-	-	-	167	25	192	-	-	-	-	-	-	-	-
2c.4.11	Security Staff Cost	-	-	-	-	-	-	1,157	174	1,331	-	-	-	-	-	-	-	27,281
2c.4.12	DOC Staff Cost	-	-	-	-	-	-	3,611	542	4,153	-	-	-	-	-	-	-	48,286
2c.4.13	Utility Staff Cost	-	-	-	-	-	-	4,747	712	5,459	-	-	-	-	-	-	-	98,020
2c.4	Subtotal Period 2c Period-Dependent Costs	130	956	12	5	-	40	10,451	1,746	13,340	-	1,012	-	-	-	20,280	248	173,587
2c.0	TOTAL PERIOD 2c COST	876	2,212	136	110	991	921	12,514	3,317	21,077	11,313	3,185	284	-	-	759,831	36,364	186,067
PERIOD 2e - License Termination																		
Period 2e Direct Decommissioning Activities																		
2e.1.1	ORISE confirmatory survey	-	-	-	-	-	-	121	36	157	-	-	-	-	-	-	-	-
2e.1.2	Terminate license	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
2e.1.3	Final report to NRC	-	-	-	-	-	-	134	20	154	-	-	-	-	-	-	-	1,560
2e.1	Subtotal Period 2e Activity Costs	-	-	-	-	-	-	254	56	311	-	-	-	-	-	-	-	1,560
Period 2e Additional Costs																		
2e.2.1	Final Site Survey	-	-	-	-	-	-	8,890	2,667	11,557	-	-	-	-	-	-	198,916	6,240
2e.2	Subtotal Period 2e Additional Costs	-	-	-	-	-	-	8,890	2,667	11,557	-	-	-	-	-	-	198,916	6,240
Period 2e Collateral Costs																		
2e.3.1	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
2e.3.2	Corporate & Site A&G Costs	-	-	-	-	-	-	674	101	776	-	-	-	-	-	-	-	-
2e.3	Subtotal Period 2e Collateral Costs	-	-	-	-	-	-	1,612	242	1,854	-	-	-	-	-	-	-	-

Table 4-15. AP1000 DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Period 2e Period-Dependent Costs																		
2e.4.1	Insurance	-	-	-	-	-	-	287	29	316	-	-	-	-	-	-	-	-
2e.4.2	Property taxes	-	-	-	-	-	-	16	2	17	-	-	-	-	-	-	-	-
2e.4.3	Health physics supplies	-	798	-	-	-	-	-	199	997	-	-	-	-	-	-	-	-
2e.4.4	Disposal of DAW generated	-	-	4	1	-	12	-	4	21	-	307	-	-	-	6,149	75	-
2e.4.5	Plant energy budget	-	-	-	-	-	-	117	18	135	-	-	-	-	-	-	-	-
2e.4.6	NRC Fees	-	-	-	-	-	-	337	34	370	-	-	-	-	-	-	-	-
2e.4.7	Emergency Planning Fees	-	-	-	-	-	-	208	21	228	-	-	-	-	-	-	-	-
2e.4.8	Security Staff Cost	-	-	-	-	-	-	604	91	695	-	-	-	-	-	-	-	14,246
2e.4.9	DOC Staff Cost	-	-	-	-	-	-	4,432	665	5,096	-	-	-	-	-	-	-	57,774
2e.4.10	Utility Staff Cost	-	-	-	-	-	-	4,175	626	4,801	-	-	-	-	-	-	-	79,934
2e.4	Subtotal Period 2e Period-Dependent Costs	-	798	4	1	-	12	10,176	1,687	12,678	-	307	-	-	-	6,149	75	151,954
2e.0	TOTAL PERIOD 2e COST	-	798	4	1	-	12	20,932	4,652	26,399	-	307	-	-	-	6,149	198,991	159,754
PERIOD 2 TOTALS		3,631	34,734	8,220	3,645	10,806	53,256	151,890	54,479	320,660	104,567	58,023	4,637	402	679	12,286,543	619,416	1,879,571
TOTAL COST TO DECOMMISSION		4,970	36,480	8,486	4,267	10,806	56,258	227,600	67,545	416,412	104,567	58,648	8,057	402	679	12,864,148	620,766	2,800,895

TOTAL COST TO DECOMMISSION WITH 19.36% CONTINGENCY: **$416,412 thousands of 2003 dollars**

End Notes:
n/a - indicates that this activity not charged as decommissioning expense.
a - indicates that this activity performed by decommissioning staff.
0 - indicates that this value is less than 0.5 but is non-zero.
a cell containing " - " indicates a zero value

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
PERIOD 1a - Shutdown through Transition																		
Period 1a Direct Decommissioning Activities																		
1a.1.1	Prepare preliminary decommissioning cost	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.2	Notification of Cessation of Operations	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.3	Remove fuel & source material	-	-	-	-	-	-	-	-	n/a	-	-	-	-	-	-	-	-
1a.1.4	Notification of Permanent Defueling	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.5	Deactivate plant systems & process waste	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.6	Prepare and submit PSDAR	-	-	-	-	-	-	171	26	197	-	-	-	-	-	-	-	2,000
1a.1.7	Review plant dwgs & specs.	-	-	-	-	-	-	394	59	453	-	-	-	-	-	-	-	4,600
1a.1.8	Perform detailed rad survey	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
1a.1.9	Estimate by-product inventory	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.10	End product description	-	-	-	-	-	-	86	13	99	-	-	-	-	-	-	-	1,000
1a.1.11	Detailed by-product inventory	-	-	-	-	-	-	111	17	128	-	-	-	-	-	-	-	1,300
1a.1.12	Define major work sequence	-	-	-	-	-	-	643	96	739	-	-	-	-	-	-	-	7,500
1a.1.13	Perform SER and EA	-	-	-	-	-	-	266	40	305	-	-	-	-	-	-	-	3,100
1a.1.14	Perform Site-Specific Cost Study	-	-	-	-	-	-	428	64	493	-	-	-	-	-	-	-	5,000
1a.1.15	Prepare/submit License Termination Plan	-	-	-	-	-	-	351	53	404	-	-	-	-	-	-	-	4,096
1a.1.16	Receive NRC approval of termination plan	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
Activity Specifications																		
1a.1.17	Total	-	-	-	-	-	-	3,614	542	4,156	-	-	-	-	-	-	-	42,174
Planning & Site Preparations																		
1a.1.18	Prepare dismantling sequence	-	-	-	-	-	-	206	31	237	-	-	-	-	-	-	-	2,400
1a.1.19	Plant prep. & temp. svces	-	-	-	-	-	-	2,419	363	2,782	-	-	-	-	-	-	-	-
1a.1.20	Design water cleanup system	-	-	-	-	-	-	120	18	138	-	-	-	-	-	-	-	1,400

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
1a.1.21	Rigging/Cont. Cntrl Envlps/tooling/etc.	-	-	-	-	-	-	2,048	307	2,355	-	-	-	-	-	-	-	-
1a.1.22	Procure casks/liners & containers	-	-	-	-	-	-	105	16	121	-	-	-	-	-	-	-	1,230
1a.1	Subtotal Period 1a Activity Costs	-	-	-	-	-	-	11,159	1,674	12,833	-	-	-	-	-	-	-	78,100
Period 1a Additional Costs																		
1a.2.1	Spent Fuel Pool Isolation	-	-	-	-	-	-	8,060	1,209	9,269	-	-	-	-	-	-	-	-
1a.2.2	Site Characterization	-	-	-	-	-	-	1,853	556	2,408	-	-	-	-	-	-	-	-
1a.2	Subtotal Period 1a Additional Costs	-	-	-	-	-	-	9,912	1,765	11,677	-	-	-	-	-	-	-	-
Period 1a Collateral Costs																		
1a.3.1	Corporate & Site A&G Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
1a.3	Subtotal Period 1a Collateral Costs	-	-	-	-	-	-	3,696	554	4,250	-	-	-	-	-	-	-	-
Period 1a Period-Dependent Costs																		
1a.4.1	Insurance	-	-	-	-	-	-	1,344	134	1,478	-	-	-	-	-	-	-	-
1a.4.2	Property taxes	-	-	-	-	-	-	21	2	23	-	-	-	-	-	-	-	-
1a.4.3	Health physics supplies	-	229	-	-	-	-	-	57	286	-	-	-	-	-	-	-	-
1a.4.4	Heavy equipment rental	-	292	-	-	-	-	-	44	336	-	-	-	-	-	-	-	-
1a.4.5	Disposal of DAW generated	-	-	5	2	-	16	-	5	28	-	404	-	-	-	8,103	99	-
1a.4.6	Plant energy budget	-	-	-	-	-	-	852	128	980	-	-	-	-	-	-	-	-
1a.4.7	NRC Fees	-	-	-	-	-	-	381	38	419	-	-	-	-	-	-	-	-
1a.4.8	Emergency Planning Fees	-	-	-	-	-	-	547	55	602	-	-	-	-	-	-	-	-
1a.4.9	Spent Fuel Pool O&M	-	-	-	-	-	-	706	106	812	-	-	-	-	-	-	-	-
1a.4.10	Security Staff Cost	-	-	-	-	-	-	2,499	375	2,874	-	-	-	-	-	-	-	58,921
1a.4.11	Utility Staff Cost	-	-	-	-	-	-	20,438	3,066	23,503	-	-	-	-	-	-	-	438,000
1a.4	Subtotal Period 1a Period-Dependent Costs	-	521	5	2	-	16	26,788	4,010	31,342	-	404	-	-	-	8,103	99	496,921
1a.0	TOTAL PERIOD 1a COST	-	521	5	2	-	16	51,555	8,002	60,102	-	404	-	-	-	8,103	99	575,021
PERIOD 1b - Decommissioning Preparations																		

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Period 1b Direct Decommissioning Activities																		
Detailed Work Procedures																		
1b.1.1	Total	-	-	-	-	-	-	2,805	421	3,226	-	-	-	-	-	-	-	32,740
1b.1	Subtotal Period 1b Activity Costs	-	-	-	-	-	-	2,805	421	3,226	-	-	-	-	-	-	-	32,740
Period 1b Collateral Costs																		
1b.3.1	Decon equipment	650	-	-	-	-	-	-	98	748	-	-	-	-	-	-	-	-
1b.3.2	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
1b.3.3	Process liquid waste	172	-	57	282	-	827	-	341	1,678	-	-	1,183	-	-	149,058	232	-
1b.3.4	Pipe cutting equipment	-	957	-	-	-	-	-	143	1,100	-	-	-	-	-	-	-	-
1b.3.5	Corporate & Site A&G Costs	-	-	-	-	-	-	1,882	282	2,164	-	-	-	-	-	-	-	-
1b.3	Subtotal Period 1b Collateral Costs	822	957	57	282	-	827	2,819	1,004	6,768	-	-	1,183	-	-	149,058	232	-
Period 1b Period-Dependent Costs																		
1b.4.1	Decon supplies	20	-	-	-	-	-	-	5	25	-	-	-	-	-	-	-	-
1b.4.2	Insurance	-	-	-	-	-	-	681	68	749	-	-	-	-	-	-	-	-
1b.4.3	Property taxes	-	-	-	-	-	-	10	1	11	-	-	-	-	-	-	-	-
1b.4.4	Health physics supplies	-	117	-	-	-	-	-	29	146	-	-	-	-	-	-	-	-
1b.4.5	Heavy equipment rental	-	148	-	-	-	-	-	22	170	-	-	-	-	-	-	-	-
1b.4.6	Disposal of DAW generated	-	-	2	1	-	8	-	2	14	-	205	-	-	-	4,107	50	-
1b.4.7	Plant energy budget	-	-	-	-	-	-	864	130	994	-	-	-	-	-	-	-	-
1b.4.8	NRC Fees	-	-	-	-	-	-	193	19	212	-	-	-	-	-	-	-	-
1b.4.9	Emergency Planning Fees	-	-	-	-	-	-	277	28	305	-	-	-	-	-	-	-	-
1b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	358	54	411	-	-	-	-	-	-	-	-
1b.4.11	Security Staff Cost	-	-	-	-	-	-	1,267	190	1,457	-	-	-	-	-	-	-	29,864
1b.4.12	DOC Staff Cost	-	-	-	-	-	-	4,955	743	5,698	-	-	-	-	-	-	-	64,486
1b.4.13	Utility Staff Cost	-	-	-	-	-	-	10,414	1,562	11,976	-	-	-	-	-	-	-	223,057
1b.4	Subtotal Period 1b Period-Dependent Costs	20	265	2	1	-	8	19,019	2,854	22,170	-	205	-	-	-	4,107	50	317,407
1b.0	TOTAL PERIOD 1b COST	842	1,222	59	283	-	835	24,644	4,279	32,164	-	205	1,183	-	-	153,165	283	350,147

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
PERIOD 1 TOTALS		842	1,743	64	285	-	851	76,200	12,281	92,266	-	609	1,183	-	-	161,268	382	925,168
PERIOD 2a - Large Component Removal																		
Period 2a Direct Decommissioning Activities																		
Nuclear Steam Supply System Removal																		
2a.1.1.3	CRDMs & NIs Removal	133	112	168	96	-	538	-	260	1,309	-	5,140	-	-	-	104,063	5,473	-
2a.1.1.4	Reactor Vessel Internals	194	2,485	4,773	2,068	-	10,723	241	9,069	29,554	-	2,504	2,056	1,148	-	690,330	35,678	1,559
2a.1.1.5	Vessel & Internals GTCC Disposal	-	-	-	-	-	16,111	-	2,417	18,527	-	-	-	-	644	110,231	-	-
2a.1.1.6	Reactor Vessel	92	4,961	1,862	1,498	-	14,877	241	12,081	35,611	-	21,022	2,504	-	-	2,525,998	35,678	1,559
2a.1.1	Totals	419	7,558	6,803	3,662	-	42,249	483	23,827	85,001	-	28,666	4,560	1,148	644	3,430,622	76,829	3,118
Removal of Major Equipment																		
2a.1.2	Main Turbine/Generator	-	446	1,363	257	9,780	-	-	1,753	13,600	57,530	-	-	-	-	4,890,045	10,468	-
2a.1.3	Main Condensers	-	1,457	531	68	5,155	-	-	1,201	8,413	57,282	-	-	-	-	2,577,687	34,499	-
Disposal of Plant Systems																		
2a.1.4.1	Circulating Water	-	99	1	1	87	-	-	38	226	1,068	-	-	-	-	43,364	2,299	-
2a.1.4.2	Condensate & Feedwater	-	1,897	83	99	7,520	-	-	1,626	11,226	92,588	-	-	-	-	3,760,040	45,384	-
2a.1.4.3	Condensate Demineralizer	-	707	12	14	1,064	-	-	340	2,137	13,101	-	-	-	-	532,057	16,709	-
2a.1.4.4	Condensate Filter Facility	-	112	1	2	125	-	-	47	287	1,544	-	-	-	-	62,703	2,614	-
2a.1.4.5	Extraction Steam	-	536	16	20	1,478	-	-	360	2,410	18,197	-	-	-	-	738,974	12,905	-
2a.1.4.6	Feedwater Heater & Drain	-	1,828	32	38	2,868	-	-	896	5,662	35,312	-	-	-	-	1,434,030	43,188	-
2a.1.4.7	Flammability Control	-	39	1	1	13	40	-	22	116	157	86	-	-	-	14,061	908	-
2a.1.4.8	Generator Cooling	-	13	-	-	-	-	-	2	15	-	-	-	-	-	-	345	-
2a.1.4.9	Generator Sealing Oil	-	13	-	-	-	-	-	2	15	-	-	-	-	-	-	332	-
2a.1.4.10	Gravity Driven Cooling	-	137	6	5	160	161	-	100	569	1,967	347	-	-	-	110,989	3,295	-
2a.1.4.11	Hydrogen Gas Cooling	-	28	-	-	-	-	-	4	32	-	-	-	-	-	-	760	-
2a.1.4.12	Isolation Cooling	-	117	7	7	135	250	-	113	628	1,656	538	-	-	-	115,562	2,795	-
2a.1.4.13	Makeup Water (condensate)	-	391	7	8	589	-	-	188	1,183	7,256	-	-	-	-	294,667	9,187	-
2a.1.4.14	Moisture Separator/Reheater	-	98	40	47	3,586	-	-	574	4,345	44,155	-	-	-	-	1,793,174	2,483	-
2a.1.4.15	PCV Pressure & Leak Testing	-	4	0	0	28	-	-	5	38	343	-	-	-	-	13,923	109	-
2a.1.4.16	Passive Containment Cooling	-	184	11	11	208	427	-	187	1,027	2,557	925	-	-	-	186,421	4,396	-

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2a.1.4.17	Reactor Bldg. Service Water	-	33	1	1	104	-	-	24	164	1,286	-	-	-	-	52,243	792	-
2a.1.4.18	Standby Liquid Control	-	35	1	1	67	-	-	19	122	825	-	-	-	-	33,484	805	-
2a.1.4.19	Tank Vent Treatment	-	39	1	1	30	37	-	24	132	373	79	-	-	-	22,220	921	-
2a.1.4.20	Turbine Auxiliary Steam	-	142	2	2	160	-	-	60	367	1,974	-	-	-	-	80,178	3,340	-
2a.1.4.21	Turbine Gland Steam	-	494	6	7	521	-	-	203	1,230	6,412	-	-	-	-	260,411	11,460	-
2a.1.4.22	Turbine Lubricating Oil	-	535	10	11	845	-	-	263	1,664	10,403	-	-	-	-	422,454	12,440	-
2a.1.4.23	Turbine Main Steam	-	292	17	18	556	556	-	300	1,739	6,840	1,198	-	-	-	385,261	7,114	-
2a.1.4.24	Turbine Plant Valves & Equip.	-	721	22	26	1,979	-	-	483	3,232	24,369	-	-	-	-	989,639	17,529	-
2a.1.4.25	Turbine Service Water	-	113	4	5	352	-	-	82	556	4,328	-	-	-	-	175,765	2,676	-
2a.1.4.26	Valve Gland Leakage Treatment	-	137	5	3	25	151	-	77	400	313	327	-	-	-	42,016	3,061	-
2a.1.4.27	Zinc Injection	-	11	0	0	2	10	-	6	29	30	22	-	-	-	3,145	249	-
2a.1.4	Totals	-	8,757	285	330	22,503	1,631	-	6,045	39,551	277,054	3,522	-	-	-	11,566,780	208,097	-
2a.1.5	Scaffolding in support of decommissioning	-	3,179	18	3	169	19	-	827	4,216	1,879	94	-	-	-	93,937	38,438	-
2a.1	Subtotal Period 2a Activity Costs	419	21,397	9,002	4,321	37,607	43,899	483	33,653	150,781	393,745	32,282	4,560	1,148	644	22,559,070	368,330	3,118
Period 2a Additional Costs																		
2a.2.1	Curie Surcharge (excluding RPV)	-	-	-	-	-	6,380	-	1,595	7,975	-	-	-	-	-	-	-	-
2a.2	Subtotal Period 2a Additional Costs	-	-	-	-	-	6,380	-	1,595	7,975	-	-	-	-	-	-	-	-
Period 2a Collateral Costs																		
2a.3.1	Process liquid waste	313	-	106	522	-	1,481	-	616	3,037	-	-	2,187	-	-	275,706	430	-
2a.3.2	Small tool allowance	-	251	-	-	-	-	-	38	289	-	-	-	-	-	-	-	-
2a.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	4,081	612	4,693	-	-	-	-	-	-	-	-
2a.3	Subtotal Period 2a Collateral Costs	313	251	106	522	-	1,481	4,081	1,265	8,020	-	-	2,187	-	-	275,706	430	-
Period 2a Period-Dependent Costs																		
2a.4.1	Decon supplies	62	-	-	-	-	-	-	16	78	-	-	-	-	-	-	-	-
2a.4.2	Insurance	-	-	-	-	-	-	848	85	933	-	-	-	-	-	-	-	-
2a.4.3	Property taxes	-	-	-	-	-	-	32	3	35	-	-	-	-	-	-	-	-

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
2a.4.4	Health physics supplies	-	1,514	-	-	-	-	-	379	1,893	-	-	-	-	-	-	-	-
2a.4.5	Heavy equipment rental	-	2,470	-	-	-	-	-	370	2,840	-	-	-	-	-	-	-	-
2a.4.6	Disposal of DAW generated	-	-	86	35	-	291	-	86	497	-	7,265	-	-	-	145,591	1,784	-
2a.4.7	Plant energy budget	-	-	-	-	-	-	1,265	190	1,454	-	-	-	-	-	-	-	-
2a.4.8	NRC Fees	-	-	-	-	-	-	693	69	762	-	-	-	-	-	-	-	-
2a.4.9	Emergency Planning Fees	-	-	-	-	-	-	769	77	846	-	-	-	-	-	-	-	-
2a.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	1,102	165	1,268	-	-	-	-	-	-	-	-
2a.4.11	Security Staff Cost	-	-	-	-	-	-	4,870	731	5,601	-	-	-	-	-	-	-	114,814
2a.4.12	DOC Staff Cost	-	-	-	-	-	-	18,527	2,779	21,306	-	-	-	-	-	-	-	247,543
2a.4.13	Utility Staff Cost	-	-	-	-	-	-	22,603	3,390	25,993	-	-	-	-	-	-	-	483,686
2a.4	Subtotal Period 2a Period-Dependent Costs	62	3,984	86	35	-	291	50,709	8,340	63,506	-	7,265	-	-	-	145,591	1,784	846,043
2a.0	TOTAL PERIOD 2a COST	794	25,633	9,193	4,877	37,607	52,051	55,273	44,854	230,282	393,745	39,547	6,747	1,148	644	22,980,370	370,544	849,161
PERIOD 2b - Site Decontamination																		
Period 2b Direct Decommissioning Activities																		
Disposal of Plant Systems																		
2b.1.1.1	Atmospheric Control	-	139	7	6	176	207	-	114	649	2,171	446	-	-	-	128,157	3,293	-
2b.1.1.2	Concentrated Waste	57	67	5	4	37	158	-	91	419	454	410	-	-	-	48,893	2,824	-
2b.1.1.3	Containment Internal Struct.	-	124	3	3	212	32	-	72	447	2,615	95	-	-	-	112,417	2,942	-
2b.1.1.4	Control Rod Drive	-	600	53	48	214	2,251	-	757	3,922	2,630	4,854	-	-	-	542,138	13,856	-
2b.1.1.5	Drywell Cooling	-	39	3	4	236	40	-	56	378	2,908	86	-	-	-	125,791	912	-
2b.1.1.6	Electrical - Primary Containment	-	3,105	28	33	2,036	309	-	1,167	6,679	25,073	667	-	-	-	1,078,074	73,504	-
2b.1.1.7	Electrical - RCA	-	1,147	12	14	1,041	-	-	446	2,659	12,819	-	-	-	-	520,593	27,181	-
2b.1.1.8	Electrical - Clean	-	1,141	-	-	-	-	-	171	1,312	-	-	-	-	-	-	28,447	-
2b.1.1.9	Fire Protection	-	106	1	1	78	-	-	38	225	965	-	-	-	-	39,198	2,376	-
2b.1.1.10	HVAC	-	1,288	24	28	1,564	343	-	649	3,897	19,262	759	-	-	-	848,678	29,017	-
2b.1.1.11	HVAC Emergency Chilled Water	-	51	1	1	64	-	-	23	139	785	-	-	-	-	31,876	1,194	-
2b.1.1.12	High Conductivity Waste	703	899	35	32	397	1,320	-	974	4,358	4,885	3,004	-	-	-	453,708	34,616	-
2b.1.1.13	Instrument Air	-	316	4	5	374	-	-	136	835	4,600	-	-	-	-	186,803	6,889	-
2b.1.1.14	Laundry Drain	-	38	1	1	9	37	-	20	105	111	79	-	-	-	11,573	875	-

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
2b.1.1.15	Low Conductivity Waste	384	520	22	19	319	755	-	563	2,582	3,924	1,801	-	-	-	305,406	20,288	-
2b.1.1.16	Nuclear Boiler System	575	517	33	32	161	1,478	-	819	3,615	1,988	3,186	-	-	-	366,543	18,238	-
2b.1.1.17	Off Gas	-	301	16	15	563	393	-	262	1,550	6,931	889	-	-	-	357,570	7,066	-
2b.1.1.18	Plumbing & Drainage	-	1,096	9	10	759	-	-	390	2,263	9,340	-	-	-	-	379,322	25,560	-
2b.1.1.19	Primary Containment Vessel	-	24	3	3	90	86	-	42	248	1,102	186	-	-	-	61,432	583	-
2b.1.1.20	Process & Dust Radiation Monitoring	-	18	1	1	38	37	-	20	115	469	79	-	-	-	26,095	436	-
2b.1.1.21	Radioactive Drain Transfer	220	456	16	15	127	667	-	414	1,916	1,567	1,439	-	-	-	192,700	15,210	-
2b.1.1.22	Reactor Bldg. Chilled Water	-	143	2	2	188	-	-	65	401	2,320	-	-	-	-	94,212	3,270	-
2b.1.1.23	Reactor Component Cooling Water	-	813	14	16	1,230	-	-	392	2,465	15,141	-	-	-	-	614,878	18,595	-
2b.1.1.24	Reactor Water Cleanup/SDC	326	297	70	60	305	2,806	-	1,001	4,865	3,759	6,065	-	-	-	695,468	8,796	-
2b.1.1.25	Shower Drain	-	155	4	5	250	64	-	94	572	3,079	162	-	-	-	137,455	3,708	-
2b.1.1.26	Solidifying	-	80	5	5	91	183	-	81	445	1,124	427	-	-	-	81,012	1,909	-
2b.1.1.27	Spent Sludge	287	317	23	18	196	767	-	449	2,056	2,410	2,045	-	-	-	246,242	13,480	-
2b.1.1.28	Station Air	-	313	4	4	311	-	-	126	758	3,834	-	-	-	-	155,714	6,891	-
2b.1.1.29	Turbine Bldg. Chilled Water	-	183	2	2	187	-	-	74	449	2,308	-	-	-	-	93,723	4,284	-
2b.1.1.30	Turbine Building Cooling Water	-	371	15	17	1,295	-	-	291	1,989	15,944	-	-	-	-	647,494	8,612	-
2b.1.1	Totals	2,551	14,661	417	404	12,550	11,933	-	9,795	52,312	154,517	26,677	-	-	-	8,583,166	384,852	-
2b.1.2	Scaffolding in support of decommissioning	-	3,974	23	4	211	23	-	1,034	5,270	2,348	117	-	-	-	117,421	48,048	-
Decontamination of Site Buildings																		
2b.1.3.1	Control Building(ABWR)	268	157	16	19	93	322	-	272	1,149	1,148	1,624	-	-	-	207,684	9,619	-
2b.1.3.2	Radwaste Building(ABWR)	325	166	19	23	51	387	-	314	1,283	623	1,941	-	-	-	218,692	11,059	-
2b.1.3.3	Radwaste Tunnel(ABWR)	37	16	2	3	2	47	-	35	143	22	236	-	-	-	24,470	1,201	-
2b.1.3.4	Reactor & Containment	2,453	3,112	186	209	1,387	6,103	-	3,788	17,239	17,073	18,685	-	-	-	2,465,150	125,793	-
2b.1.3.5	Steam Tunnel	11	16	1	1	-	19	-	14	62	-	95	-	-	-	9,498	565	-
2b.1.3.6	Turbine Building(ABWR)	781	621	50	59	334	972	-	853	3,670	4,112	4,930	-	-	-	653,082	31,577	-
2b.1.3	Totals	3,876	4,088	274	314	1,866	7,850	-	5,277	23,545	22,979	27,512	-	-	-	3,578,575	179,815	-
Demolition of Remaining Site Buildings																		
2b.1.4.1	Reactor & Containment	-	381	-	-	-	-	-	57	438	-	-	-	-	-	-	5,509	-
2b.1.4.2	Turbine Building(ABWR)	-	63	-	-	-	-	-	9	73	-	-	-	-	-	-	1,062	-
2b.1.4.3	Auxiliary	-	63	-	-	-	-	-	9	73	-	-	-	-	-	-	1,062	-

Table 4-16. ESBWR DECON Decommissioning Cost Estimate (Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
2b.1.4.4	Remove Rubble	-	528	-	-	-	-	-	79	608	-	-	-	-	-	-	847	-
2b.1.4	Totals	-	1,035	-	-	-	-	-	155	1,191	-	-	-	-	-	-	8,480	-
2b.1	Subtotal Period 2b Activity Costs	6,427	23,759	714	722	14,628	19,807	-	16,261	82,317	179,844	54,306	-	-	-	12,279,162	621,194	-
Period 2b Additional Costs																		
2b.2.1	Survey and Release of Scrap Material	-	-	-	-	-	-	3,489	523	4,012	-	-	-	-	-	-	-	-
2b.2	Subtotal Period 2b Additional Costs	-	-	-	-	-	-	3,489	523	4,012	-	-	-	-	-	-	-	-
Period 2b Collateral Costs																		
2b.3.1	Process liquid waste	407	-	497	1,500	-	5,930	-	1,961	10,295	-	-	7,477	-	-	1,136,254	685	-
2b.3.2	Small tool allowance	-	408	-	-	-	-	-	61	469	-	-	-	-	-	-	-	-
2b.3.3	Corporate & Site A&G Costs	-	-	-	-	-	-	6,094	914	7,008	-	-	-	-	-	-	-	-
2b.3	Subtotal Period 2b Collateral Costs	407	408	497	1,500	-	5,930	6,094	2,936	17,773	-	-	7,477	-	-	1,136,254	685	-
Period 2b Period-Dependent Costs																		
2b.4.1	Decon supplies	1,088	-	-	-	-	-	-	272	1,360	-	-	-	-	-	-	-	-
2b.4.2	Insurance	-	-	-	-	-	-	1,319	132	1,451	-	-	-	-	-	-	-	-
2b.4.3	Property taxes	-	-	-	-	-	-	50	5	55	-	-	-	-	-	-	-	-
2b.4.4	Health physics supplies	-	2,481	-	-	-	-	-	620	3,101	-	-	-	-	-	-	-	-
2b.4.5	Heavy equipment rental	-	3,866	-	-	-	-	-	580	4,446	-	-	-	-	-	-	-	-
2b.4.6	Disposal of DAW generated	-	-	120	48	-	406	-	121	695	-	10,152	-	-	-	203,435	2,493	-
2b.4.7	Plant energy budget	-	-	-	-	-	-	1,553	233	1,787	-	-	-	-	-	-	-	-
2b.4.8	NRC Fees	-	-	-	-	-	-	1,078	108	1,186	-	-	-	-	-	-	-	-
2b.4.9	Emergency Planning Fees	-	-	-	-	-	-	1,064	106	1,171	-	-	-	-	-	-	-	-
2b.4.10	Spent Fuel Pool O&M	-	-	-	-	-	-	1,715	257	1,973	-	-	-	-	-	-	-	-
2b.4.11	Radwaste Processing Equipment/Services	-	-	-	-	-	-	437	66	503	-	-	-	-	-	-	-	-
2b.4.12	Security Staff Cost	-	-	-	-	-	-	6,074	911	6,985	-	-	-	-	-	-	-	143,187
2b.4.13	DOC Staff Cost	-	-	-	-	-	-	27,697	4,154	31,851	-	-	-	-	-	-	-	370,006
2b.4.14	Utility Staff Cost	-	-	-	-	-	-	33,777	5,067	38,844	-	-	-	-	-	-	-	722,271
2b.4	Subtotal Period 2b Period-	1,088	6,347	120	48	-	406	74,765	12,632	95,406	-	10,152	-	-	-	203,435	2,493	1,235,464

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes				Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
												Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet			
	Dependent Costs																	
2b.0	TOTAL PERIOD 2b COST	7,923	30,513	1,330	2,270	14,628	26,143	84,348	32,353	199,508	179,844	64,458	7,477	-	-	13,618,851	624,372	1,235,464
PERIOD 2c - Decontamination Following Wet Fuel Storage																		
Period 2c Direct Decommissioning Activities																		
2c.1.1	Remove spent fuel racks	351	34	44	11	831	-	-	315	1,585	9,234	-	-	-	-	415,548	867	-
Disposal of Plant Systems																		
2c.1.2.1	Fuel Pool Cooling & Cleanup	-	470	43	39	412	1,654	-	603	3,220	5,074	3,567	-	-	-	525,926	11,211	-
2c.1.2	Totals	-	470	43	39	412	1,654	-	603	3,220	5,074	3,567	-	-	-	525,926	11,211	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Decontamination of Site Buildings																		
2c.1.3.1	Auxiliary	360	357	7	8	100	126	-	318	1,278	1,237	633	-	-	-	113,443	16,383	-
2c.1.3	Totals	360	357	7	8	100	126	-	318	1,278	1,237	633	-	-	-	113,443	16,383	-
2c.1.4	Scaffolding in support of decommissioning	-	795	5	1	42	5	-	207	1,054	470	23	-	-	-	23,484	9,610	-
2c.1	Subtotal Period 2c Activity Costs	711	1,656	98	59	1,386	1,785	-	1,442	7,138	16,015	4,223	-	-	-	1,078,401	38,071	-
Period 2c Additional Costs																		
2c.2.1	Final Site Survey	-	-	-	-	-	-	1,236	371	1,607	-	-	-	-	-	-	-	12,480
2c.2	Subtotal Period 2c Additional Costs	-	-	-	-	-	-	1,236	371	1,607	-	-	-	-	-	-	-	12,480
Period 2c Collateral Costs																		
2c.3.1	Process liquid waste	61	-	21	105	-	343	-	134	664	-	-	440	-	-	55,476	87	-
2c.3.2	Small tool allowance	-	30	-	-	-	-	-	5	35	-	-	-	-	-	-	-	-
2c.3.3	Decommissioning Equipment Disposition	-	-	58	12	540	60	-	104	774	6,000	300	-	-	-	300,000	735	-
2c.3.4	Corporate & Site A&G Costs	-	-	-	-	-	-	759	114	872	-	-	-	-	-	-	-	-

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Burial Volumes Class A Cu. Feet	Burial Volumes Class B Cu. Feet	Burial Volumes Class C Cu. Feet	Burial Volumes GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
2c.3	Subtotal Period 2c Collateral Costs	61	30	80	117	540	403	759	356	2,345	6,000	300	440	-	-	355,476	822	-
Period 2c Period-Dependent Costs																		
2c.4.1	Decon supplies	83	-	-	-	-	-	-	21	104	-	-	-	-	-	-	-	-
2c.4.2	Insurance	-	-	-	-	-	-	214	21	236	-	-	-	-	-	-	-	-
2c.4.3	Property taxes	-	-	-	-	-	-	9	1	10	-	-	-	-	-	-	-	-
2c.4.4	Health physics supplies	-	219	-	-	-	-	-	55	274	-	-	-	-	-	-	-	-
2c.4.5	Heavy equipment rental	-	676	-	-	-	-	-	101	777	-	-	-	-	-	-	-	-
2c.4.6	Disposal of DAW generated	-	-	23	9	-	76	-	23	131	-	1,911	-	-	-	38,287	469	-
2c.4.7	Plant energy budget	-	-	-	-	-	-	145	22	166	-	-	-	-	-	-	-	-
2c.4.8	NRC Fees	-	-	-	-	-	-	188	19	207	-	-	-	-	-	-	-	-
2c.4.9	Emergency Planning Fees	-	-	-	-	-	-	163	16	179	-	-	-	-	-	-	-	-
2c.4.10	Radwaste Processing Equipment/Services	-	-	-	-	-	-	153	23	176	-	-	-	-	-	-	-	-
2c.4.11	Security Staff Cost	-	-	-	-	-	-	1,061	159	1,221	-	-	-	-	-	-	-	25,021
2c.4.12	DOC Staff Cost	-	-	-	-	-	-	3,312	497	3,809	-	-	-	-	-	-	-	44,286
2c.4.13	Utility Staff Cost	-	-	-	-	-	-	4,354	653	5,007	-	-	-	-	-	-	-	89,900
2c.4	Subtotal Period 2c Period-Dependent Costs	83	895	23	9	-	76	9,599	1,611	12,296	-	1,911	-	-	-	38,287	469	159,207
2c.0	TOTAL PERIOD 2c COST	855	2,582	200	185	1,926	2,264	11,593	3,780	23,385	22,015	6,434	440	-	-	1,472,164	39,362	171,687
PERIOD 2e - License Termination																		
Period 2e Direct Decommissioning Activities																		
2e.1.1	ORISE confirmatory survey	-	-	-	-	-	-	121	36	157	-	-	-	-	-	-	-	-
2e.1.2	Terminate license	-	-	-	-	-	-	-	-	a	-	-	-	-	-	-	-	-
2e.1.3	Final report to NRC	-	-	-	-	-	-	134	20	154	-	-	-	-	-	-	-	1,560
2e.1	Subtotal Period 2e Activity Costs	-	-	-	-	-	-	254	56	311	-	-	-	-	-	-	-	1,560
Period 2e Additional Costs																		
2e.2.1	Final Site Survey	-	-	-	-	-	-	7,905	2,371	10,276	-	-	-	-	-	-	174,858	6,240
2e.2	Subtotal Period 2e Additional Costs	-	-	-	-	-	-	7,905	2,371	10,276	-	-	-	-	-	-	174,858	6,240

Table 4-16. ESBWR DECON Decommissioning Cost Estimate
(Thousands of 2003 Dollars)

												Burial Volumes						
Activity Index	Activity Description	Decon Cost	Removal Cost	Packaging Costs	Transport Costs	Offsite Processing Costs	LLRW Disposal Costs	Other Costs	Total Contingency	Total Costs	Processed Volume Cu. Feet	Class A Cu. Feet	Class B Cu. Feet	Class C Cu. Feet	GTCC Cu. Feet	Burial/ Processed Wt., Lbs.	Craft Manhours	Utility and Contractor Manhours
Period 2e Collateral Costs																		
2e.3.1	DOC staff relocation expenses	-	-	-	-	-	-	937	141	1,078	-	-	-	-	-	-	-	-
2e.3.2	Corporate & Site A&G Costs	-	-	-	-	-	-	672	101	773	-	-	-	-	-	-	-	-
2e.3	Subtotal Period 2e Collateral Costs	-	-	-	-	-	-	1,609	241	1,851	-	-	-	-	-	-	-	-
Period 2e Period-Dependent Costs																		
2e.4.1	Insurance	-	-	-	-	-	-	286	29	315	-	-	-	-	-	-	-	-
2e.4.2	Property taxes	-	-	-	-	-	-	16	2	17	-	-	-	-	-	-	-	-
2e.4.3	Health physics supplies	-	722	-	-	-	-	-	180	902	-	-	-	-	-	-	-	-
2e.4.4	Disposal of DAW generated	-	-	4	1	-	12	-	4	21	-	306	-	-	-	6,127	75	-
2e.4.5	Plant energy budget	-	-	-	-	-	-	129	19	148	-	-	-	-	-	-	-	-
2e.4.6	NRC Fees	-	-	-	-	-	-	335	34	369	-	-	-	-	-	-	-	-
2e.4.7	Emergency Planning Fees	-	-	-	-	-	-	207	21	228	-	-	-	-	-	-	-	-
2e.4.8	Security Staff Cost	-	-	-	-	-	-	602	90	692	-	-	-	-	-	-	-	14,194
2e.4.9	DOC Staff Cost	-	-	-	-	-	-	4,416	662	5,078	-	-	-	-	-	-	-	57,566
2e.4.10	Utility Staff Cost	-	-	-	-	-	-	4,160	624	4,784	-	-	-	-	-	-	-	79,646
2e.4	Subtotal Period 2e Period-Dependent Costs	-	722	4	1	-	12	10,151	1,664	12,554	-	306	-	-	-	6,127	75	151,406
2e.0	TOTAL PERIOD 2e COST	-	722	4	1	-	12	19,920	4,334	24,992	-	306	-	-	-	6,127	174,933	159,206
	PERIOD 2 TOTALS	9,572	59,449	10,727	7,334	54,161	80,470	171,133	85,320	478,166	595,604	110,745	14,664	1,148	644	38,077,512	1,209,210	2,415,518
	TOTAL COST TO DECOMMISSION	10,414	61,192	10,791	7,619	54,161	81,321	247,333	97,602	570,433	595,604	111,354	15,847	1,148	644	38,238,780	1,209,593	3,340,686

TOTAL COST TO DECOMMISSION WITH 20.64% CONTINGENCY: **$570,433 thousands of 2003 dollars**

End Notes:
n/a - indicates that this activity not charged as decommissioning expense.
a - indicates that this activity performed by decommissioning staff.
0 - indicates that this value is less than 0.5 but is non-zero.
a cell containing " - " indicates a zero value

Table 4-17. Present Value of the Cost of Decommissioning

	Cost Estimate Value (Millions of 2003 dollars)	Cost Estimate Value Discounted to PV[2,3] (Millions of present value dollars) 40 years operation	60 years operation
NRC Minimum Estimates[1]			
ABWR	445.12	187.64	126.28
ACR-700 (unit)	318.68	134.34	90.41
AP1000	360.27	151.87	102.21
ESBWR	445.12	187.64	126.28
NRC Minimum Estimates[4]			
ABWR	678.11	285.86	192.38
ACR-700 (unit)	508.00	214.15	144.11
AP1000	574.29	242.09	162.92
ESBWR	678.11	285.86	192.38
Study Estimates[5]			
ABWR	594.99	250.82	168.79
ACR-700 U1	426.36	179.73	120.95
ACR-700 U2	444.19	187.25	126.01
AP1000	416.41	175.54	118.13
ESBWR	570.43	240.47	161.83

Notes:

1 Based on 10 CFR 50.75 valuation process (South [non-compact] - with use of waste processors)
2 Discounted value based on an annual real rate of return of 2%
3 Assumes fund continues earning after plant shutdown (50% of fund balance for 7 years)
4 Based on 10 CFR 50.75 valuation process (South [non-compact] - burial only)
5 Costs based on the results of this study