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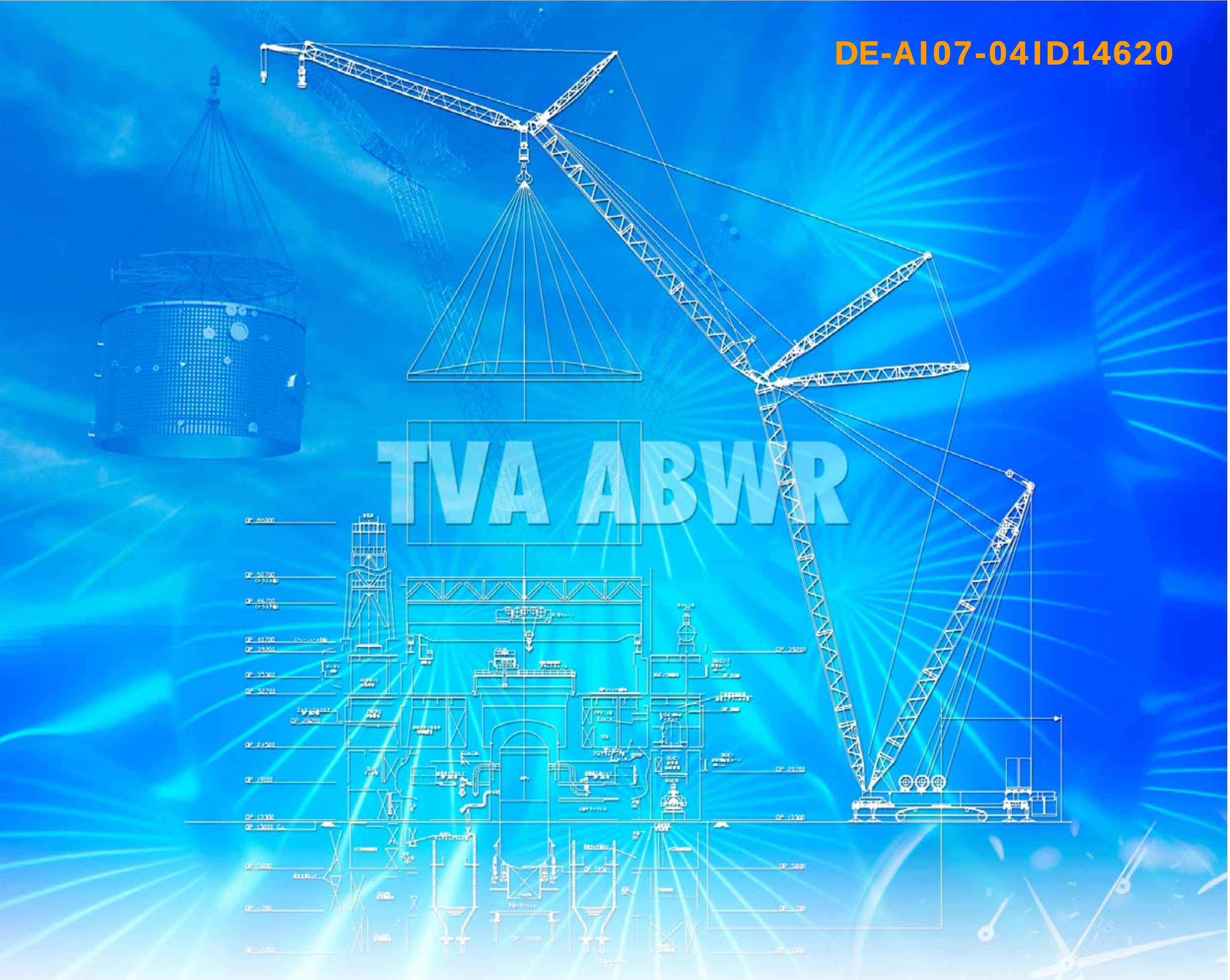

New Nuclear Power Plant Licensing Demonstration Project

ABWR Cost / Schedule / COL Project at TVA's Bellefonte Site

August 2005

TENNESSEE VALLEY AUTHORITY

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ABWR COST/SCHEDULE/COL AT TVA'S BELLEFONTE SITE

CONTENTS

Appendices contain information that is proprietary in nature, therefore the appendices are not part of this public report.

List of Tables

List of Figures

List of Abbreviations

ABWR	Advanced Boiling Water Reactor
AC	Alternating Current
AE(A/E)	Architect Engineer
AET	Advanced Engineering Team
AFP	Advanced Flow Pattern
ANSI	American National Standards Institute
AOO	Anticipated Operational Occurrence
APR	Automatic Power Regulator System
ARI	Alternative Rod Insertion
ASD	Adjustable Speed Drive
ASME	American Society of Mechanical Engineers
BNFL	British Nuclear Fuels
BOL	Bellefonte Owners LLC
BOP	Balance of Plant
BQ	Bill of Quantity
BWR	Boiling Water Reactor
CAD	Computer-Aided Design
C/B	Control Building
CFCAE	Condensate, Feedwater and Condensate Air Extraction System
CFR	Code of Federal Regulations
COL	Combined Construction and Operation License
COLA	COL Application
COND	Condenser
CONW	Concentrated Waste System
CP	Critical Path
CRD	Control Rod Drive
CSDM	Core Shutdown Margin
CTG	Combustion Turbine Generator
CUW	Reactor Water Clean-up System
CV	Control Valve
CVCF	Constant Voltage Constant Frequency
CWS	Circulating Water Syetem
DC	Direct Current, Design Certification
DCD	Design Control Document
DCIS	Distributed Control Information System
DOC	Department of Commerce
DOE	Department of Energy
EAB	Exclusion Area Boundary
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator System
EEDB	Energy Economics Data Base
EPC	Engineering Procurement Construction
EPD	Electrical Power Distribution System
ESF	Engineering Safety Feature

ESP	Early Site Permit
EUP	Energy Utilization Plan
FCB	Field Circuit Breaker
FCS	Flammability Control System
FCV	Flow Control Valve
F/D	Filter-Demineralizer
FWL	Feedwater Line
FDWC	Feedwater Control System
FICA	Federal Insurance Contributions Act
FIN-5	Finland-5
FPC	Fuel Pool Cooling and Clean-up System
FMCRD	Fine-Motion Control Rod Drive
FNM	Field Non Manual
FOAKE	First of a Kind Engineering
FSAR	Final Safety Analysis Report
FWHD	Feedwater Heater and Drain System
GDP	Gaseous Diffusion Plant
GE	General Electric
GEN	Generator
GNF-A	Global Nuclear Fuel
GNSS	Globe Nuclear Services and Supply
GSC	Gland Steam Condenser
H-5	Hamaoka Unit No.5
HCW	High Conductivity Waste System
HEU	Highly-Enriched Uranium
HP	High Pressure
HPCF	High Pressure Core Flooder System
HPCP	High Pressure Condensate Pump
HSD	Hot Shower Drain System
HVAC	Heating, Ventilating and Air Conditioning System
H/X	Heat Exchanger
I&C	Instrumentation and Control
IEEE	International of Electrical and Electronics Engineers
IMS	Information Management Service
IP	Intermediate Pressure
ISO	International Organization of Standardization
ITAAC	Inspection, Tests, Analysis, and Acceptance Criteria
ITC	International Trade Commission
JV	Joint Venture
K-6	Kashiwazaki-Kariwa Unit No.6
LCV	Level Control Valve
LCW	Low Conductivity Waste System
LDS	Leak Detection and Isolation System
LEU	Low Enriched Uranium
LO	Lubricating Oil System
LP	Low Pressure

LPCP	Low Pressure Condensate Pump
LPRM	Local Power Range Monitor
LPZ	Low Population Zone
LWA	Limited Work Authorization
MCC	Motor Control Center
MCPR	Minimum Critical Power Ratio
MDCT	Mechanical Draft Cooling Tower
MD-RFP	Motor Drive Reactor Feedwater Pump
METI	Ministry of Economy, Trade and Industry
MFLCPR	Maximum Fraction of Limiting CPR
MFLPD	Maximum Fraction of Limiting Power Density
MG-set	Motor and Generator set
MLHGR	Maximum Linear Heat Generation Rate
MOV	Motor Operated Valve
MSH	Moisture Separator Reheater
MSIV	Main Steam Isolation Valve
MSL	Main Steamline
MSR	Moisture Separator Reheater
MSV	Main Stop Valve
MUW	Make-up Water System
MT	Main Turbine
MWe	Megawatt Electric
MWt	Megawatt Thermal
NBS	Nuclear Boiler System
NDCT	Natural Draft Cooling Tower
NECSS	National Engineering and Construction Salary Survey
NEI	Nuclear Energy Institute
NERAC	Nuclear Energy Research Advisory Committee
NFPA	National Fire Protection Association
NM	Non Manual
NNSA	National Nuclear Security Administration
NPP	Nuclear Power Plant
NPS	Nuclear Power Station
NRC	Nuclear Regulatory Commission
NRHX	Non-Regenerative Heat Exchanger
NSSS	Nuclear Steam Supply System
O&M	Operation and Maintenance
OLMCPR	Operating Limit MCPR
P&ID	Piping and Instrument Diagram
PCS	Process Computer System
PCV	Primary Containment Vessel
PIP	Position Indication Probe
PLA	Project Labor Agreement
PP	Physical Protection
PPA	Power Purchase Agreement
PPSA	Power Purchase Supply Agreement

PRA	Probabilistic Risk Assesment
PWR	Pressurized Boiling Water Reactor
P4S	Power for SWU
QA	Quality Assurance
QC	Quality Control
RACC	Rods Action Control Cabinet
RAM	Random access memory
RAT	Reserve Auxiliary Transformer
R/B	Reactor Building
RCC	Remote Communication Cabinet
RCCV	Reinforced Concrete Containment Vessel
RCIC	Reactor Core Isolation Cooling System
RCIS	Rod Control and Information System
RCW	Reactor Building Cooling Water System
RFC(S)	Recirculation Flow Control System
RFP	Reactor Feedwater Pump
RFQ	Request for Quotation
RHR	Residual Heat Removal System
RHX	Regenerative Heat Exchanger
RIN	Reactor Internals
RIP	Reactor Internal Pump
RNCW	Reactor Building Normal Cooling Water System
ROE	Return on Equity
RPV	Reactor Pressure Vessel
RRS	Reactor Recirculation System
RSS	Remote Shutdown System
RSW	Reactor Service Water System
RW	Radwaste System
RW/B	Radwaste Building
SAR	Safety Analysis Report
SB&PC	Steam Bypass and Pressure Control System
S/B	Service Building
SCC	Stress Crack Corrosion
SGTS	Standby Gas Treatment System
SICLR	Supplemental Initial Core Licensing Report
SIP	Separation Indication Probe
SJAE	Steam Jet Air Ejector
SLC	Standby Liquid Control System
SPC	Special Purpose Company
SPCU	Suppression Pool Cleanup System
SRLR	Supplemental Reload Licensing Report
SRV	Safety Relief Valve
SSE	Safe Shutdown Earthquake
SWU	Separative Work Unit
TBV	Turbine Bypass Valve
T/B	Turbine Building

TC-4F	Tandem Compound 4 Flow
TC-6F	Tandem Compound 6 Flow
TCW	Turbine Building Cooling Water System
TEPCO	Tokyo Electric Power Company
TGS	Turbine Gland Steam System
TMI	Three Mile Island
TVA	Tennessee Valley Authority
UAT	Unit Auxiliary Transformer
UHS	Ultimate Heat Sink
URD	Utility Requirement Document
USEC	United States Enrichment Corporation
VAC	Volts Alternating Current
VWPA	Visualized Work Process Analysis
VDU	Video Display Unit
WMD	Weapons of Mass Destruction

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

After a series of construction orders in the 1970s and 1980s, no new nuclear power plants have been ordered in the U.S. One of the major hurdles for new construction was the regulatory regime of two step licensing under 10 CFR Part 50. The two step licensing system prolonged the overall lead time until operation of new nuclear power plants and caused significant delays in construction completion and high construction and financing costs. For the purpose of making the regulatory regime streamlined and more efficient, the NRC established 10 CFR Part 52. Under the new regulatory regime, three new processes were introduced: Early Site Permit (ESP), Design Certificate (DC), Combined construction permit, and conditional Operating License (COL). Under the COL process, the construction permit and conditional operating license are issued at the same time, and the risk of delay during construction should be significantly reduced.

The U.S. National Energy Policy as established in May 2001 made it clear that nuclear energy will play an important role in meeting our growing energy needs. In 2002, DOE initiated the Nuclear Power 2010 program to conduct regulatory demonstration and advanced reactor development activities to support deployment of new nuclear power plants. In August 2005, Congress passed an energy bill including strong incentives to construct new nuclear power plants, such as Production Tax Credit, Federal Risk Insurance, and a loan Guarantee Program. Passage of the Energy Bill demonstrates a strong policy of the Federal Government for new nuclear energy in the U.S. The ABWR is qualified for the incentive mechanism in the Energy Bill.

TVA, in cooperation with DOE, decided to perform a cost and schedule study for construction of twin units of ABWR under the Inter-agency Agreement (DE-AI07-04ID14620) with support of the delivery team (Toshiba, GE, and USEC). The results of this study and other critical issues will determine if TVA will move on to the next step, preparation of COL application (COLA) documents.

TVA decided to perform this Study to evaluate the cost and schedule of constructing twin units of ABWR at Bellefonte because of the following reasons:

- There will be a need for new base load power in mid 2010s.
- The Bellefonte site is an existing nuclear plant site. There are existing facilities that can be re-used.
- The ABWR design has already been certified and there is enough information to evaluate the construction process from construction and operation experience in Japan and Taiwan.

This Study was conducted under TVA's leadership and Toshiba, GE, USEC, Bechtel, and GNF-A cooperated to perform the following tasks.

- Task-1: Completing the plant concept, including evaluating any potential licensing activities, finalizing the BOP and yard facilities, and determining material quantities based on the plant concept
- Task-2: Completing a detailed ABWR cost and schedule evaluation including a fuel management and supply plan, and a project deployment model
- Task-3: Based on state of the art technology, potential modifications and/or enhancements were proposed in order to improve efficiency and economy of the ABWR and evaluate the impact on licensing and the overall cost and schedule.
- Task-4: Publish final report
- Task-5: This task was added while the study was underway. This task includes study of the turbine building, the radwaste building and the service building to enhance the project economics.

1.2 PLANT CONCEPT

The ABWR is the evolutional design of the conventional BWR and the only design, among the third generation designs, with construction and operating experience. Its design was developed by a consortium led by Toshiba, GE and others. The first completed unit, Kashiwazaki Kariwa Unit-6 (K-6), operated by Tokyo Electric Power Company (TEPCO), entered into commercial operation in 1996. In parallel, GE applied for Design Certification (DC) to the U.S. NRC. The DC was issued in 1997. Toshiba contributed to GE's DC effort. Toshiba completed the third ABWR unit in Japan, Hamaoka Unit 5 (H-5), which has been commercially operated since January 2005. Another unit is being constructed in Japan and two units are currently being constructed in Taiwan. More construction is planned in Japan.

Based on the current DC, Toshiba and GE developed the plant concept, incorporating lessons learned and technology advancements developed during the Japanese and Lungmen unit design and construction.

During this study, Toshiba and GE identified 96 candidate design improvements which are deviations from the DCD, and adopted 66 of those items as a result of this evaluation. The following items are major improvements from the DCD and these improvements will result in reduction of construction and O&M cost:

- **Increase of power output**: Through adoption of an ultrasonic feed water flow measurement system, the safety margin of measurement error is optimized and the thermal output is increased by 1.7%. In addition, an advanced design of the turbine generator has been adopted. As a result, the net power output is increased to 1371MW.

- **Seal-less Fine Motion Control Rod Drive (Seal-less FMCRD)**: A magnetic coupling is used to allow a Seal-less FMCRD. This reduces construction and O&M costs, as well as radiation exposure to workers. Toshiba has already applied Seal-less FMCRDs at H-5.

- **Reduction in number of RIP-ASDs**: In the DCD, 10 Adjustable Speed Drives (ASD) were used for Reactor Internal Pumps (RIP), one ASD per RIP. Some of the ASDs have been eliminated through the common use of the ASDs, which leads to lower construction cost and more space becomes available. Toshiba has already applied common use of ASDs at H-5.

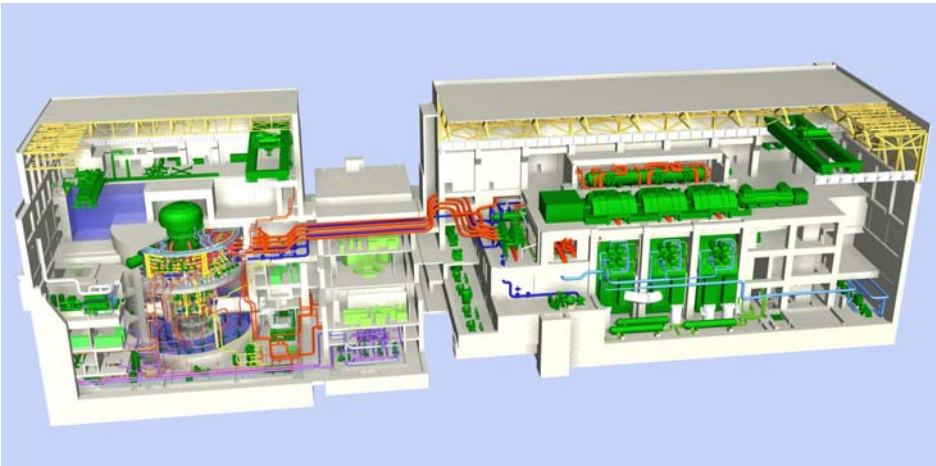


Figure 1-1 Three Dimensional Picture of ABWR

Table 1-1 Major Features Comparison between ABWR and BWR6

Parameter	BWR6-Mark III (Grand Gulf)	ABWR
Power (MWt / Mwe Net) Nominal Uprated	3900 / 1360	3992 / 1371 4300 / 1465
Vessel Height / Diameter (m)	21.6 / 6.4	21.1 / 7.1
Fuel Bundles	800	872
Recirculation pumps	2 (Large pump with external recirculation loop)	10 internal pump
CRD type /number of CRDs	LPCRD / 193	Seal-less FMCRD / 205
Core Damage Frequency (/year)	1E-6	1E-7
Containment	Pressure Suppression	Pressure Suppression

- **Application of compact RCIC turbine pump**: In the DCD, there is a barometric condenser and associated equipment for the Reactor Core Isolation Cooling (RCIC) system. A Compact RCIC turbine pump has been adopted based on those used in the British submarine service to eliminate the barometric condenser and associated equipment. GE has already applied this at Lungmen and qualified it through functional testing.

- **Change of configuration in service water system and chillers**: Safety and non-safety portions of this system have been separated and simplified so that the construction cost is reduced. In addition, the new water system configuration reduces maintenance and eases surveillance testing by having the non-safety systems normally off.

In addition, the following U.S. proven or advanced designs are incorporated into the plant concept:

- **Simplified structure of turbine building**: The turbine building design has been simplified from a full concrete structure (Japanese standard and DCD basis) to a steel structure with concrete radiation shielding walls so that the building quantities can be reduced by one third or more.

Figure 1-2 Bellefonte ABWR Plant Concept

- **Simplified radwaste facilities and radwaste building**: Based on TVA's practices at Browns Ferry nuclear power plant, a new U.S. design for the radwaste facility has been incorporated. Utilizing Toshiba's lined pool concept, the radwaste system is streamlined and the radwaste building is downsized by two thirds.

Based on the defined plant concept, system descriptions, system flow diagrams, major control block diagrams, general arrangement and single line diagrams were developed and a bill of materials was established. These were the basis for this evaluation. Bechtel developed the site specific bill of materials for the yard facilities. The improvement items identified in the process of evaluation of the power block, such as simplified design for the service building is incorporated in the evaluation of yard facilities.

1.3 CONSTRUCTION SCHEDULE EVALUATION

The first ABWR, K-6, was constructed on a 37 month schedule from first reactor building structural concrete pour to fuel load. The result of the evaluation of this study for construction duration of Bellefonte ABWR, as determined by Toshiba and GE, is 40 months. The 40-month schedule is based on two shifts working five days per week (Monday - Friday) eight hours per shift and alternate Saturdays plus 5% non-scheduled overtime resulting in an average workweek of 46 hours.

The major construction concepts for the Bellefonte ABWR construction project follow. These concepts are based on the most advanced construction technology recently applied in Japanese construction projects and optimized using U.S. practice and infrastructure.

- **Modularization**: Modularization is applied to the ABWR construction for the purpose of shortening installation duration of the critical path components as well as reducing the field installation work at the site. Components which may be on the critical path of the construction schedule are modularized to the maximum extent to achieve cost reduction by shortening the construction duration. The modularization of bulk commodities is applied to significantly reduce the site construction population.

- **Open-top construction**: Extensive use of Toshiba's open top construction methods have been assumed to include large equipment and bulk commodities such as piping and cable trays. The open top construction reduces the material handling costs of bulk commodities by placing them using a large sized crane before the ceiling is completed, in comparison with conventional method where bulk materials are transported into buildings using temporary openings.

- **Large-sized crane**: A large-sized crane is applied to the critical path to lift the 1,000 ton-class modules or equipment into the buildings utilizing open top construction methods.

- **3D CAD for construction**: The ABWR design utilized a 3D CAD model. Toshiba has applied an interactive installation simulation system to the 3D CAD which links Time, Resources and Quantities (yielding a 6D system). This enables improved pre-planning and interference elimination before commencing construction of facilities. This system can be utilized not only during the planning stage but in the construction sequence review activity by superintendent and craft during the construction stage.

The most important factor in determining a construction schedule, labor productivity, was determined by Toshiba using historical U.S. data for nuclear construction projects, recent fossil projects, discussions with U.S. A/E companies and Japanese experience. In the process of the evaluation of labor productivity, precise comparison between the U.S. and

Japanese construction process and confirmation of detailed scope were conducted through detailed review of construction labor work practices, interviews with the U.S. construction experts and a work process evaluation.

Utilizing these technology advancements and a proven and constructed design results in a reduced construction schedule duration of 40 months as presented in this analysis.

The cost evaluation in Section 4.2 is consistent with the 40-month construction schedule.

The 40-month schedule is a very aggressive target in comparison with the past U.S. construction experience. However, it is achievable given the results of items listed above.

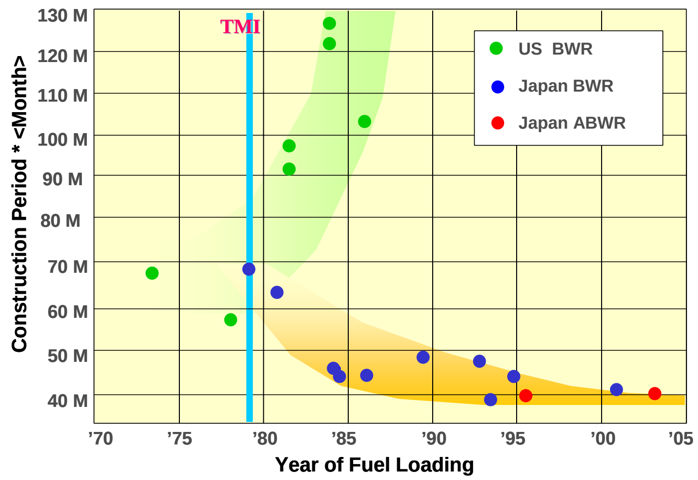


Figure 1-3 History of Construction Period

Figure 1-3 is representative of construction duration for U.S. and Japanese BWR plants. Before the TMI incident in 1979, there were not many differences between the U.S. and Japan, both construction schedules were in the 60-70 months range. After the TMI incident, the construction schedules in the U.S. were extended significantly or some of the plants were forced to suspend construction activities. In Japan, continuous improvements in construction processes have been made and now a less than 40-month construction schedule has become a Japanese standard.

In addition to the methods used to determine this study's 40-month schedule, Section 4.1 provides additional opportunities for schedule reduction by further development of the Japanese construction techniques and their applications in the U.S.

1.4 COST EVALUATION

The cost evaluation in this study incorporates site specific parameters at Bellefonte. The evaluation is comprehensive and the most detailed and accurate among the new nuclear construction cost studies conducted in recent years.

The EPC overnight cost concluded by Toshiba and GE in this study is $1,611/KW for twin units with a one-year lag of commercial operation. (Table 1-2 is the summary of the cost evaluation results).

This report provides the EPC price to TVA (i.e. GE/Toshiba's price) and schedule for construction of a two unit ABWR power plant at TVA's Bellefonte plant site. This information is useful in demonstrating the economic viability of advanced nuclear plants, prior to a decision to add generating capacity. The study is based on actual construction experience in Japan and Taiwan modified by a preliminary engineering design specific to the Bellefonte site, the material quantities needed to construct the plant, and current market conditions related to materials, supplier prices, and local labor market.

The EPC costs under this study include provisions for standard commercial terms and conditions, and a project contingency. Thus, the EPC cost presented in this study represent all inclusive costs, excluding owner's costs. The all inclusive EPC costs, however, would require adjustment to specific terms and conditions as applied to a specific contract. Unless otherwise specified, the EPC costs and its components in this report are expressed in 2004 dollars.

The EPC costs developed in this study are indicative prices based on mutually agreeable terms and conditions and site conditions for a firm fixed price offering.

Table 1-2 Bellefonte ABWR EPC Overnight Costs Summary in 2004 Dollars

Plant capacity	Entire Plant	Power Block
Base Output(1371MWe-Net)	$1,611/kW	$1,443/kW
Uprate Output(1465MWe-Net)	$1,535/kW	$1,377/kW

Builder's risk, property and liability insurances and import duty are not included in the above costs. The ballpark estimate for the insurances and import duty is approximately equivalent to $20/KW in the case of EPC Overnight Cost of $1,611/KW for Entire Plant, but could vary based upon specific terms and conditions.

Toshiba and GE performed independent evaluations with support of U.S. A/E companies based on the defined plant concept. The close agreement between Toshiba and GE cost estimate results gives high confidence in the results of this study.

Key points considered in the study were (1) use of global sourcing based on the U.S. codes and standards and NRC regulations will be applied to procured equipment. Additionally U.S. standard quality assurance requirements were assumed and will be applied to subcontracted/supplier activities. (2) application of Japanese construction technologies developed during the past continuous construction experience in Japan.

In addition to the methods used to determine the final cost, Section 4.2 provides additional opportunities for further cost reduction, e.g. elimination of the 2004/2005 equipment price spike, optimizing yard facility design for other sites and competitive bids by sub-suppliers.

This information is useful in determining the economic viability of the ABWR.

1.5 FUEL COST EVALUATION

1.5.1 Fuel Management Plan

Core and Fuel Design studies have been performed to demonstrate the feasibility and performance of the Bellefonte Advanced Boiling Water Reactor (ABWR) using the GNF fuel designs. These studies were performed to obtain a detailed fuel management plan and cost estimate as well as to demonstrate the capability of the ABWR and its flexibility to accommodate different energy utilization plans. The Reference design developed describes a 24-month refueling interval, which is consistent with the typical U.S. practice, while another option included an initial 12-month cycle followed by two 18-month cycles with subsequent cycles of 24-months. All of these cycles demonstrated high fuel efficiency while maintaining ample margin to thermal and reactivity limits. The project schedule describes the construction and licensing of the ABWR with commercial operations commencing in 2014. As a subset of the overall project schedule, a core and fuel schedule has been developed consistent with the key milestones of the overall project. In the proposed core and fuel schedule, it is observed that approximately seven years will elapse from the time the Combined Operating License Application (COLA) is provided to the NRC and the time the plant begins commercial operations. Since a relatively large amount of time elapses between the COLA and plant operations, improved fuel designs are anticipated to be available. Thus, two different licensing scenarios that would permit the use of available improved fuel designs were included in the fuel management plan to improve flexibility.

1.5.2 Fuel Supply Plan

This section outlines two distinct fuel supply plans and analyzes the costs associated with obtaining fuel for TVA's potential twin unit ABWR plant at its Bellefonte site in Hollywood, Alabama; The Isaiah Project Plan, which is the preferred option and The Traditional Plan.

The Isaiah Project Plan concept provides TVA with low cost fuel while addressing vital U.S. energy security, non-proliferation, and national security objectives. Under this plan, a consortium of nuclear industry participants would manage and finance the recycling of surplus U.S. government highly enriched uranium (HEU) into low enriched uranium (LEU) fuel. The U.S. government would donate HEU and natural uranium to the consortium for processing. The resulting LEU would be returned to the U.S. government less a percentage to cover the consortium's processing costs. Lastly, the U.S. government would provide LEU to TVA for initial cores in its new ABWR reactors. This scenario is anticipated to result in significant fuel cost savings for TVA because the U.S. government will provide the LEU and the natural uranium needed for the initial core at no cost to TVA. TVA's only cost would be fabrication. Additionally, by pursuing this option, TVA would be making a contribution to the Administration important policy objectives, and would build upon other successful HEU-to-LEU programs supported by the Administration.

The Traditional Plan which provides LEU by enriching natural uranium, is based on fuel management plans (Option 1 and Option 2) from GNF-A. This plan would provide fuel for the TVA Bellefonte ABWR at a higher cost than the Isaiah Project Plan. Option 1 calls for a 24-month initial core followed by 24-month cycles. Option 2 calls for a 12-month initial core following by two transitional 18-month cycles followed by 24-month cycles. USEC developed projections of total initial core and fuel cycle costs for fueling under both options. Although costs in the early years deviate between the options due to length of fuel cycles, the costs are similar over the long-term. It is important to consider that supply and demand conditions and price movements across the components of the nuclear fuel cycle will affect the ultimate price that TVA pays for its nuclear fuel requirements. Several means of financing fuel purchases are identified including capitalization, leasing, and power-for-SWU.

1.6 PROJECT DEPLOYMENT MODEL

The objective of the Project Deployment Model activity was to propose a project structure for deployment of the Bellefonte ABWR Project, including high-level agreement on the roles, responsibilities, and interfaces for the project ABWR Delivery Team.

The Project Deployment Model proposed for the Bellefonte ABWR Project considered past contributors to project construction delays and incorporates a more consolidated project structure to improve the project implementation. Many of the improvements in the proposed deployment model for the Bellefonte ABWR Project grew out of the cooperative experience between Toshiba and GE on the first ABWR project in Japan. Key points of this Japan ABWR project experience include:

- Joint work to develop the complete plant design
- Joint Venture (JV) type contract
- Separate Civil JV
- NSSS/BOP vendor scope including installation work
- Fixed price, lump sum basis contracts

As the result of discussions, Toshiba and GE propose the Project Deployment Model presented in Chapter 5.

(1) A key advantage for the Bellefonte ABWR Project will be the application of the Certified ABWR Design. The Certified ABWR Design, as implemented in the DOE-sponsored First-of-a-Kind-Engineering (FOAKE) Program and the Lungmen Nuclear Power Station, will be used as the design basis for the Bellefonte ABWR Project.

(2) TVA and the ABWR Delivery Team can proceed with the project step by step and make decisions to move the project forward. This approach will optimize the total plant costs and minimize the risks for both the owner and vendor teams. Competitive tenders are expected not only for equipment supply but also for construction activities, which will further result in minimizing the project costs.

(3) The ABWR Delivery Team under a Consortium or Joint Venture (JV) agreement will be proposed. The project may utilize three major JV partners, with one partner nominally responsible for the design and delivery of the Nuclear Island, another JV partner nominally responsible for the design and delivery of the Turbine Island and Balance of Plant, and a third JV partner responsible for the civil construction.

(4) The project will proceed in three phases. In Phase 1, COL preparation & COL work, GE and Toshiba will establish a Consortium or Joint Venture (JV) to perform basic and some detailed design. In Phase 2, Detailed engineering, the project JV will continue in the same organization and structure as Phase1 to accomplish the detailed design engineering, detailed construction planning, and procurement engineering. In Phase 3, Construction, the project Consortium or JV will invite a constructor responsible for civil construction to join the project team to perform civil construction work. GE and Toshiba will use the common subcontractors for mechanical/electrical installation work.

(5) Since the Bellefonte ABWR Project will be a United States-based construction project, and implemented under the regulation of the USNRC, Toshiba and GE have agreed that GE should take a leadership role for the ABWR Delivery Team and act as the primary interface with TVA. GE will have responsibility for overall Project Management, and Toshiba will have primary responsibility for Construction Management.

(6) Toshiba and GE will split the responsibilities for supply of equipment packages. International sourcing will be used to ensure that the most cost effective, qualified equipment suppliers are selected for the Bellefonte ABWR Project.

1.7 ADDITIONAL PLANT ENHANCEMENT OPTIONS

In the evaluation of potential plant enhancement options, potential improvements for electric power companies were identified, such as an increase of power output, adoption of new technologies and improvement of operation and maintainability. In the case of potential O&M cost savings, such options were evaluated in spite of potential increases of initial capital cost.

A total of 21 items were identified and screened in terms of economics, constructability, licensability, operatability and maintainability. Eighteen items were adopted as potential options for utility companies.

In particular, the following two items contribute significant economic advantages and should be adopted in the Bellefonte ABWR project:

(1) Power Up-rating

In recent years in the U.S., processes have been established to uprate the power output significantly while maintaining the plants' safety margin, and a lot of U.S. BWR plants have been uprated. The same uprate method is applicable to the ABWR, and the thermal output of the ABWR can be uprated by 8% beyond the improved feed water measurement uprate, without making significant changes from the DCD.

Licensability for this option was reviewed and it was concluded that it is better to apply this amendment to the operating license to the second cycle for the purpose of reducing the licensing risk at the COL.

(2) Modernization of Turbine Generator

Recently, advanced compact and more efficient turbine designs have been developed and demonstrated. Such advanced turbine designs may be adopted as an option. As an example, one of the following applications may be used at the time of actual design of the project.

(a) Longer last stage blade of low pressure (LP) turbine would improve thermal efficiency, and the number of LP turbines can be reduced to 2. Use of the longer last stage blade of LP allows a shorter and lighter turbine-generator.

(b) Replacement of dual flow high pressure turbine with combination high pressure and intermediate pressure turbine in a single casing. Use of the intermediate pressure turbine and its lower exit pressure allows the use of three shorter low pressure turbine. This configuration allows reduction of the quantities of equipment and material and the size of the turbine building.

1.8 COST AND SCHEDULE REVIEW RESULT

The conclusion of this study is that two ABWR units can be constructed at the Bellefonte site on a 40 month schedule, each, from first reactor structure concrete to fuel load. The EPC cost for the two units is $1611/KW (at 1371MWe) and $1535/KW (at 1465MWe). These EPC costs are indicative prices based on mutually agreeable terms and conditions and site conditions for a firm fixed price offering.

2.0 PROJECT DESCRIPTION

2.1 INTRODUCTION

The U.S. National Energy Policy, as established in May 2001, made it clear that nuclear energy will play an important role in meeting our growing energy needs. In 2002, DOE initiated the Nuclear Power 2010 program to conduct regulatory demonstration and advanced reactor development activities to support deployment of new nuclear power plants. While our team fully supports that position, we also understand that building new nuclear power generation in the United States faces serious obstacles, including commercial, regulatory, and public acceptance issues.

DOE's Nuclear Energy Research Advisory Committee (NERAC) is on the leading edge of efforts to identify and solve these issues by working with the nuclear industry. NERAC's Near-Term Deployment Working Group has recognized that one of the critical requirements for restarting nuclear power plant construction is demonstrating the economic viability of the next generation of nuclear power plants. To achieve this goal, DOE and the utility industry need to be confident that:

- The level of cost to construct and operate the next generation of nuclear plants is economically viable.
- The costs have been evaluated in sufficient detail and specificity and validated where possible, such that both the utilities and vendors believe that the projected costs can be achieved.
- The schedule has been validated in sufficient detail and specifics and with applicable actual construction experience such that utilities and vendors believe that the projected schedule can be achieved.

2.2 BACKGROUND

Most of the nuclear power plants put into service during the 1970s and 1980s experienced some kind of negative economic impact during construction, either through increased cost or extended construction schedule and, in many instances, both. Part of the cause for the additional cost was changing regulatory requirements and unrealistic expectations regarding nuclear plant cost and schedule. Through the use of a regulatory-approved design, completed prior to construction start, the regulatory impact on plant cost and schedule can be minimized. However, to avoid unrealistic cost expectations at construction start, detailed and specific pre-construction cost and schedule evaluations must be completed very early in the overall project development process to reduce any uncertainty. By having a detailed cost and schedule model in place, utilities, vendors and regulators can have beneficial and informative cost-benefit discussions regarding construction of an ABWR, including any necessary design changes to a previously-approved, new nuclear power plant certified design.

2.3 STUDY PARTICIPANTS, ROLES AND RESPONSIBILITIES

2.3.1 Study participants

TVA selected Toshiba, GE, USEC, GNF-A, and Bechtel as unique participants to assist with the cost and schedule evaluation effort (Figure 2.3-1). Toshiba, GE, USEC, GNF-A, and Bechtel supplied personnel, systems, and resources to work as an integrated team with TVA.

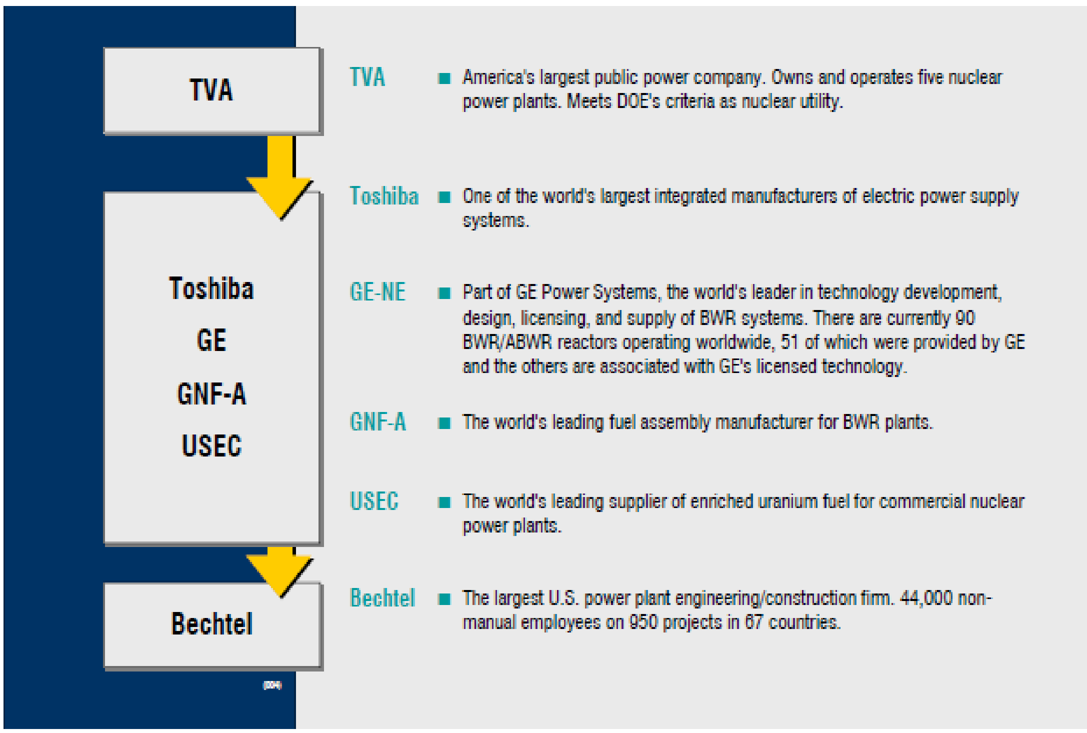


Figure 2.3-1 Team Organization

2.3.2 Roles and Responsibilities

While the organization was designed to function as an integrated project team in support of key personnel, we also carefully defined the roles and responsibilities for each position. Figure 2.3-2 lists some of the more critical responsibilities for each company in our organization chart. By clearly defining these roles and responsibilities, we ensured that each member of the team understands his/her duties, authorities, accountabilities, and interaction with other team members. When defining these roles, we matched responsibilities to authorities to streamline management and empower team members to make decisions at the appropriate level.

Project Director
- Ensures project performance meets or exceeds DOE expectations
- Serves as primary interface with DOE
- Provides owner's cost information to Toshiba for inclusion in the study
- Responsible for cost, schedule, and scope

Technology — Toshiba (GE will support Toshiba and review together with Toshiba)
- Responsible for all reactor building, turbine building, control building, and radwaste building engineering
- Responsible for all pricing for equipment in the reactor building, turbine building, control building, and radwaste building
- Responsible for the review and coordination of the Bechtel design of the yard facilities within Toshiba.

Construction — Toshiba (GE will support Toshiba and review together with Toshiba)
- Provides detailed engineering information for the proposed ABWR modularization at Bellefonte
- Provides input to the expected startup requirements for Toshiba-supplied components
- Ensures the construction methods proposed by Bechtel are consistent with the Toshiba-developed engineering design

Cost/Schedule — Toshiba (GE will support Toshiba and review together with Toshiba)
- Responsible for accumulating all costs for the ABWR at Bellefonte
- Responsible for the accurate compilation of all Toshiba-designated costs
- Provide Toshiba equipment site delivery dates to Bechtel in support of the ABWR's schedule development

Cost Support — Toshiba (GE will support Toshiba and review together with Toshiba)
- Ensures the coordination of information among TVA, Toshiba, and Bechtel
- Supports development of final cost and schedule report

Deployment Model – Toshiba and GE
- Develop Project Deployment Model
- Establish a high level project structure with roles, responsibilities and interfaces for a project deployment team

Licensing – GE
- Evaluate plant design concept for compliance to ABWR Certification.
- Evaluate licensing issues associated with suggested alternatives for evaluation
- Licenseability evaluation
- Develop Plant concept with Toshiba
- Support Toshiba and review together with Toshiba
- Develop and recommend any potential modifications and enhancements together with Toshiba

Technology — GNF-A
- Responsible for nuclear core and fuel engineering
- Responsible for fuel management plan with Toshiba

Technology — Bechtel
- Responsible for all engineering outside of the reactor building, turbine building, control building, radwaste building or those areas referred to as "yard facilities"
- Provides all yard facilities equipment and bulk material pricing
- Coordinates and reviews all engineering information provided by TVA and Toshiba

Construction — Bechtel
- Performs a labor survey in the Bellefonte site area to support wage rate
- Develops a construction plan to build the facility
- Reviews Toshiba-defined modularization to evaluate whether the modules can be constructed per the design drawings

Cost/Schedule Input for Toshiba's Evaluation — Bechtel
- All equipment and bulk material pricing for the yard facilities
- An overall schedule for the erection of the ABWR at Bellefonte
- ABWR construction cost
- Pricing for bulk materials in the reactor, turbine, control, and radwaste buildings

Fuel Supply Plan and Cost/Schedule Support — Toshiba, GNF-A, USEC
- Develop detailed fuel cost estimates
- Identify fuel contracting options, assist in the procurement of U_3O_8, natural and enriched UF_6, and the purchase of fabricated fuel assemblies
- Assist in coordination and implementation of cost and schedule tasks

Figure 2.3-2 Roles and Responsibilities.

The Project Director had authority to take any actions needed to ensure the team's performance and product met DOE's and TVA's satisfaction. This included negotiating changes to the cooperative agreement among team members, committing or releasing resources, authorizing corporate expenditures, and taking any other reasonable actions required to meet agreed-upon project goals, cost, and schedule. Ultimate responsibility for the study's cost, schedule, and scope rested with the Project Director.

In addition to the roles shown here, our study team was supported by various technical and business groups within TVA, Toshiba, GE, GNF-A, USEC, and Bechtel, including plant layout, civil/plant design, construction, project controls, contracting, and administrative support.

2.4 MAJOR PROJECT TASKS

This study was accomplished through a five-step process, with the first step being preliminary engineering and data accumulation. The work accomplished in each of these steps (pre-award tasks and this study's tasks) is described in the following section (Figure 2.4-1).

The outline of each major task(Task 1,2 and 3) was as follows.

Task1: Completing the plant concept, including evaluating any potential licensing activities, finalizing the BOP and yard facilities, and determining material quantities based on the plant concept;

Task2: Completing a detailed ABWR cost and schedule evaluation including a fuel management and supply plan; and a project deployment model; and

Task3: Based on state of the art technology, potential modifications and/or enhancements were reviewed and discussed in order to improve efficiency and economy of ABWR and evaluate the impact on licensing and the overall cost and schedule.

2.5 SCOPE OF THE STUDY

In support of implementing the Nuclear Power 2010 program, the scope of this study is to perform a cost and schedule estimate for the design, licensing and construction of a twin ABWR and/or enhanced twin ABWR at the TVA Bellefonte site.

A realistic cost includes only the EPC portion of the cost, and does not include owner cost. Moreover, in order to compare with another reactor type, a realistic construction cost only for the power block is included.

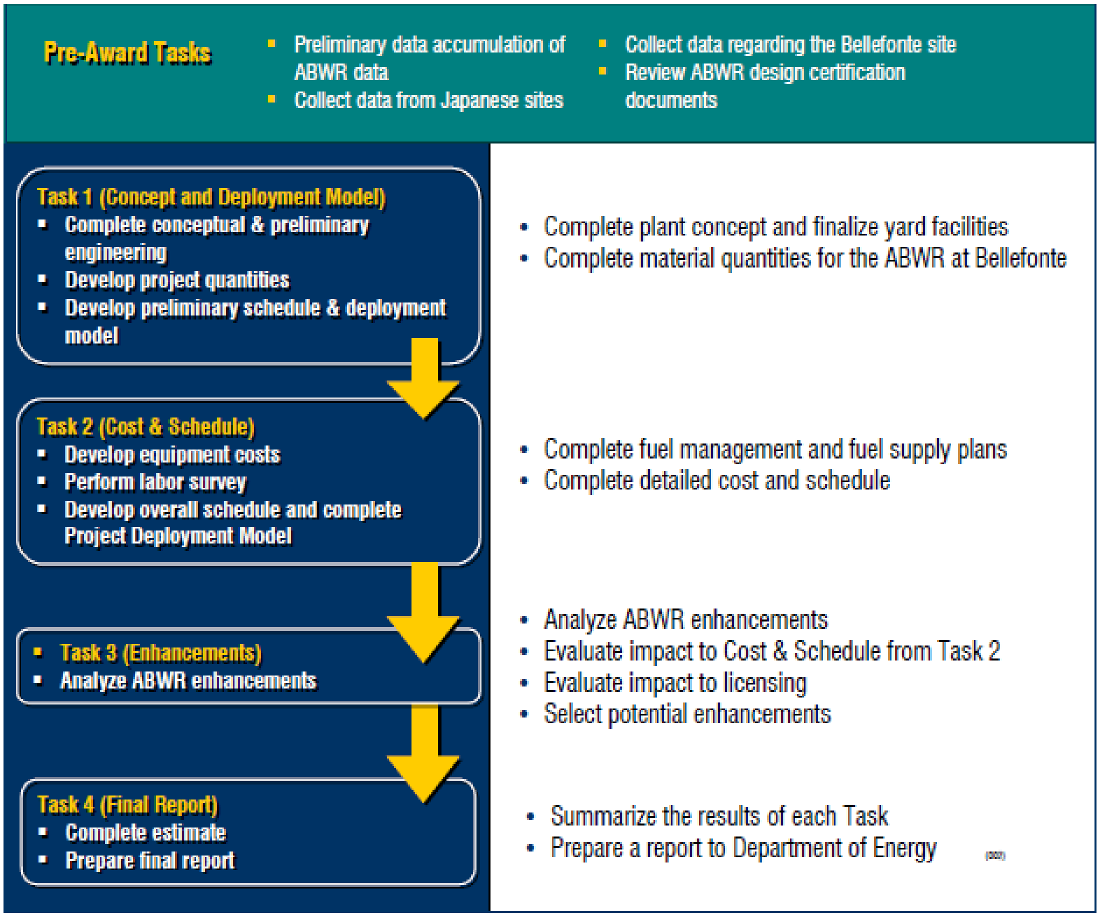


Figure 2.4-1 Step Work Plan

2.6 APPROACHES TO THE WORK

2.6.1 Approach to Accomplishing Pre-Award Tasks

Before this study, TVA, Toshiba, GE, Marubeni, and USEC were engaged in discussions regarding the use of the Bellefonte site for the deployment of an ABWR nuclear plant. To support Bellefonte siting studies, Toshiba began to assemble engineering data from its ABWR projects in Japan and to modify the information to suit the Bellefonte site. These activities included:

- Reflection of the latest technologies utilized with consideration of GE's ABWR Design Control Document (DCD) from the U.S. ABWR Certification.

- Surveying the Bellefonte site for basic site conditions, including existing facilities and making the basic plot plan.
- Surveying the existing cooling towers on the Bellefonte site and studying the cooling system for determination of electric output.

A second major task undertaken by Toshiba was the evaluation of the ABWR reactor building civil schedule. Bechtel was retained to validate the ABWR reactor building civil schedule assumptions developed by Toshiba for TVA's Bellefonte site.

Bechtel has initially validated the feasibility of the Toshiba schedule of constructing the civil scope of the ABWR reactor building in 29 months from the first concrete pour to building completion. With the assistance of TVA, the evaluations were based on the Bellefonte, Alabama site—located approximately 38 miles east of Huntsville (southwest of Chattanooga, Tennessee). At Bellefonte, there is a partially constructed, two-unit nuclear power plant on site with a significant amount of infrastructure present that may be reused as part of the new construction.

2.6.2 Approach to Accomplishing Task 1

Task 1 accomplished the following:

- Defining the plant concept, including any licensing risk.
- Finalizing the preliminary engineering design of BOP and yard facilities.
- Determining material quantities.
- Developing preliminary schedule.
- Providing TVA with a basic project deployment model.

These activities are critical to the cost and schedule evaluation. The concept design influences bulk material quantities and equipment design. Bulk material quantities represent a significant material cost and are among the key parameters in determining the total craft manpower required to construct the facility. Equipment information must be accurate and concise to determine representative material costs, erection durations, and erection sequences.

The following issue was reviewed in detail to complete the basic plant concept.

- Deviations/enhancements to the Tier 1 and Tier 2* ABWR Design Control Document (DCD) were reviewed to determine their appropriateness. This review will also cover the economic benefit of any enhancements.
- Items in Tier 2 that would result in cost reduction were chosen for review and reflected in the basic plant concept.

The above activity helped to finalize the basic plant concept. System outline drawings were developed based on the basic plant concept.

2.6.3 Approach to Accomplishing Task 2

With the information generated in both Task 1 and pre-award activities, Task 2 accomplished the following:

- Assessed the availability and adequacy of equipment and component fabricating capabilities in the United States for the ABWR.
- Evaluated modularization concepts and capabilities
- Performed a labor survey in the Bellefonte area to assess the local labor market conditions.
- Using the plant concept completed to date, developed appropriate equipment and material bid information.
- Completed fuel management and fuel supply plans.
- Completed a detailed cost and schedule evaluation including the development of a detailed level 2 overall schedule.
- Complete a Project Deployment Model, which describes, at a high level, a proposed project structure for the deployment of an ABWR for TVA. This identified key project roles, hierarchy, responsibilities and interfaces.

2.6.4 Approach to Accomplishing Task 3

In order to improve the performance and cost evaluation of ABWR at the Bellefonte site, Task 3 accomplished the following:

- Identified any potential modifications and further enhancements, including power uprating not evaluated in Task 1.
- Reviewed impact to the cost, schedule, and licensing evaluated in Task-2 by applying such modifications and enhancements.
- Recommended which enhancement and modifications should be implemented.

2.7 PROJECT QUALIFICATIONS AND ASSUPMTIONS

2.7.1 Project Qualifications

The evaluation of constructing a twin ABWR at the Bellefonte site is considered to be a highly useful initiative for the utility industry because of the following considerations:

- Bellefonte is an excellent site for baselining the study because of the availability of site information and the opportunity for a fast-track project using existing plant facilities.
- The ABWR is an NRC certified design.
- GE is the pioneer of the ABWR certified design and has design and construction experience for this design on its two ABWR's currently under construction in Taiwan
- TVA and the integrated delivery team have a history of working together effectively.
- Toshiba retained the service of Bechtel—the world's most experienced nuclear engineering and construction firm—for this initial evaluation of applying the ABWR in the United States.
- GNF-A is a joint venture of GE, Toshiba, and Hitachi is a global leader of BWR fuel and fuel engineering services.
- USEC is the world's leading supplier of enriched uranium fuel for commercial nuclear power plants.

2.7.2 Project Assumptions

The fundamental characteristics and assumptions required to support such a goal included:

- Plant design essentially complete except for site unique areas
- Immediate availability of an NRC certified design or timely licensing update
- Pre-licensed site (site with an existing plant or an ESP)
- Extensive use of prefabricated modules
- Capable construction labor pool
- Open-top construction
- Wide use of a heavy lift crane

2.8 USE AND INTENT OF THE REPORT

Figure 2.8-1 is a preliminary representative schedule showing the series of decisions TVA must make to add new nuclear generating capacity to the TVA system. This schedule is intended to show only the relationship of this study to other decision points necessary to complete capacity addition to the TVA system. If a decision is made to proceed beyond this study, a new project schedule will be developed based on actual project plans. Before making a decision to proceed with nuclear power as one of its options, it is essential that TVA have a realistic estimate of cost and schedule for all options being considered. Therefore, this study, which provides a realistic estimate for the nuclear option, is a necessary element in TVA's ability to support the Nuclear Power 2010 goals. Following the completion of such a study, TVA would determine whether to take the next steps to proceed with required environmental reviews and other decision points to add new nuclear generation.

If TVA power demand indicates new base-load generation is needed, TVA would be required to complete an environmental review of the options which are economically feasible to meet that demand. As indicated in the schedule in Figure 2.8-1, the completion of TVA's decision making steps could result in submittal of a COL application as early as 2007, if environmental and economic reviews result in new nuclear generation being the preferred alternative and new generation is needed in the 2014 timeframe. The cost of completing a COL application is estimated to range from $25 to $40 million dollars.

Although the study specifically evaluated the cost of constructing two units at TVA's Bellefonte site, the study and report are structured to allow the extrapolation of these costs by other utilities to estimate the costs of two units at another site.

2.9 INCORPORATION OF LESSONS LEARNED

This report also includes lessons learned from the evaluation process, especially highlighting the lessons derived from our combined experience in designing, building, and operating a nuclear power plant.

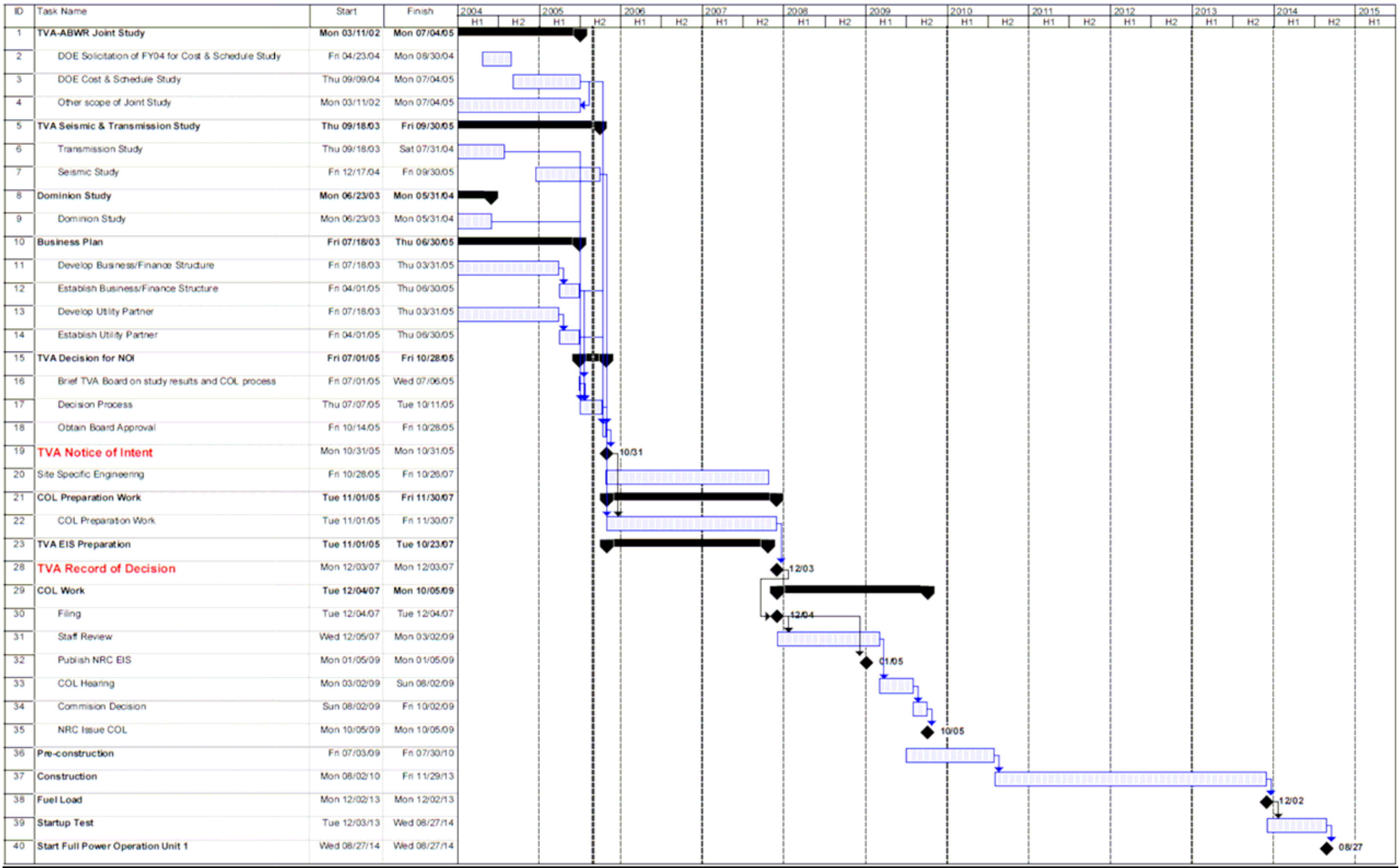


Figure 2.8-1 Preliminary Representative Schedule

3.0 PLANT CONCEPT

3.1 ABWR DEVELOPMENT

The BWR design was originally developed and patented by GE in the 1950s. Starting with the first BWR-1 commercial plant, Dresden-1 which entered into commercial operation in 1960s, the BWR has been improved on an evolutional basis. Over the following couple of decades new improvements and advanced technical features were incorporated into the BWR to yield the BWR-2, BWR-3, BWR-4, BWR-5 and BWR-6 designs which offered enhanced operability and reduced cost. To date over ninety BWR units have been constructed by GE and its licensees, not only in the U.S. but also in Asia and Europe.

In Japan, as a leading company among nuclear vendors, Toshiba introduced BWR technology licensed from GE and took leadership in the design and construction of BWR-4 and BWR-5 plants in Japan.

When GE introduced the BWR-6 design, Japanese utilities preferred to continue constructing BWR-5 plants because the design of the BWR-6 containment system did not fit the Japanese operating philosophy. Instead, the Japanese vendors and utilities believed new technologies could be incorporated into the BWR to yield a design even more advanced than the BWR-5 and -6. With the help of Toshiba, GE established the Advanced Engineering Team (AET) in 1978 to develop this new advanced design of the BWR. GE, Toshiba, Hitachi, Asea-Atom and Ansaldo participated in AET and developed the conceptual design of the advanced BWR (ABWR). The conceptual design of the ABWR attracted the interests of TEPCO and other Japanese BWR operators. Since 1981, the ABWR was adopted in the Japanese government's Third Improvement and Standardization Program.

The target features in the ABWR design were established as follows:

- Improved reliability and safety
- Reduction in radiation exposure and radioactive waste
- Better operatibility
- Improved economics

Through a series of demonstration tests of each improved technology, TEPCO made a decision in 1987 to adopt the advanced design of BWR (ABWR) at the Kashiwazaki-Kariwa site. GE, Toshiba and Hitachi formed an international consortium to conduct detailed design and licensing work. Kashiwazaki-Kariwa Units 6 and 7 entered into commercial operation in 1996 and 1997 respectively. It is important to note that Toshiba, as primary contractor for Kashiwazaki-Kariwa Unit 6, achieved the short construction period of 37 months, from the first reactor building concrete pour to fuel load.

In parallel with its design and construction of Kashiwazaki-Kariwa Units 6 and 7 in Japan, GE was pursuing Design Certification of the ABWR in the United States. GE submitted the GE ABWR design to the U.S. Nuclear Regulatory Commission (NRC) for design certification under 10CFR Part 52. The U.S. NRC issued a Final Design Approval for the GE ABWR in 1996 and Design Certification in 1997. During this period the U.S. Department of Energy (DOE) also adopted the ABWR design as part of the Advanced Light Water Reactor Program, and GE completed First of a Kind Engineering (FOAKE) design of the ABWR with DOE funding support in 1996. Toshiba participated in GE's activities in the Design Certification Process and FOAKE process and some of the documents were prepared by Toshiba.

After the successful completion of construction of the first ABWR in Japan and the issuance of the Design Certification by the U.S. NRC, GE succeeded in winning the award for the contract to construct two units of the ABWR at the Lungmen site in Taiwan. The Taiwan Power Company required that the design to be built at the Lungmen site already be licensed in the country of origin and so GE utilized its U.S. NRC Certified ABWR design. GE also applied the design detailing performed under the U.S. FOAKE Program. As a result, the ABWR design being constructed at the Lungmen site is based on USNRC licensing requirements and will be consistent with the U.S. Utility Requirements Document (URD). As a subcontract to GE, Toshiba provided key ABWR equipment including a reactor pressure vessel, reactor internals, and reactor internal pumps (RIP) for the Lungmen Plant.

In Japan, Toshiba was awarded the nuclear island contract for the third ABWR, Hamaoka Unit 5, which has been commercially operated without problems since January 2005. Toshiba adopted further advanced technologies at Hamaoka Unit-5; such as seal-less FMCRD and common use of Adjustable Speed Drive (ASD) for multiple RIPs (originally, single use of ASD for a RIP).

The major purpose of the "ABWR COST/SCHEDULE/COL Study at TVA's BELLEFONTE SITE" is to evaluate the cost and schedule for construction of a twin unit ABWR at the Bellefonte site. Background knowledge of basic equipment and bulk materials (piping, cable, civil materials etc.) used in the ABWR are necessary as the basis of the evaluation. Such information is available only to vendors who have been responsible for construction of the ABWR, Toshiba and GE. As Toshiba is the primary vendor for construction of the first ABWR and third ABWR, it is reasonable for Toshiba to provide the basic information on the plant equipment and bulk materials as the basis of evaluation of cost and schedule. Because GE is the holder of the ABWR Design Certification and Design Control Document and has experience with the construction of Lungmen and recent bidding on the 5th nuclear unit in Finland, it is reasonable for GE to review and compare Toshiba's cost and schedule estimates against its own database and estimates, evaluate the licensability of proposed design enhancements, and evaluate design detailing for consistency with the Design Certification and U.S. utility practices. Also, both vendors will be using their recent advanced engineering activities to develop potential design enhancements to make the design for Bellefonte even more cost effective during Bellefonte's detail design prior to the COL application. (The design will be frozen at this point to stabilize the licensing process.). Thus, together Toshiba and GE combine to make a strong design and construction team.

3.2 BELLEFONTE DESIGN CONCEPT AND ENHANCEMENTS

As mentioned above, regarding the nuclear island, the ABWR design being constructed at the Lungmen site is based on U.S. NRC licensing requirements and is consistent with the U.S. Utility Requirements Document (URD). Accordingly, the design basis for Lungmen will be the starting point for nuclear island of the Bellefonte ABWR design concept.

Regarding the BOP including the turbine island and radwaste, the U.S. ABWR Certified Design (DCD) is the starting point for the Bellefonte ABWR design concept and is further developed by adopting advanced technologies.

Site specific yard facilities are developed for the Bellefonte units in this study.

Since the Lungmen design is based on the ABWR Certified Design, it is very consistent with the ABWR Design Control Document (DCD). Some modifications have been made for Lungmen to meet the Lungmen site-specific conditions and Republic of China Licensing Requirements. Some of these modifications will be reversed for the Bellefonte design. Similarly, the Japanese ABWR design, which is based on the ABWR DCD, should be changed a little in order to meet U.S. requirements. However, some of these changes will be incorporated into the Bellefonte design. Both Toshiba and GE have developed some equipment advances that would lower the construction cost for Bellefonte and improve its operability. A key part of the Bellefonte Cost and Schedule Study has been to evaluate these design enhancements for potential application to Bellefonte.

One strength of this cost and schedule study is that Toshiba and GE have independent databases from recent projects that they utilize to do their estimating. Toshiba has used its information from constructing Kashiwazaki-Kariwa Unit-6 and -7 / Hamaoka Unit-5 and the next Japanese ABWR, and GE has used its information from constructing Lungmen and its FIN5 bid. With the final results in this report representing a composite from these two databases, its creditability is enhanced.

Figure 3.2-1 shows the process followed in flow chart form to estimate quantities of bulk materials and equipment for the Bellefonte Cost and Schedule Study. Toshiba and GE first evaluated the ABWR DCD and identified potential enhancements to the ABWR design that, if adopted, would be deviations from the DCD. GE reviewed these proposed enhancements in light of the 10CFR Part 52 licensing process to evaluate the significance of their licensing risk.

Based on the review and selection of design enhancements to be recommended for Bellefonte by GE and Toshiba, Toshiba utilized their Kashiwazaki-Kariwa and Hamaoka design to develop drawings of the major plant systems, System and Building Descriptions, System Flow Diagrams, Control Block Diagrams, General Arrangements, and Single Line

Diagrams. GE reviewed these drawings and documents, provided review comments to Toshiba considering the Lungmen design, and worked with Toshiba to resolve the comments. The resulting drawings and documents represent a detail constructed design which reflects closely the Certified Design, yet incorporates key design enhancements.

Toshiba used these drawings and documents to provide Bechtel with input information including requirements from the power block for Bechtel's yard engineering. Bechtel developed System and Building Descriptions, and System Flow Diagrams for the yard facilities.

Toshiba and Bechtel developed a list of bulk materials and equipment, based on past construction experience and those lists have been completed as a result of the team review.

One advantage of the Bellefonte site is that it is home to two partially constructed PWR units which will permit some of the existing facilities to be utilized for ABWR construction. This unique feature of this study is different from general construction at a greenfield site. Prior to the initiation of this study, a site survey was conducted in order to determine which of the existing facilities may be utilized for construction of the ABWR. ("ABWR Project Site Survey Report", A10-9801-0001 Rev.0, dated Sep 30, 2002.) TVA currently has no plans to remove non-usable existing facilities. Therefore this report contains no costs associated with facility removal. This information was also incorporated into the development of the plant concept and the yard facilities and summarized in Table 3.2-1. The biggest items of the existing facilities in terms of cost reduction are the cooling towers. These cooling towers will be used for the Bellefonte ABWR, but it will be necessary to supplement them with mechanical draft cooling towers in order to optimize the electric power output for the site. The costs for the additional cooling towers are also included in the cost evaluation of this study.

In order to determine the bulk materials and specify the equipment needed to construct the Bellefonte ABWR it is necessary to specify the Bellefonte site parameters. The following parameters described in the DCD were adopted for this study.

(1) Maximum ground water level — 61.0 cm below grade

(2) Maximum flood level — 30.5 cm below grade

(3) Precipitation (for roof design)

(a) Maximum rainfall rate — 49.3 cm/h

(b) Maximum snow load — 2.394 kPa

(4) Ambient design temperature

(a) 1% exceedance values

(Maximum) 37.8 degrees C dry bulb

		25 degrees C wet bulb (coincident)
		26.7 degrees C wet bulb (non-coincident)
	(Minimum)	-23.3 degrees C
(b) 0% exceedance values (Historical limit)		
	(Maximum)	46.1 degrees C dry bulb
		26.7 degrees C wet bulb (coincident)
		27.2 degrees C wet bulb (non-coincident)
	(Minimum)	-40 degrees C

(5) Extreme wind (Basic wind speed)	177 km/h (non-safety-related structures)
	197 km/h (safety-related structures)
(6) Tornado	
(a) Maximum tornado wind speed	483 km/h
(b) Maximum pressure drop	13.827 kPa
(c) Missile spectra	Spectrum I
(7) Soil properties	
(a) Minimum static bearing capacity	718.20 kPa
(b) Minimum shear wave velocity	305 m/s
(c) Liquefaction potential	none
(8) Safe shutdown earthquake (SSE)	0.3 g
(9) Meteorological dispersion (Chi/Q)	
(a) Maximum 2-hour 95% exclusion area boundary (EAB)	1.37×10^{-3} s/m^3
(b) Maximum 2-hour 95% low population zone (LPZ)	4.11×10^{-4} s/m^3
(c) Maximum annual average (8760-hour) LPZ	1.17×10^{-6} s/m^3

Table 3.2-1(1/2) List of the Facilities in Plot Plan Study

No	FACILITY	Abbreviation	New /Reuse*	Remarks
1	REACTOR BUILDING	R/B	N	Containing Reactor Containment, Main Steam /Feedwater Tunnel, Equipment Entry Lock, and Radwaste Tunnel
2	CONTROL BUILDING	C/B	N	Containing Main Steam /Feedwater Tunnel
3	TURBINE BUILDING	T/B	N	Containing Stack and Radwaste Tunnels
4	ELECTRICAL BUILDING	E/B	N	Containing Technical Support Center and Normal Switchgear
5	RADWASTE BUILDING	RW/B	N	
6	SERVICE BUILDING	S/B	N	
7	RSW BUILDING	RSW/B	N	
8	SPRAY POND	—	N	
9	CONDENSATE STORAGE TANK	CST	N	
10	MUWC BUILDING	MUWC/B	N	
11	MAIN / UNIT AUXILIARY / EXCITER TRANSFORMERS	MTr/ExTr /AuxTr	N	
12	RESERVE AUXILIARY TRANSFORMERS	RsvTr	N	Containing DG Oil Transfer Tunnel
13	DIESEL OILSTORAGE TANK	OST	N	
14	FIRE PROTECTION WATER STORAGE TANK	FPT	N	
15	FIRE PROTECTION PUMPHOUSE	FP/H	N	(Described as Bunker Fuel Tank in DCD)
16	COMBUSTION TURBINE GENERATOR HEAVY OIL STORAGE TANK	CTGHT	N	
17	COMBUSTION TURBINE GENERATOR	CTG	N	
18	ADDITIONAL COOLING TOWER	—	N	
19	CCW BUILDING	CCW/B	N	
20	DESILTING BASIN	—	N	
21	FILTERED WATER STORAGE TANK	FWT	N	
22	DEMINERALIZED WATER STORAGE TANK	DWT	N	
23	MUW BUILDING	MUW/B	N	
24	LIQUID NIROGEN FACILITY	LN	N	
25	PHYSICAL PROTECTION BUILDING	PP/B	N	
26	DISCHARGE MONITORING SAMPLING BLDG	DMS/B	N	
27	GAS STORAGE FACILITY	—	N	
28	FOAM EXTINGUISHER BUILDING	—	N	
29	CIRCULATING WATER CHEMICAL INJECTION BUILDING	CCI/B	N	
30	SOLID WASTE STORAGE BUILDING	—	N	Construction after commercial operation
31	WATER INTAKE BUILDING AND INTAKE CANAL	WI/B	R	

Table 3.2-1(2/2) List of the Facilities in Plot Plan Study

No	FACILITY	Abbreviation	New /Reuse*	Remarks
32	COOLING TOWERS	CT	R	
33	161Kv SWITCH YARD	—	R	
34	500Kv SWITCH YARD	—	R	
35	HOUSE BOILER FACILITY	HB	R	
36	YARD DRAINAGE POND	—	R	
37	SUMP COLLECTION POND	—	R	
38	HOT MACHINE SHOP	—	R	
39	BARGE DOCK AND UNLOADONG FACILITY	—	R	
40	ADMINISTRATION BUILDING	—	R	
41	OPERATION TRAINING BUILDING	—	R	
42	MAINTENANCE TRAINING BUILDING	—	R	
43	WARE HOUSE	—	R	

＊・・・N : New construction , R : Reuse Existing facility

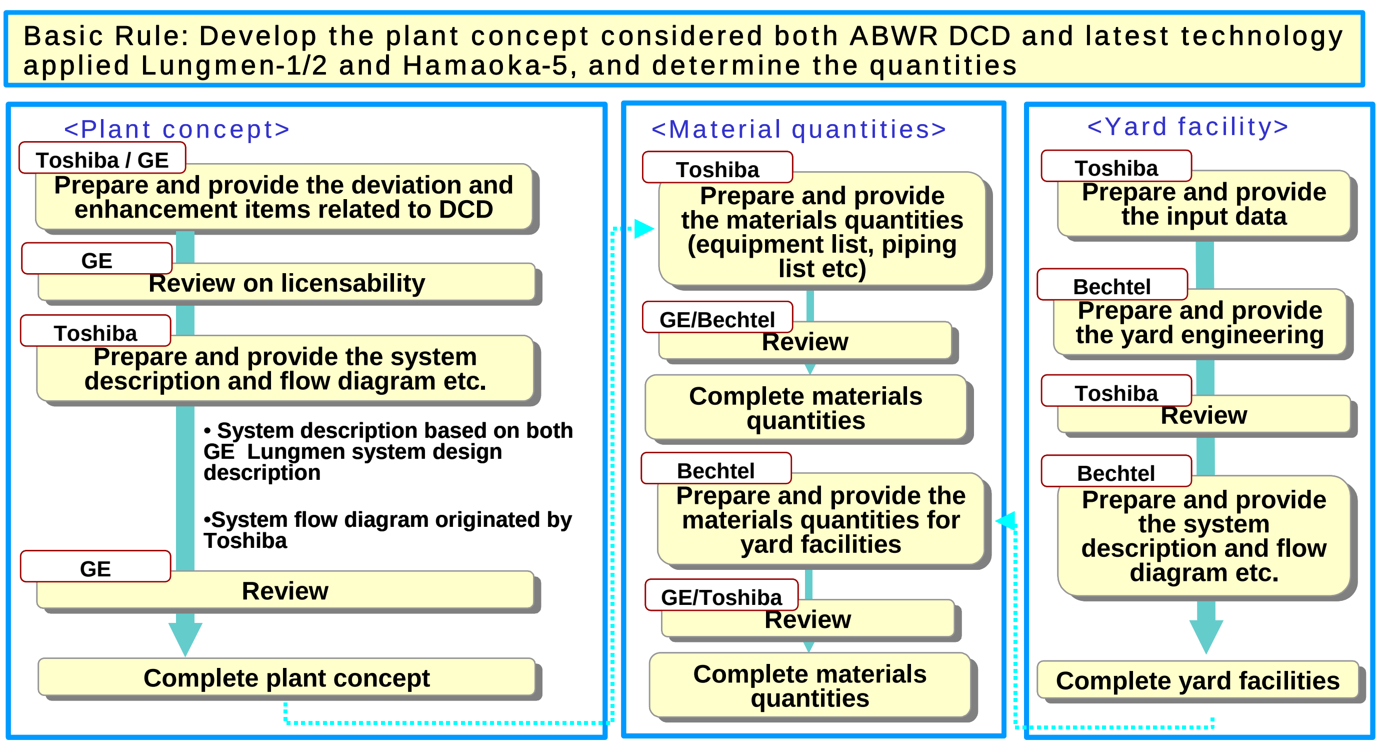


Figure 3.2-1Key flow chart in TASK 1

3.3 ENHANCEMENT FOR THE BELLEFONTE PLANT DESIGN

3.3.1 Basic Process to Determine the Deviations from the DCD

A key element to the Bellefonte ABWR Cost and Schedule Project is the identification of design enhancements that will lower the cost of the project and improve the plant operability. As the starting point for the Bellefonte ABWR design is the ABWR Design Control Document (DCD), some of these design enhancements will be deviations from the DCD.

The basic process used to define the Bellefonte ABWR design and to incorporate its enhancements is as follows:

(1) As the first step, most of the U.S. ABWR certified design was incorporated in the plant concept under Task-1. Deviations from the certified design are summarized below:

   (a) The standard design scope in the DCD, namely, structures, systems and components of the reactor building, common building, turbine building, rad-waste building and service building are generally taken from DCD. Site specific features at Bellefonte are considered for the remaining plant features.

   (b) While the DCD is based on a single unit, the plant concept under Task-1 is for the construction of twin units.

   (c) After the DCD was issued, there were several changes in U.S. regulations, and design changes were incorporated where appropriate to address these new regulations. A small power uprate due to the change in Appendix-K for feedwater flow measurement uncertainty and elimination of the recombiners are examples.

   (d) In addition to the above, some design enhancements were incorporated where it was concluded that the plant cost could be reduced with no adverse impact to safety or unacceptable increase in regulatory risk. The deviation items are selected based on experiences of other ABWR projects in operation or under construction, new technologies applied to BWRs in Japan and U.S. BWRs, and advanced technologies.

   (e) TVA's preferences including maximum power output not exceeding 1400MW (net), 24-month fuel cycle operation and maximum use of existing facilities.

(2) The following criteria, summarized from Section 3.4.4.4, were established to determine whether to deviate from DCD or not:

   (a) For Tier 1 exemptions, deviations may only be taken from the DCD if significant improvement can be achieved and there is no significant decrease in safety.

(b) For Tier 2* departures, the same principle as describe above for Tier-1 exemptions was applied.

(c) For Tier 2 departures, the designs may be improved beyond DCD only if the improvement can be achieved and there is no significant increase in the amount of regulatory work. Since this cost and schedule study is performed on a conceptual level, not all items with small impact on construction cost reduction were evaluated at this stage.

The licensability evaluation is discussed in Section 3.4. The enhanced plant concept based on these changes from the DCD is discussed in Section 3.5.

3.3.2 Identification of DCD Enhancements and Deviations

The enhancements and deviations are classified as Tier 1 exemptions, Tier 2* departures, and Tier 2 departures. Table 3.3-1 shows the selected enhancements and deviations from Task 1-1 activities. In Table 3.3-1, the items are arranged according to the related DCD section. The licensability and advantage of each item are summarized.

An explanation of each item is attached as Appendix G. The description of each design enhancement includes:

- Description in DCD
- Description of Proposed Change
- Basis of Proposed Change
- Advantage of Change
- Licensability of Change
- Licensability Evaluation

"Advantage of Change" is classified into two categories, that is, cost reduction and other advantage. Furthermore, cost reduction is classified into three categories, that is, >$1M, <$0.1M, and between $0.1M and $1M. "Licensability of Change" is classified into three categories; inconsistent with current U.S. regulations, consistent with regulatory change after Design Certification, and consistent with current U.S. regulations. Some enhancements are combined and there are not independent listings for the sub items.

Table 3.3-2 shows the proposed but withdrawn enhancements in Task 1-1 activities. The reasons they were withdrawn is summarized in the remarks column. Those items that were not adopted under Task-1 were primarily a result of perceived licensing risk, lower impact in economics or not appropriate in light of U.S. practices.

One item that was proposed under Task-1 was relocated to Task 3. That is a 10% Power uprate, which is evaluated under Task-3 due to the guidance from TVA.

Table 3.3-1 Selected Enhancements and Deviations from Task 1-1 Activities

Category	No.	Title	Licensability	Advantage	Remarks
Tier 1	*1.2 General Provisions*				
	1	Thermal Power Uprate	Minimal Licensing Risk. Revised Regulation supports approximately 1.7% thermal power uprate.	Increase electrical output	
	2.2 Control and Instrument Systems				
	2	Application of the Seal-less FMCRD	Minor Licensing Risk, worth the >$1M cost reduction	More than $1M initial cost reduction Reduction in radiation exposure and leakage potential of coolant	
	3	FDWC	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	4	Reduction in Number of RIP-ASDs	Acceptable Licensing Risk for estimated cost savings.	From $0.1M to $1M initial cost reduction	
	5	APR	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	2.4 Core Cooling Systems				
	6	Elimination of Cooling Water Supply Lines to FCS	Minimal Licensing Risk	Less than $0.1M initial cost reduction	Incorporated into Tier 1 No.24
	7	Elimination of RHR Jockey Pumps	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	8	Reassignment of RHR Divisions for Augmented Fuel Pool Cooling	Minimal Licensing Risk	From $0.1M to $1M initial cost reduction	
	9	LDS	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	10	Application of Compact RCIC Turbine-Pump	Minimal Licensing Risk	More than $1M initial cost reduction 50% reduction in the installation space	
	11	Elimination of RCIC Steam Supply Bypass Line	Minimal Licensing Risk	Less than $0.1M initial cost reduction	
	2.5 Reactor Servicing Equipment				
	12	Elimination of the Auxiliary Platform	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	13	Design of Auxiliary Hoists on Refueling Platform	Minor Licensing Risk	Improvement of work efficiency	
	14	Design of New Fuel Storage Rack	Minor Licensing Risk	Less than $0.1M initial cost reduction	
	15	Capacity of New Fuel Storage Vault	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	2.6 Reactor Auxiliary Systems				
	16	Elimination of RCW Surge Tank Makeup Lines from SPCU System	Acceptable Licensing Risk, if coupled with more significant exemption	Less than $0.1M initial cost reduction	Incorporated into Tier 1 No.19
	2.10 Power Cycle Systems				
	17	Change of Number of the Stage of Condensate Pumps	Minor Licensing Risk due to BOP scope, probably worth the >$1M cost reduction	More than $1M initial cost reduction	
	18	Change of Configuration of Main Condenser Evacuation System	Minor Licensing Risk due to BOP scope, but check $ savings to confirm worthy of risk	Less than $0.1M initial cost reduction Reduction in time to vacuum up	
	2.11 Station Auxiliary Systems				
	19	Service Water Systems and Chillers	Acceptable Licensing Risk, worth the >$1M cost reduction plus O&M and Outage Savings	More than $1M initial cost reduction	
	2.12 Station Electric Systems				
	20	Plant Electrical System	Necessary Licensing Risk, DCD electrical design not consistent with U.S. industry practice	Consistency with U.S. industry practice	
	21	EPD System/Circuit Breakers	Minor Licensing Risk	More appropriate application for the GCB	
	22	Combustion Turbine Generator	Minor Licensing Risk	Improvement of operability by standardization of displays for the CTG and D/Gs	
	2.14 Containment and Environmental Control Systems				
	23	SGTS Process Fan Capacity Size Down	Acceptable Licensing risk for estimated savings as long as the draw-down analysis is performed in accordance with SRPs and does not introduce any previously unreviewed assumptions.	More than $1M initial cost reduction	
	24	Removal of FCS	Minimal Licensing Risk. Revised Regulation supports removal of recombiners.	More than $1M initial cost reduction	
	2.15 Structures and Servicing Systems				

Category	No.	Title	Licensability	Advantage	Remarks
	25	FCS Room FCUs Elimination	Minimal Licensing Risk	Less than $0.1M initial cost reduction	Incorporated into Tier 1 No.24
	26	R/B Primary Containment Supply Fan and Filter Unit Elimination	Minor Licensing Risk	From $0.1M to $1M initial cost reduction	
	27	T/B HVAC Exhaust System Elimination	Minimal Licensing Risk	More than $1M initial cost reduction	
	28	Technical Support Center Relocation	Necessary Licensing Risk if Bellefonte is to have common Services/Access Building	Enhancement of separation between units	
	3.2 Radiation Protection				
	29	N-16 Concentration	Moderate Licensing Risk, probably worth the >$1M cost reduction	More than $1M initial cost reduction	
Tier 2star	*1.0 Introduction and General Description of Plant*				
	1	Application of a Grouting Joint for Connecting RCCV Main Rebar	Minimal Licensing Risk as long as consistent with applicable ASME Code	Reduction in construction job hours	
	4.0 Reactor				
	2	Application of 10X10 Latest Fuel	Minimal Licensing Risk	Improvement of burn-up capability and core operating flexibility	
Tier 2	*1.0 Introduction and General Description of Plant*				
	1	Common-Use of RW/B and S/B	Minimal Licensing Risk as long as Safety Related and Security Features retain Slide Along Geometry	More than $1M initial cost reduction	
	2	Exciter	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	3	MG-Set Relocation	No Licensing Risk	Optimization of arrangement	
	3.0 Design of Structures, Components, Equipment and Systems				
	4	Penetration Design Method	No Licensing Risk	Less than $0.1M initial cost reduction	
	6.0 Engineered Safety Features				
	5	Change of Material of HPCF Pump Discharge Piping	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	8.0 Electric Power				
	6	Single Failure of Unit Auxiliary Transformers	Minor Licensing Risk	Improvement of robustness at the UAT single failure	
	7	Class 1E 125V DC System and 120V AC Class 1E Vital AC Power Supply System	Minor Licensing Risk, probably worth the >$100K cost reduction	From $0.1M to $1M initial cost reduction	
	9.0 Auxiliary Systems				
	8	Increase in Storage Capacity for Spent Fuel	Potential Licensing Risk. Regulator could be concerned due to increased sabotage risk.	Management of spent fuel becomes more flexible.	
	9	Application of Plate Type FPC Heat Exchanger	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	10	Elimination of One of Two Skimmer Surge Tanks	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	11	Increase in Capacity of RCW Division C Pumps and Heat Exchangers	No Licensing Risk	Less than $0.1M initial cost reduction	
	12	Reduction in RSW Pump Flow Rate	No Licensing Risk	The diameter of the RSW main piping can be reduced.	Incorporated into Tier 2 No.15
	13	Elimination of Redundancy of EDG Cooling Water Outlet Valve	No Licensing Risk	Less than $0.1M initial cost reduction	
	14	Reduction in Diameter of RCW Main Piping	No Licensing Risk	More than $1M initial cost reduction	
	15	Reduction in Diameter of RSW Main Piping	No Licensing Risk	More than $1M initial cost reduction	
	16	Elimination of MOV on RSW Pump Discharge Line	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	17	Elimination of MOV on RSW Pump Return Line	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	18	Change of Type of TCW Heat Exchangers	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	19	T/B HVAC Supply System Recirculation Component Elimination	No Licensing Risk	Less than $0.1M initial cost reduction	
	20	Duration without the Secondary Cooling Water	No Licensing Risk	Less than $0.1M initial cost reduction	
	21	Basis of the Crank Case Negative Pressure	No Licensing Risk	Less than $0.1M initial cost reduction	
	10.0 Steam and Power Conversion System				
	22	Change of Configuration of SJAE, GSC and Off-Gas Condensers in Condensate System	No Licensing Risk	Optimization of arrangement	

Category	No.	Title	Licensability	Advantage	Remarks
	23	Change of Number of MSRs and Stage of Reheat	No Licensing Risk	Increase in net output	
	24	Change of Number and Quantity of Condensate Pumps	No Licensing Risk	Optimization of arrangement	
	25	Change of Number of Heater Drain Tank	No Licensing Risk	Less than $0.1M initial cost reduction	
	26	Change of Type of Intermediate Valve	No Licensing Risk	Increase in net output	
	27	Change of Material of Connection between Low Pressure Turbine Exhaust Hood and Condenser	Minor Licensing Risk	Less than $0.1M initial cost reduction	
	11.0 Radioactive Waste Management				
	28	LCW Demineralizer	No Licensing Risk	Less than $0.1M initial cost reduction	
	29	HCW, HSD Processing System	No Licensing Risk	Improvement of O&M	
	30	Off-Site Laundry	No Licensing Risk	More than $1M initial cost reduction	
	31	Concentrated Waste System	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	32	Off-Gas Recombiner	No Licensing Risk	From $0.1M to $1M initial cost reduction	
	33	Stack Height	No Licensing Risk	More than $1M initial cost reduction	
	34	Solidification System	No Licensing Risk	More than $1M initial cost reduction	
	35	Incineration System	No Licensing Risk	More than $1M initial cost reduction	

Table 3.3-2 Proposed but Withdrawn Enhancements in Task 1-1 Activities

Category	No.	Title	Licensability	Advantage	Remarks
Tier 1	*2.1 Nuclear Steam Supply Systems*				
	1	SRV Capacity	Moderate to High Licensing Risk, will appear to regulator to be a safety margin reduction and variation from Standard Plant	More than $1M initial cost reduction	Moderate to High Licensing Risk, will appear to regulator to be a safety margin reduction and variation from Standard Plant
	2	Simplification of CUW Return Line	Licensing Risk of increased exemptions for Tier 1 changes is not prudent for cost reductions <$100K.	Less than $0.1M initial cost reduction	May cause need to analyze for break in accordance with MEB3-1 May impact thermal stratification, core power distribution
	2.2 Control and Instrument Systems				
	3	ARI	Decrease in reliability is not acceptable.	Less than $0.1M initial cost reduction	Decrease in reliability is not acceptable.
	4	SB&PC	The SB&PC System contained in the Main Turbine EHC System is not a standard in the U.S., so that Licensing Risk is high.	From $0.1M to $1M initial cost reduction	The SB&PC controllers should be separated from the Main Turbine controllers.
	2.4 Core Cooling Systems				
	5	Sharing Motor-Operated Valve on Line from RHR System to FPC System	Licensing Risk of increased exemptions may not be worth the <$100K cost reduction	Less than $0.1M initial cost reduction	Licensing Risk of increased exemptions may not be worth the <$100K cost reduction
	2.11 Station Auxiliary Systems				
	6	Elimination of Motor-Operated Valves on RCW Water Supply to FPC Components	Licensing Risk of increased exemptions for Tier 1 changes is not prudent for cost reductions <$100K.	Less than $0.1M initial cost reduction	The non-safety-related portion should be able to be isolated from the safety-related portion.
	2.12 Station Electric Systems				
	7	EPD System/Parameter Displays in MCR	Licensing Risk of increased exemptions for Tier 1 changes is not prudent for cost reductions <$100K.	Less than $0.1M initial cost reduction	The plant's major feeders need to be monitored by the plant computer system for automatic condition monitoring.
	8	Direct Current Power Supply	Licensing Risk of increased	Enhancement of durability against	Because there is the

Category	No.	Title	Licensability	Advantage	Remarks
			exemptions for Tier 1 changes is not appropriate for unnecessary changes	station blackout	CTG, two hour batteries for all but div 1 are sufficient.
	9	Lighting and Servicing Power Supply	Unacceptable Licensing Risk	From $0.1M to $1M initial cost reduction	The cables should be Class 1E.
	2.14 Containment and Environmental Control Systems				
	10	Flammability Control System	Acceptable Licensing Risk considering magnitude of cost reduction and passive benefits of proposed enhancement.	More than $1M initial cost reduction O&M cost reduction Tech. Spec. relaxation	Superseded by Tier 1 No.24 in Table 3.3-1
	5.0 Site Parameters				
	11	HVAC Ambient Design Temperature Identification	NRC expects 0% excedence for safety-related areas, especially control room.	From $0.1M to $1M initial cost reduction	NRC expects 0% excedence for safety-related areas, especially control room.
	12	The Peak Ground Acceleration for the SSE Considering for Seismic Design	This would absolutely be an NRC licensing concern.	More than $1M initial cost reduction	This would absolutely be an NRC licensing concern.
	13	The SSE Spectra Shape	NRC is not in agreement with the new ASCE Standard.	From $0.1M to $1M initial cost reduction	NRC is not in agreement with the new ASCE Standard.
Tier 2	*6.0 Engineered Safety Features*				
	1	Reduction in Number of Motor Operated Valves in RCIC Test Return Line	Significant Licensing Risk relative to cost reduction due to concern for erosion	Less than $0.1M initial cost reduction	Erosion of the valve is concerned.
	2	Change of Material of HPCF Pump Suction Piping	Significant Licensing Risk relative to cost reduction due to concern for corrosion	From $0.1M to $1M initial cost reduction	Corrosion of the piping by oxygen diffused from the CST is concerned.
	3	Reduction in Number of Motor Operated Valves in HPCF Test Return Line	Significant Licensing Risk relative to cost reduction due to concern for erosion	Less than $0.1M initial cost reduction	Erosion of the valve is concerned.
	4	SGTS Charcoal Adsorber	Unacceptable Licensing Risk	More than $1M initial cost reduction	Elimination of the adsorber is not acceptable.
	7.0 Instrumentation and Control Systems				
	5	Protection of RAM Information from a System Power Failure	Licensing Risk of increased deviations may not be worth the <$100K cost reduction	Less than $0.1M initial cost reduction	The information in memory device should be kept by the redundant system at the system power failure.
	6	Elimination of PCS's VDUs at the Local Room	Licensing Risk of increased deviations may not be worth the <$100K cost reduction	Less than $0.1M initial cost reduction	The Technical Support Center, Emergency Operation Facility and other office require the PCS's VDUs.
	7	Elimination of Providing Control Command and Guidance	No Licensing Risk	From $0.1M to $1M initial cost reduction	This function is preferable for the utilities.
	8.0 Electric Power				
	8	Class 1E 125V DC System	Licensing Risk of increased departures may not be worth the <$100K cost reduction	Less than $0.1M initial cost reduction	Licensing Risk of increased departures may not be worth the <$100K cost reduction
	9	Physical Identification of Associated Lighting Circuits and Associated FMCRD Circuits	Not worth Licensing Risk	From $0.1M to $1M initial cost reduction	It should be designated which safety division supplies power to the FMCRD.
	10	Physical Identification of Neutron-Monitoring and Scram Solenoid Cables	Licensing Risk of increased departures may not be worth the <$100K cost reduction	Less than $0.1M initial cost reduction	The neutron-monitoring cables and the scram solenoid cables should be distinguished.
	9.0 Auxiliary Systems				
	11	Change of Material of FPC Buried Piping	No Licensing Risk	From $0.1M to $1M initial cost reduction	From the viewpoint of O&M, stainless steel is recommended.
	12	Elimination of Potable Water Injection Lines to RSW System	Licensing Risk of increased deviations may not be worth the <$100K cost reduction	Less than $0.1M initial cost reduction	According to Tier 1 No. , the RSW system is normally on standby and the potable water

Category	No.	Title	Licensability	Advantage	Remarks
					injection is preferable to prevent water from being stagnant.
	10.0 Steam and Power Conversion System				
	13	Change of Configuration of Reactor Feedwater Pumps	No Licensing Risk	Increase electrical output	The latest ASD has higher efficiency than a turbine as a driver of a pump.
	11.0 Radioactive Waste Management				
	14	Charcoal Adsorbers	Not worth Licensing Risk	Reduction in number of the adsorbers	Not Worth Licensing Risk
	15	Off-Gas Vacuum Units	Not a cost reduction, not worth Licensing Risk	Reduction in number of the adsorbers	Not a cost reduction, not worth Licensing Risk
	16	Average Annual Noble Radio gas Source Term	Licensing Risk of increased departures may not be worth the <$1M cost reduction	From $0.1M to $1M initial cost reduction	Licensing Risk of increased departures may not be worth the <$1M cost reduction
	18.0 Human Factors Engineering				
	17	Elimination of Control of Non-Safety System by Plant Process Computer	No Licensing Risk	Less than $0.1M initial cost reduction	This is a matter of definition of the Process Computer.

3.4 LICENSABILITY EVALUATION

One of the advantages of the Bellefonte ABWR Project in leading a nuclear renaissance is that it would be building a plant based on an existing pre-certified design under the U.S. NRC's 10CFR Part 52. The ABWR received Final Design Approval in 1996 and Design Certification in 1997. Thus, it is eligible for one step licensing.

As explained in the prior sections, the opportunity was taken at the beginning of the Bellefonte Cost and Schedule Study in Task 1 to consider design enhancements that would reduce the construction cost for the plant. Each of these potential design enhancements was compared to the ABWR Design Control Document (DCD) to determine its impact on the Part 52 licensing process.

The following paragraphs describe the Licensability Evaluation that was performed as part of the study. The Licensability Evaluation consisted of 1) a comparison of the proposed design enhancements to the DCD, 2) the identification of impacts on the DCD, 3) comparison against regulations, and 4) the evaluation of licensing risk.

3.4.1 Comparison of the Proposed Design Enhancements to the DCD

Each proposed design enhancement was compared against the DCD by writing a design description of the enhancement and searching the DCD for the sections that described equipment performing similar functions. Enhancement sheets for Task1 in Appendix G document the design enhancements and the DCD descriptions for the original equipment performing similar functions.

3.4.2 Identification of Impacts on the DCD

Also provided in enhancement sheets is a listing of the DCD subsections which contain text that would need to be modified to describe the proposed design enhancement. The design enhancements are also subdivided into three groups: those that impact Tier 1 of the DCD, those that impact Tier 2, and those that impact Tier 2*.

3.4.3 Comparison against Regulations

Each proposed design enhancement was compared to U.S. NRC Regulations (i.e. 10CFR) and assigned to one of three categories: 1) consistent with current U.S. regulations, 2) consistent with regulatory changes after design certification or 3) inconsistent with current U.S. regulations. No design enhancements were recommended for adoption for the Bellefonte Project that were in the third category, inconsistent with current U.S. Regulations.

3.4.4 Evaluation of Licensing Risk

Each proposed Design Enhancement was evaluated for the risk it would present towards obtaining Bellefonte's Combined License under 10CFR Part 52. Of course, the lowest licensing risk would result from proposing no changes from the DCD. However, with the experience of constructing both the Hamaoka Unit-5 project (the third ABWR in the world) and the Lungmen Project (the first ABWR based on U.S. certified design), it has become apparent that there are some design details in the DCD that will need to be changed in order to have a feasible design. Thus, knowing that there will be changes to the DCD for constructing an ABWR in the U.S. it becomes reasonable to ask what other changes should be considered to make the design more cost effective without substantially increasing the licensing risk.

The first step in evaluating the licensing risk of each proposed design enhancement was to categorize if the design change impacted Tier 1, Tier 2 or Tier 2* of the DCD.

3.4.4.1 Tier 1 information

Tier 1 means the portion of the design-related information contained in the generic DCD that is approved and certified by Part 52 Appendix A (hereinafter Tier 1 information). The design descriptions, interface requirements, and site parameters are derived from Tier 2 information. Tier 1 information includes:

- Definitions and general provisions;
- Design descriptions;
- Inspections, tests, analyses, and acceptance criteria (ITAAC);
- Significant site parameters; and
- Significant interface requirements.

3.4.4.2 Tier 2 information

Tier 2 means the portion of the design-related information contained in the generic DCD that is approved but not certified by Part 52 Appendix A (hereinafter Tier 2 information). Compliance with Tier 2 is required, but generic changes to and plant-specific departures from Tier 2 are governed by Section VIII of Appendix A. Compliance with Tier 2 provides one accepted method for complying with Tier 1. Compliance methods differing from Tier 2 must satisfy the change process in Section VIII of Appendix A. Regardless of these differences, an applicant or licensee must meet the requirement in Section III.B to reference Tier 2 when referencing Tier 1. Tier 2 information includes:

1. Information required by 10 CFR 52.47, with the exception of generic technical specifications and conceptual design information;

2. Information required for a final safety analysis report under 10 CFR 50.34;

3. Supporting information on the inspections, tests, and analyses that will be performed to demonstrate that the acceptance criteria in the ITAAC have been met; and

4. Combined license (COL) action items (COL license information), which identify certain matters that shall be addressed in the site-specific portion of the final safety analysis report (FSAR) by an applicant who references Part 52 Appendix A. These items constitute information requirements but are not the only acceptable set of information in the FSAR. An applicant may depart from or omit these items, provided that the departure or omission is identified and justified in the FSAR. After issuance of a construction permit or COL, these items are not requirements for the licensee unless such items are restated in the FSAR.

3.4.4.3 Tier 2* information

Tier 2* means the portion of the Tier 2 information, designated as such in the generic DCD, which is subject to the change process in VIII.B.6 of Appendix A. This designation expires for some Tier 2* information under VIII.B.6.

3.4.4.4 Changes to Tier 1, Tier 2 and Tier 2* information

Changes to Tier 1 information are the most sensitive and require the Commission's Exemption to the Certification. An applicant or licensee who references a standard design certification may request an exemption from one or more elements of the design certification Tier 1 information. The Commission may grant such a request only if it determines that the exemption will comply with the requirements of 10 CFR 50.12(a). In addition to the factors listed in § 50.12(a), the Commission shall consider whether the special circumstances which § 50.12(a)(2) requires to be present outweigh any decrease in safety that may result from the reduction in standardization caused by the exemption. The granting of an exemption on request of an applicant must be subject to litigation in the same manner as other issues in the operating license or combined license hearing.

An applicant or licensee who references this appendix may depart from Tier 2 information, without prior NRC approval, unless the proposed departure involves a change to or departure from Tier 1 information, Tier 2* information, or the technical specifications, or involves an unreviewed safety question as defined in paragraphs B.5.b and B.5.c of Part 52 Appendix A. When evaluating the proposed departure, an applicant or licensee shall consider all matters described in the plant-specific DCD.

A licensee who references this appendix may not depart from the following Tier 2* matters without prior U.S. NRC approval. A request for a departure will be treated as a request for a license amendment under 10 CFR 50.90.

- Fuel burnup limit (4.2).
- Fuel design evaluation (4.2.3).
- Fuel licensing acceptance criteria (Appendix 4B).

3.4.4.5 Licensing risk for Tier 1 changes

Since the Bellefonte Project may be the first plant to be licensed under Part 52, no precedent or yardstick exists to quantitatively measure the licensing risk for changes to Tier 1 information. Since Tier 1 changes are exemptions to the certification and have to be approved by the Commission, it is difficult to judge if the Commission will approve alternative design detailing as long as there is no decrease in safety, or if they will want to adhere strictly to the certified design in order to achieve design standardization. In order to provide a relative ranking of the licensing risks for the Tier 1 changes, they have been evaluated assuming the former.

However, since every Tier 1 change will require an exemption, they should not be pursued lightly. The licensing risk evaluation for each design enhancement proposal that has a cost reduction in the neighborhood of $100K indicates that the change should only be considered in light of its addition to the licensing risk and its relatively minor cost reduction. A relatively liberal screening process has been applied for the Tier 1 changes in order to provide the customer with the maximum possible cost reduction opportunities from which the final selections will be made. The results of the licensing risk evaluations for the Tier 1 changes are provided in Table 3.3-1.

3.4.4.6 Licensing risk for Tier 2 changes

Changes to Tier 2 information are much less sensitive than Tier 1 changes. They do not require prior U.S. NRC approval unless the change impacts the technical specifications, or involves an unreviewed safety question. Note that items identified as Tier 2 changes have been determined to not impact Tier 1. Thus, the licensing risk evaluations for Tier 2 items provided in Table 3.3-1 primarily conclude that there is no licensing risk or there is minor licensing risk.

3.4.4.7 Licensing risk for Tier 2* changes

There are only two Design Enhancement proposals that fall in the Tier 2* category. Their licensing risk evaluations are presented in Table 3.3-1. The first Tier 2* change is for the use of the current NRC approved 10X10 fuel design rather than the 8X8 fuel design being used when the DCD was submitted. This design enhancement is considered to have minimal licensing risk since it meets the Tier 2* criteria described above in Section 3.4.4.4. The other Tier 2* enhancement is for the application of a grouting joint for connecting the RCCV main rebar. This item is considered to be a minimal licensing risk as long as it is consistent with the currently applicable ASME Code. It is probably worth pursuing considering the minimal licensing risk since it will reduce the construction job hours for connecting RCCV main rebar.

3.4.4.8 Results of Licensing Risk Review

As a result of applying the above Licensing Risk Review process and other considerations, the total list of 96 potential design enhancements was screened down to 66 design enhancements that are being adopted for the Bellefonte Project. The adopted design enhancements have been drawn from past plant experience and are proven technologies. They are evolutionary improvements and do not change system functionality. Examples of these proven technologies are application of the Appendix K rule change for 1.7% power uprate, the seal-less Fine Motion Control Rod Drives, reduction in Reactor Internal Pump Adjustable Speed Drives, and the compact Reactor Core Isolation Cooling Turbine Pump. In order to reduce any adverse impact on the licensing schedule, including consideration of their cumulative effect, all of the adopted design enhancements will be pre-reviewed with the U.S. NRC prior to extensive work on the COL Application. Any items which appear to present an unwarranted risk to the Bellefonte licensing schedule may be deleted.

3.5 RESULT OF EVALUATION OF PLANT CONCEPT

Based on the result of the enhancement study in Sec. 3.3, a plant concept for the Bellefonte ABWR has been developed as follows.

3.5.1 Electric Power

The thermal output of the first ABWR, Kashiwazaki-Kariwa Unit -6/ -7 is 3926MW and the net electrical output is approx. 1310 MW. As described in Sec. 3.3, the Appendix-K uprate is adopted, which results in a 1.7% increase of thermal output to 3992MW.

In addition, the electric output is evaluated using site specific conditions at Bellefonte, including an average condenser cooling water temperature of 23.2 degree C and the existing cooling tower. Also, better turbine efficiency is taken into account for optimization. The net electric output is concluded to be 1371 MW per unit.

Figure 3.5-1 illustrates the key turbine system with major specifications. In principle, the turbine system adopted in the study is approximately the same as the one in the DCD.

In order to reduce costs, the following items were evaluated to increase electric power output.

System Type	Reheat / Regenerative
Main Turbine Type	TC-6F / 52-inch Last Stage Blade
Condenser Type	3 Shells / Single Pass / Multi Pressure
Stages of Reheat	Double Stages*1
Stages of Regeneration	Six Stages
Heater Drain System	HP Drain - Pumping up LP Drain - Cascade
Main RFP Driver Type	Motor
Heat Sink Condenser Cooling System	Cooling Towers (NDCT+MDCT)

DCD Spec. (Tier2)

*1: Single Stage

NDCT : Natural Draft Cooling Tower

MDCT : Mechanical Draft Cooling Tower

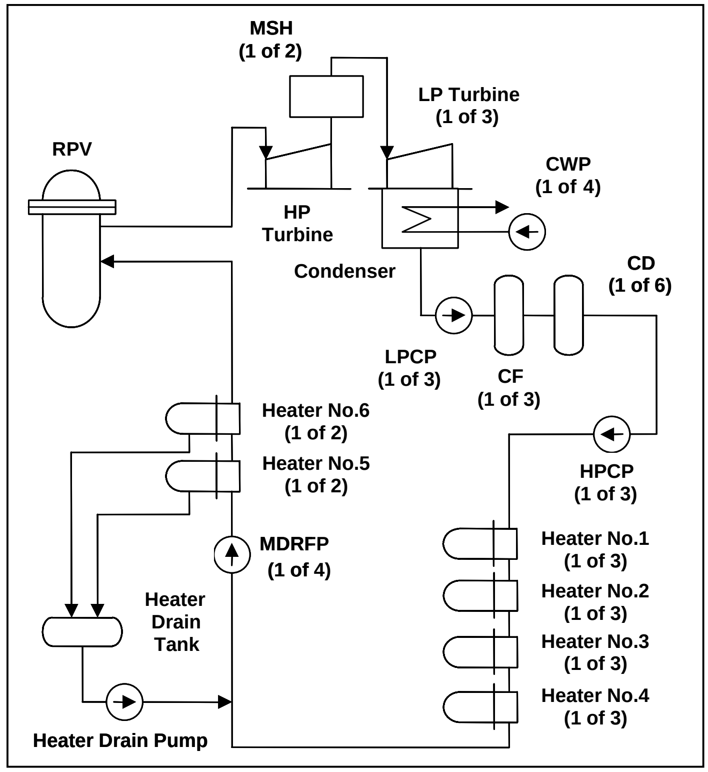


Figure 3.5-1 Turbine System Major Specification

- Increase of thermal power output through ultrasonic feed water measurement system
- Higher efficiency turbine
- Optimization of cooling system

The result of the electric power uprate evaluation is summarized in Figure 3.5-2. The latest technologies which achieve higher efficiency turbines are summarized in Figure 3.5-3, and the evaluation result of net electric power output is in Table 3.5-1. As a result, Bellefonte's gross output is determined to be 1438MW, and its net output is 1371MW, which is 4% higher than the first ABWR. .

This 1.7% increase in electric power output enhances the cost competitiveness of the Bellefonte ABWR in a $/kW evaluation.

3.5.2 Major Plant Concept

Based on the result of the enhancement study in Section 3.3, a plant concept of the Bellefonte ABWR was developed.

This plant concept was optimized for the Bellefonte ABWR based on the Bellefonte site specific conditions and by adopting advanced technologies. Furthermore this plant

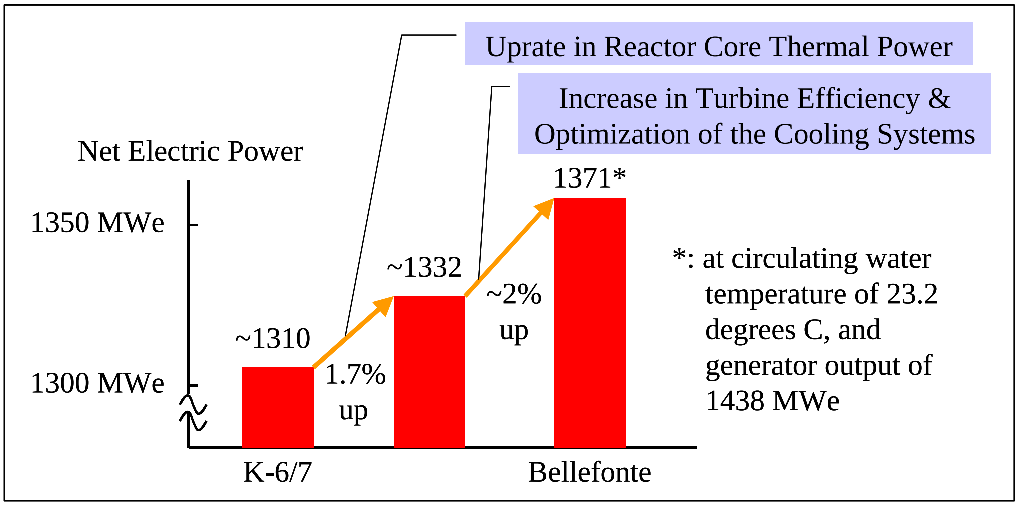


Figure 3.5-2 Electric Power Increase Evaluation

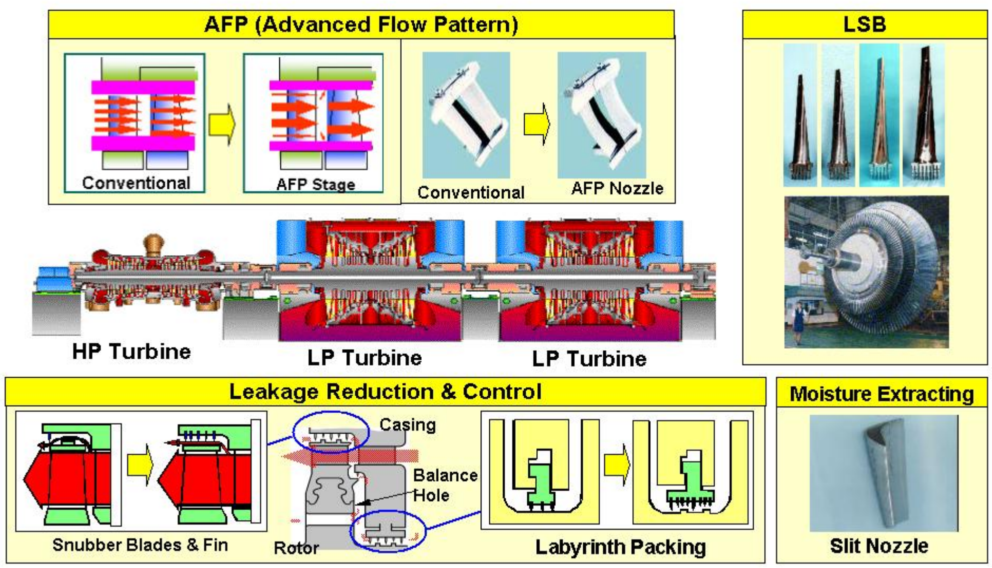


Figure 3.5-3 Latest Technologies for Higher Efficiency Turbine

Table 3.5-1 Electrical Power Output

Item	Power
Thermal power	3,992MWt
Electric power*	
- Generator output(Gross)	1,438MWe
- Service loads	67MWe
- Net electric output	1,371MWe

*: at circulating water temperature of 23.2 degrees C

concept has been reviewed in the licensability evaluation in Section 3.4. This optimized concept significantly enhances the cost competitiveness of the Bellefonte ABWR.

3.5.2.1 Major technologies for Bellefonte ABWR plant concept

Table 3.5-2 shows the major specifications of the Bellefonte ABWR plant, with comparisons to the ABWR DCD and Japanese ABWR. This table identifies the major plant concept with deviation items from ABWR DCD as discussed in Section 3.3. The major differences for the Bellefonte ABWR specification from the ABWR DCD are the 1.7% Appendix- K uprate, the Seal-less FMCRD, common use of RIP-ASDs, compact RCIC turbine-pump, SGTS fan capacity downsize, new cooling system concept, FCS elimination, and the turbine system. Toshiba developed Seal-less FMCRD and common use of RIP-ASDs and applied them to Hanaoka 5, and GE applied compact RCIC turbine-pump to Lungmen. The major differences between Bellefonte ABWR specifications and Japanese ABWR are the 1.7% Appendix-K uprate, compact RCIC turbine-pump, the new concept of the cooling system and FCS elimination.

Figure 3.5-4 shows the heat balance for the Bellefonte nuclear island including the Appendix-K 1.7% uprate.

(1) Seal-less FMCRD

Current FMCRD has ground packing, but the Seal-less FMCRD has a closed RPV boundary by using a magnetic coupling instead of ground packing. The benefits of "Seal-less FMCRD" are initial cost reduction by using induction motors instead of stepping motors, and lower radiation exposure by the elimination of both penetrations and related systems, for example, scram discharge system and leakage detection system. The changes achieve the O&M cost reduction.

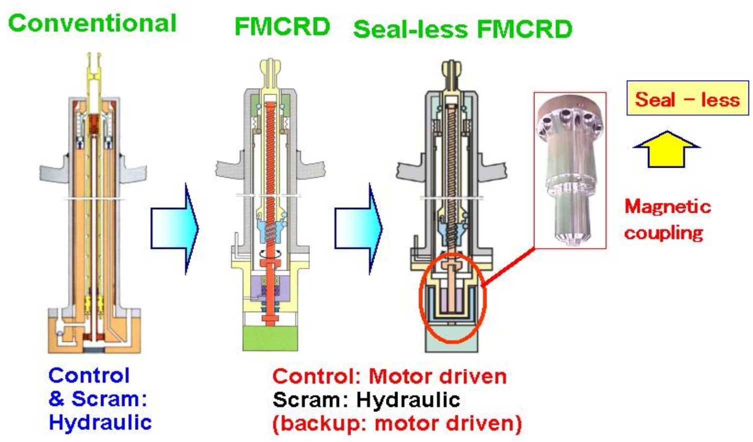


Figure 3.5-5 Feature of Seal-less FMCRD

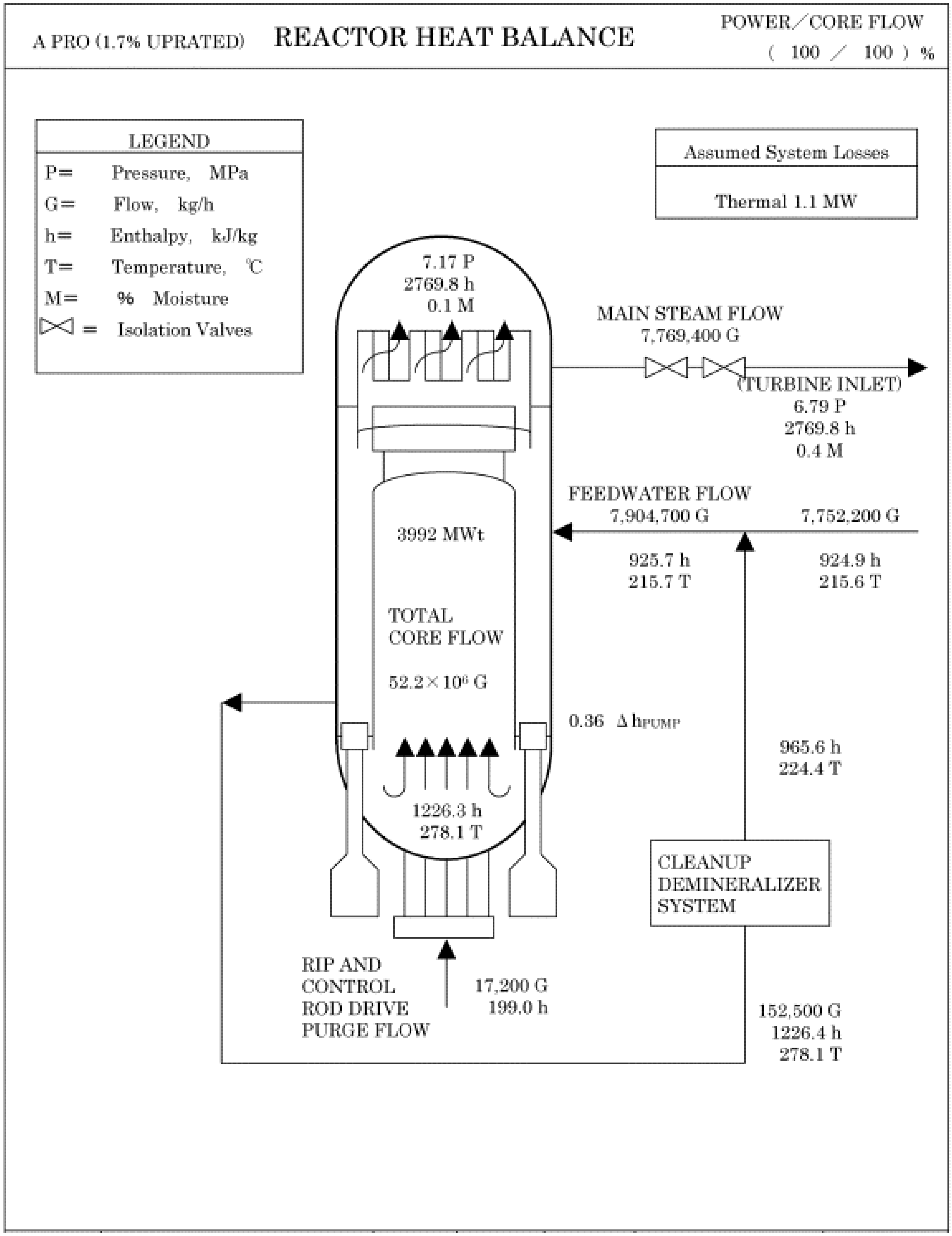


Figure 3.5-4 Reactor Heat Balance at Rated Power

(2) Common use of RIP ASD

"Common use" is defined as one ASD drives 2 or 3 RIPs and in total, 4 ASDs drive 10 RIPs (See Figure 3.5-6. The number of ASDs is reduced from 10 to 4). The benefits of "common use" are initial cost reduction and consistency with the current safety analysis. Driving multiple drives with one ASD is a proven technology. TOSHIBA verified its adequacy in the RIP power supply application in its test facility. Four larger ASD drives are capable of maintaining the transient response characteristics (thermal margin at the transient) equivalent to 10 smaller traditional ASD drives, without changing the 4 bus composition described in the ABWR DCD.

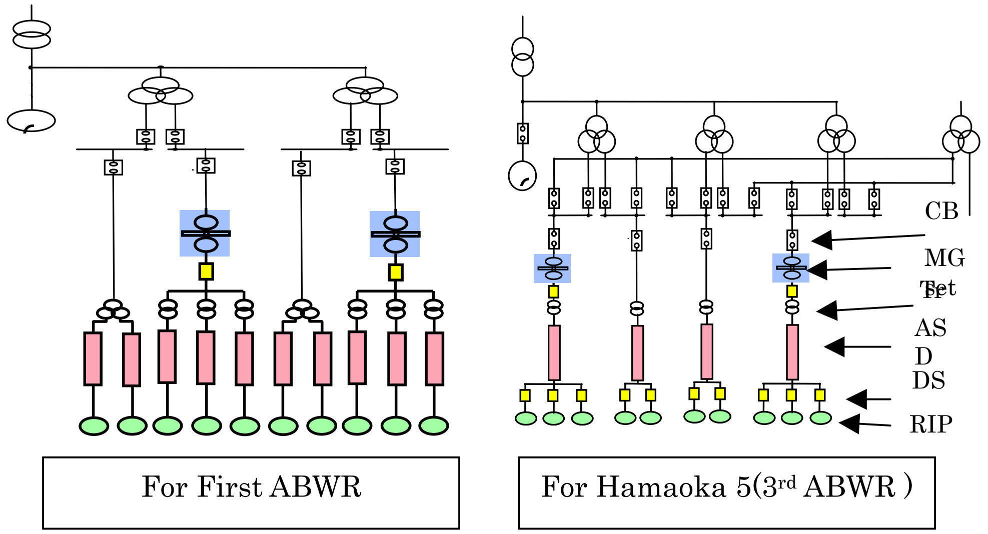


Figure 3.5-6 Simplified Configuration of RIP ASDs

(3) Compact RCIC turbine-pump

"The Compact RCIC turbine-pump" is defined as a single casing composed of both pump and turbine. The benefits of the "compact RCIC turbine-pump" are installation space reduction because there is no need for both a barometric condenser and oil lubrication system and the improved start feature by the mechanical speed governor.

Figure 3.5-7 The RCIC Turbine-pump for Lungmen

(4) New Cooling System Concept

The new concept of the cooling system configuration leaves the safety related functions of the water systems essentially unchanged, but reduces maintenance and eases surveillance testing by having the systems normally off. Additionally, since the systems are no longer required for power generation, only one service and one cooling water pump per division is required. Finally, the addition of a non safety related closed cooling water system to provide water to the non safety loads originally cooled by the safety systems allows for higher capacity fuel pool cooling (the RHR system can still provide backup cooling). The larger FPC system and normally off status of the safety systems allows for shorter outages by allowing both refueling and surveillance activities to be scheduled separately and optimally. This concept saves O&M cost

3.5.2.2 System description

Figure 3.5-8 shows a system outline for the Bellefonte ABWR. The major differences of the Bellefonte plant concept shown in the figure from the ABWR DCD and Japanese ABWR are the elimination of the FCS (consistent with new U.S. NRC regulations; see Appendix G), new cooling system concept, updated turbine system and simplified radioactive waste treatment system reflecting the latest U.S. conditions.

Descriptions of each system are attached as Appendix A, system flow diagrams of each system are attached as Appendix B, control block diagram of each system are attached as Appendix C, and the general arrangement drawings are attached as Appendix D.

3.5.2.3 Electrical and I&C system

Figure 3.5-9 shows the Bellefonte main single line diagram. The dual structure high voltage bus configuration is adopted, in addition to the conventional 6.9kV line. A 13.8kV line is added, which is different from the ABWR DCD and Japanese ABWR.

The detail single line diagram is attached as Appendix-E.

Table 3.5-2 Major Specifications of the ABWR

Item	Bellefonte ABWR	ABWR DCD	Japanese ABWR
Electric Power(net)	1371 MWe	~1400 Mwe gross	~1310 MWe
Reactor Thermal Power	3992 MWt	3926 MWt	3926 MWt
Reactor Dome Pressure	7.17 MPaA	7.171 MPaA	7.17 MPaA
Main Steam Flow	7769 t/h	7641 t/h	7640 t/h
Feedwater Temperature	215.6 degrees C	215.6 degrees C	215.6 degrees C
Rated Core Flow	52,200 t/h	52,200 t/h	52,200 t/h
Number of Fuel Bundles	872	872	872
Number of Control Rods	205	205	205
Active Fuel Length	3810 mm (Tentative)	-	3708 mm
Average Power Density	50.1 kW/l(Tentative)	50.6 kW/l	50.6 kW/l
RPV Inner Diameter	7.1m	7.112m	7.1m
RPV Height	21m	-	21m
Recirculation System	Reactor Internal Pump (10)	Reactor Internal Pump (10)	Reactor Internal Pump (10)
CRD (Normal/Scram)	Electric/Hydraulic	Electric/Hydraulic	Electric/Hydraulic
ECCS	3 Division	3 Division	3 Division
PCV	Reinforced Concrete Containment Vessel with Steel Liner (RCCV)	Reinforced Concrete Containment Vessel with Steel Liner (RCCV)	Reinforced Concrete Containment Vessel with Steel Liner (RCCV)
Turbine	TC6F-52" (2 Stages Reheat)	TC6F-52" (1 Stage Reheat)	TC6F-52" (2 Stages Reheat)
Reactor Feedwater Pump	Motor-Driven	Motor-Driven	Turbine-Driven (Standby: Motor-Driven)
Heater Drain Pump-Up System	High-Pressure Heater Only	High-Pressure Heater Only	Both High-Pressure Heater and Low-Pressure Heater
Power Cycle Heat Sink	Cooling Towers	Cooling Tower (Reference Only)	Sea

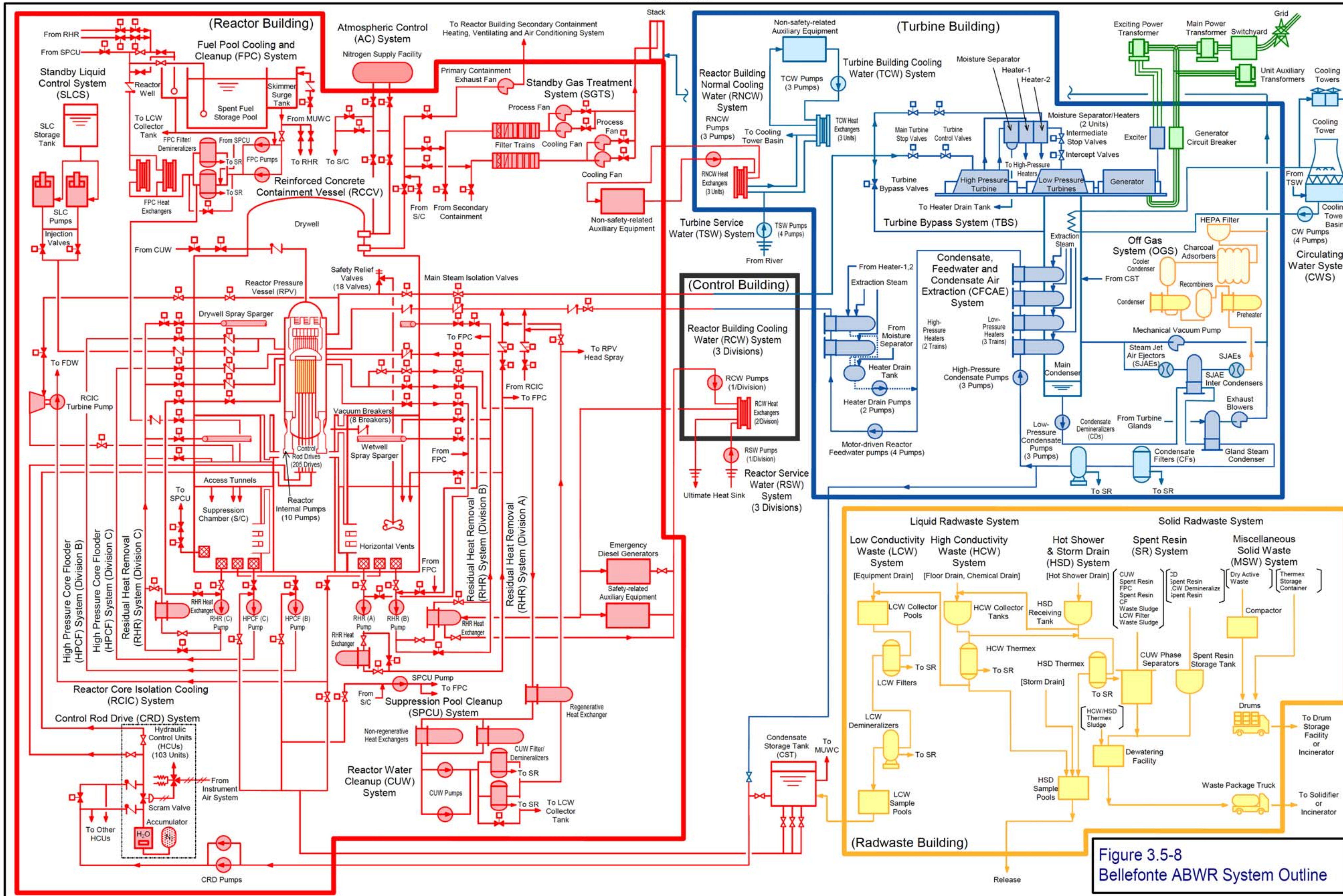


Figure 3.5-8
Bellefonte ABWR System Outline

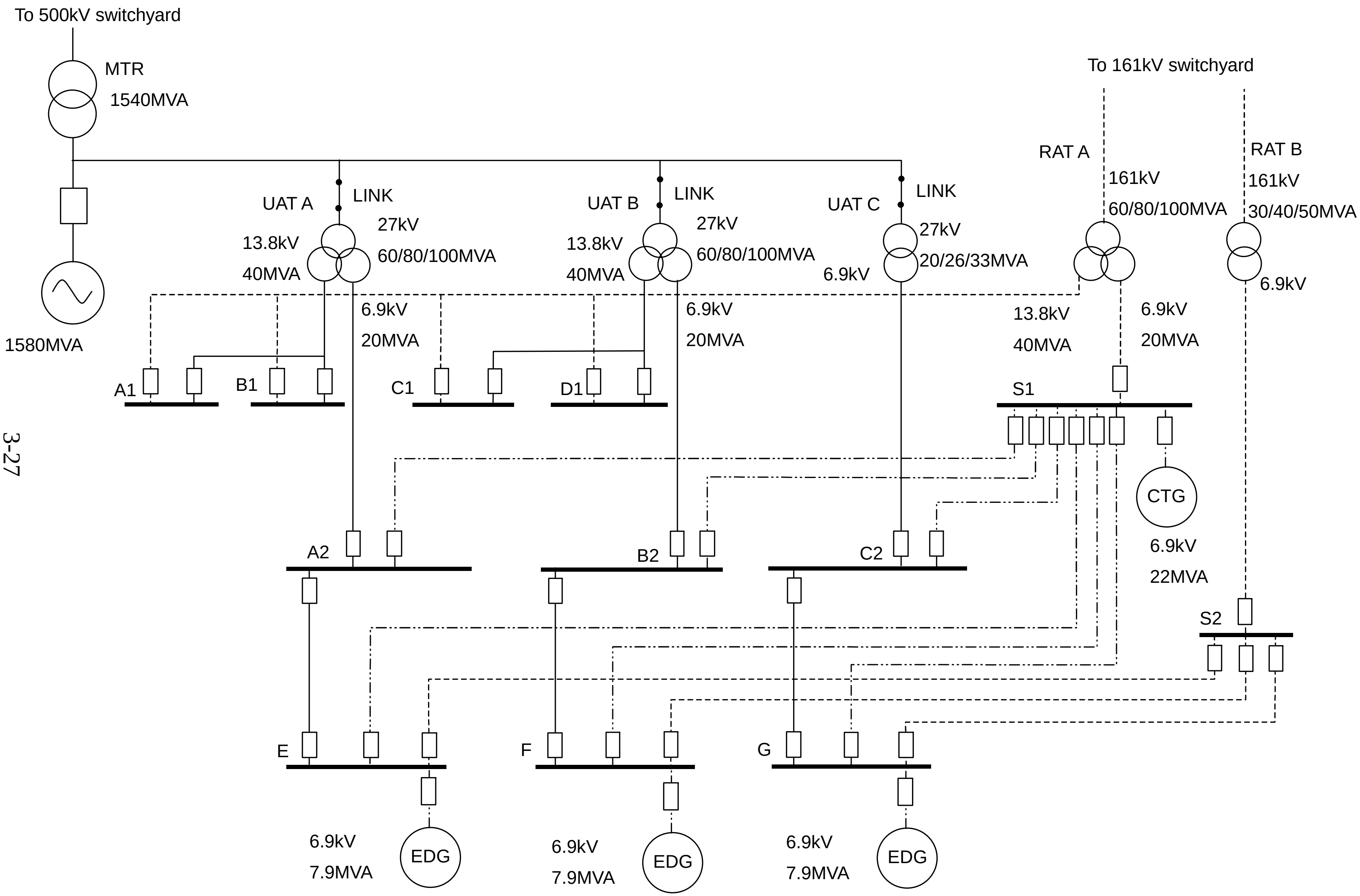


Figure 3.5-9 Bellefonte ABWR Electrical System

3.6 RESULT OF EVALUATION OF YARD FACILITIES

Yard facilities, other than the power block, are basically site specific systems and facilities. A site specific yard facility design and evaluation were done by Bechtel based on the Bellefonte site survey and required conditions provided by TVA and Toshiba.

3.6.1 Existing Bellefonte Facilities

During the development of the yard system design, the existing Bellefonte systems were integrated into the design where feasible. Use of the Bellefonte site affords the use of the 2 existing hyperbolic cooling towers, intake structure on the Tennessee River, switchyard, auxiliary boiler, and various miscellaneous non-power block type buildings.

3.6.2 Yard Systems / Facilities

The yard systems and facilities for the 2 Unit ABWR study included:

- Diesel fuel oil
- Combustion turbine fuel oil
- Auxiliary boiler piping
- Discharge monitoring and sampling
- Fire protection facility and system for entire site
- Service gas (N_2, H_2, CO_2, and O_2)
- Potable water
- Condensate system and building
- Cooling tower chemical feed system and building
- Yard facility HVAC
- Demineralized water
- Reactor service water system, building, and UHS – spray pond
- Circulating water system and building
- Raw water system and building
- River water system
- Wastewater system
- Service building

3.6.3 Engineering Process

Yard conceptual engineering was based on design inputs from the power block (primarily the nuclear island) and applied the ABWR Design Control Document and other nuclear industry design standards and / or regulations.

Appendices-A, B, D and E contain the System Descriptions, System Flow Diagrams, General arrangement, Single line diagram.

3.6.4 Design Enhancements

During the yard systems study, two items were identified as potential design enhancements for cost reduction. Relocating the Service Building from above the safety-related reactor service water piping would result in classifying this building as non-seismic. Instead of placing the reactor service water piping in a concrete trench it is proposed to direct bury this piping with a minimum of 6 feet of earthen cover for tornado missile protection.

Therefore, the cost estimate is based on a non-seismic type service building and directly burying the RSW piping.

3.7 Plot Plan and Building Design

The plot plan is basically site specific and designed by Toshiba and Bechtel based on the Bellefonte site survey result and power block system and building design. Each power block building design was started from the ABWR DCD design and developed applying the latest technologies.

Extra attention was paid to the design of the Turbine Building (T/B), Radwaste Building (RW/B) and Services Building (S/B) in the study in order to minimize cost. Whereas the design of the Reactor Building and Control Building are specified in detail in the ABWR DCD, the DCD allows more flexibility in the design of the T/B, RW/B and S/B. As the result of additional study which considered construction and operation experience in the U.S. and the site specific conditions, significant reduction in the bills of quantities from the BQ originally based on the Japanese ABWR construction experience were identified.

The site plot plan drawing and general arrangements drawings of each building are shown in Appendix-D

3.7.1 Site Plot Plan

The plot plan for the Bellefonte ABWR has been developed to include yard facilities which are not part of the ABWR DCD. The Bellefonte site includes the partially completed PWR, and the plot plan was structured with the policy of maximum use of the existing facilities for ABWR construction. The existing facilities to be reused are selected from the results of a former ABWR team site survey. Toshiba reported the result of site survey in "ABWR Project Site Survey Report (A10-9801-0001. Rev.0, dated Sep 30, 2002)" in Pre-Award Task. Table 3.2-1 is the Total Facility List for all plant facilities including Yard Facilities. In the Total Facility List, the existing facilities and new facilities are clearly distinguished.

Figure 3.7-1 shows the plot plan and Figure 3.7-2 shows the 3D image of the plot plan of the Bellefonte ABWR. As the existing cooling towers will be utilized, the twin units of the ABWR would be constructed at the south side of the cooling towers. The geographical configuration of R/B, C/B and T/B is designed as a "I" Shape, as in the ABWR DCD. The RW/B and S/B would be for common use between Unit-1 and Unit-2.

3.7.2 Reactor Building and Control Building

The Reactor building and control building design was based on the ABWR DCD design and developed by reflecting latest technologies.

3.7.3 Turbine Building

The Turbine building design was based on the ABWR DCD design and developed by reflecting the Japanese first ABWR design and adopting up-to-date turbine technologies.

The shielding and structure designs of the Grand Gulf turbine building, whose seismic condition was almost the same as the Bellefonte site, were applied to the turbine building in which the ABWR turbine equipment is arranged. In the shielding design, since the high radiation equipment was concentrated on the circumference of the main condensers, the shielding wall was changed so that equipment might be surrounded collectively, minimizing the amount of shielding concrete. In the superstructure design, since steel frame and concrete slab was applied on a basemat of reinforced concrete for the main structure of the building, minimization of the amount of concrete and steel in the structure was attained.

By applying U.S. practices, a significant reduction of the civil BQ for the Bellefonte ABWR turbine building was obtained from the previous BQ based on the construction experience of ABWR turbine building in Japan. Results of the turbine building optimization study are shown on Figure 3.7-3 and Table 3.7-1. Concrete volume of the turbine building excluding the turbine pedestal was reduced to 65% of the original design, and structural steel was reduced to 56%. This result is dependent on a turbine building that is not overly restricted by seismic conditions and a civil design based on the DCD.

3.7.4 Radwaste Building

The building design for the radioactive waste treatment system was based on the ABWR DCD design and developed reflecting the latest U.S. conditions and Japanese technology.

Instead of using the system and equipment described in the ABWR DCD Tier2, the following changes were applied to reduce the building size and obtain a significant reduction in the amount of concrete.

1) Application of a reverse osmosis system utilized at Browns Ferry NPS instead of an evaporation system

2) Elimination of the solidification facility by applying direct shipment of spent resin

and concentrated waste water as done at Browns Ferry NPS

3) Application of a lined type pool for radwaste water storage as used in Japanese radwaste facilities instead of vertical cylindrical tanks

Results of optimizing the radwaste building are shown on Figure 3.7-4 and Table 3.7-2. The radwaste building volume and concrete volume were reduced to 1/3 of the original design based on the DCD.

3.7.5 Service Building

Since the service building structure was changed from reinforced concrete to simple steel frame and siding based on the U.S. standard design, a significant reduction in the amount of concrete was obtained.

3.8 CONCLUSION

GE developed the ABWR DCD based on the plant concept of the first ABWR in Japan, with some modification including countermeasures for severe accidents added in order to gain certification by the NRC. The basic plant concept for the Bellefonte ABWR was developed based on the DCD as applied for Lungmen and FOAKE.

The advanced technologies described in this chapter were adopted from successive ABWR units under construction or in operation in Japan and GE's continuing development activities and schedule study and become part of the plant concept. All proposed enhancements for Bellefonte were reviewed for licensability.

In the next Chapter, the construction schedule and construction cost of this basic plant concept is evaluated.

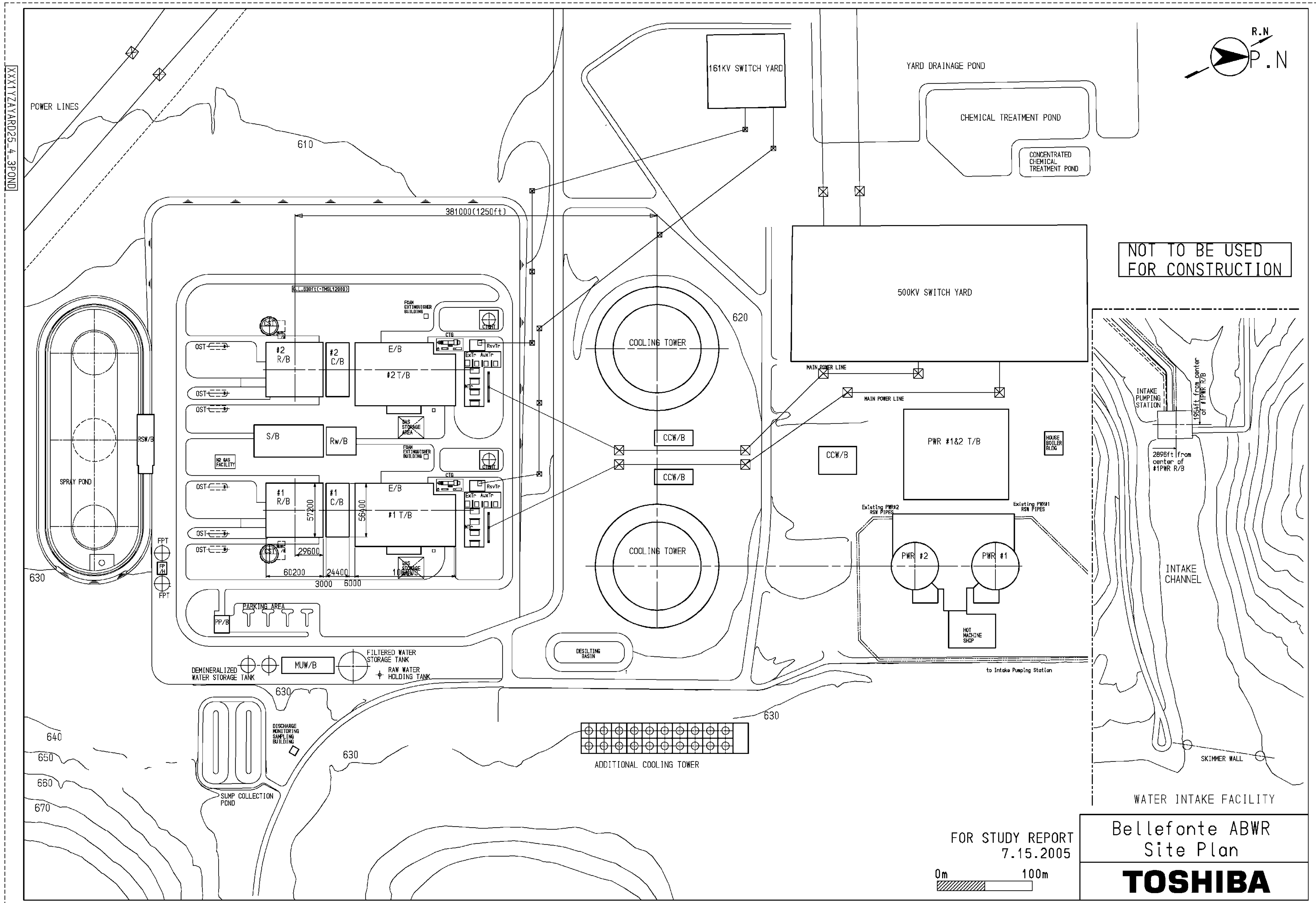


Figure 3.7-1 Preliminary Plot Plan for Bellefonte ABWR

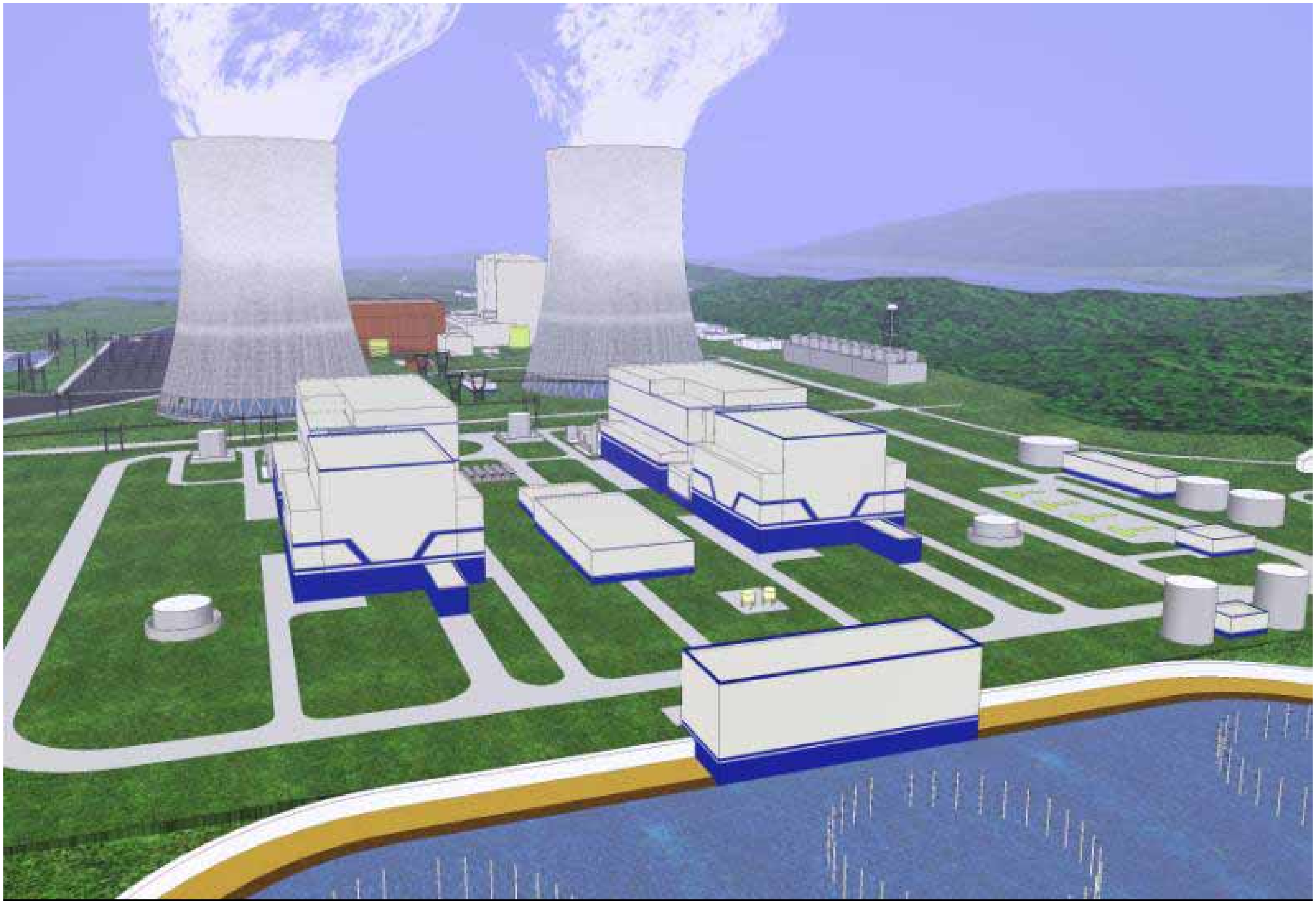
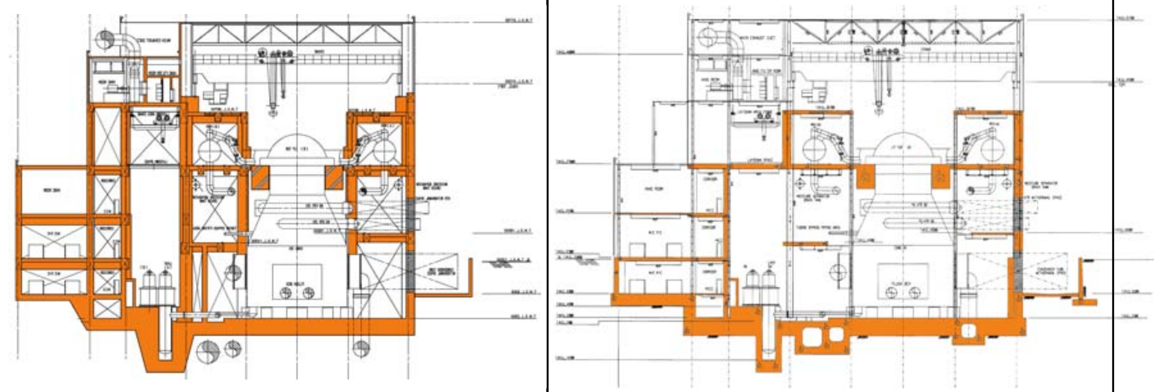


Figure 3.7-2 Preliminary 3D Plot Plan Image for Bellefonte ABWR

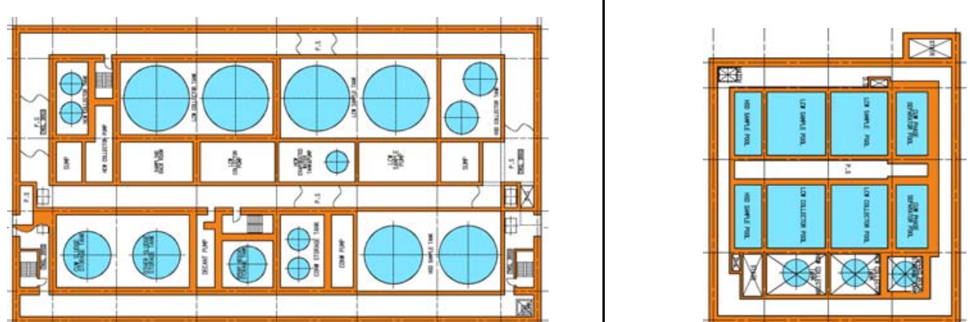


Original Bellefonte | Revised Bellefonte

Figure 3.7-3 Result of Optimization of Turbine Building

Table 3.7-1 Result of Optimization of Turbine Building

Type	Original Bellefonte Proposal	Revised Bellefonte Proposal
Arch-design concept	Full concrete for seismic wall	Steel structure and concrete for shielding
Seismic condition	0.24G (KK-site in JPN)	0.18G
Building volume	795,000 cy/twin	795,000 cy/twin
Concrete quantity except for pedestal	189,000 cy/twin (100%)	122,000 cy/twin (65%)
Steel structure	20,000 TN/twin (100%)	11,200 TN/twin (56%)



Original Bellefonte | Revised Bellefonte

Figure 3.7-4 Result of Optimization of Radwaste Building

Table 3.7-2 Result of Optimization of Radwaste Building

Type	Original Bellefonte Proposal	Revised Bellefonte Proposal
Arch-design concept	Full concrete for seismic wall	Steel structure and concrete for shielding
System	Conventional as shown in U.S. DCD	Simplified considering latest U.S. condition
Storage tanks	Vertical cylindrical tanks, same as U.S. DCD	Lined type pools based on Japanese RW experience
Building volume	82,200 cy/twin (100%)	26,700 cy/twin (33%)
Concrete quantity	32,200 cy/twin (100%)	10,200 cy/twin (32%)

4.0. COST AND SCHEDULE

4.1. CONSTRUCTION SCHEDULE

4.1.1 Overall Construction Schedule Summary

The construction schedule is based on the ABWR construction and startup schedule logics provided by Toshiba and the modularization and the "Open Top" method of construction defined by Toshiba (refer to 4.1.2 Construction concepts). Starting with this basis, the construction schedule has been evaluated and adjusted to estimated quantities, man-hours and installation durations.

With an extensive review of past construction projects and new improvements, techniques and methods, Toshiba developed a construction duration for Bellefonte from the first reactor building concrete pouring to fuel loading of 40 months. A Level 2 construction schedule has been developed using floor-by-floor and building-by building approach assuming use of these new construction methods and the bulk material quantities.

GE also has independently developed a construction schedule for Bellefonte of 40 months.

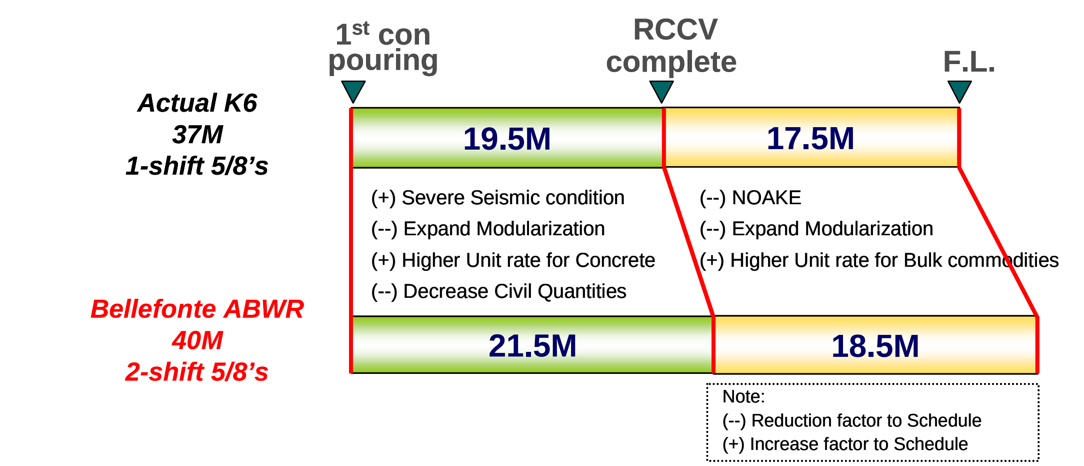
The 40-month schedule is an aggressive schedule as compared to the past construction schedule achieved in the U.S., however the following advantages, which are applicable to the Bellefonte ABWR, make it achievable:

- Design completed, assumed no regulatory "late" changes
- 3-D model in place to minimize interferences
- Design is optimized based on the several ABWR projects completed.
- Enhanced Modularization to meet the projects critical paths
- Bulk materials and equipment in place on the floor prior to placing the ceiling. (Open top construction)
- Schedule logics are optimized based on the ABWR projects completed.
- All materials available as needed to support the construction sequence.
- Use of state of the art construction tools, equipment and methods
- Working full back shift for the entire duration

Prior to the start of Reactor Building Concrete, thirteen (13) months of site preparation, including a significant amount of blasted and excavated rock, is required. Additionally, the Turbine base mat concrete starts 4 months before the start of the reactor building concrete work. Following the fuel loading, seven (7) months of Power Ascension testing, is scheduled to achieve the full power operation. For this study, the lag time between the units is 12 months.

The 40-month schedule is based on two shifts working 5 days per week (Monday - Friday) 8 hours per shift and alternate Saturdays plus 5% unscheduled overtime resulting in an average workweek of 46 hours.

The work schedule in rolling 4/10's "4 days at 10 hours" provides a 70-hour workweek as compared to the 46-hours above. Therefore, if Rolling 4/10's is applied to the site, the construction schedule will be shortened. However, it is necessary to consider the availability of craftsmen needed to support the Rolling 4/10's (refer to Section 4.1.4). In order to minimize the construction costs, the 40-month construction schedule was determined based on 5/8'. Overall project economics (saving by a shorter construction schedule and penalties by increasing craft labor costs) must be reviewed separately. Figure 4.1-1 shows the result of the schedule evaluation study.



Work Schedule

1-shift 5/8's:

One shift working 5 days per week (Monday-Friday) 8 hours per shift and alternate Saturdays resulting in an average workweek of 44 hours

2-shift 5/8's:

Two shifts (60% day-shift &40% night-shift) working 5 days per week (Monday-Friday) 8 hours per shift and alternate Saturdays plus 5 % unscheduled overtime resulting in an average workweek of 46 hours

Figure 4.1-1 Construction Schedule Evaluation Results

4.1.2 Construction Concepts

It has been more than 32 years since the last commercial nuclear reactor was ordered in the United States. In the same period, 32 commercial nuclear power plants (16 BWRs, 13

PWRs and 3 ABWRs) were ordered and built in Japan. In addition, 2 plants are currently being constructed in Japan. Due to the continuous experience in constructing nuclear power plants in Japan, significant advancements/improvements were achieved over the last thirty years while executing each construction processes. Such achievements include Modularization, Preassembly, automation /advanced technologies and Open top construction. The proposed ABWR construction concept is comprised of these advances/improvements, which will facilitate and streamline the construction process.

Reference: Appendix H, ABWR CONSTRUCTION PLAN.

4.1.2.1 Construction concepts

The basic ABWR construction concepts minimize the fieldwork and increase the productivity at the jobsite, which will maximize the potential savings of construction costs and schedule. Toshiba is confident that the following principal construction methods will achieve this goal. Figure 4.1-2 illustrates the application of the principal construction methods to the ABWR.

- Modularization
- Open-top construction
- Composite steel-concrete structure for buildings
- Large-sized crane
- 3DCAD for construction

(1) Modularization

These modularization principles are applied to the ABWR construction:

- Large-sized modules of critical path components shorten the installation duration as well as reduce the field installation work
- Modules of bulk commodities reduce the field installation work and shorten critical paths

Large-sized modules are applied to the components which may be on the critical path of the construction schedule such as the RCCV (Reinforced Concrete Containment Vessel), the Reactor Internals, and the Condensers in the Turbine building.

The RCCV modules are composite modules comprised of RCCV liners and rebar, which will be the maximum weight modules with approximately 1,000 tons per each module. The Reactor Internals are assembled into the RPV as much as possible at the off-site shop. Core plate, Shroud, RIP casings, RIP guide rails and HPCF sparger couplings are

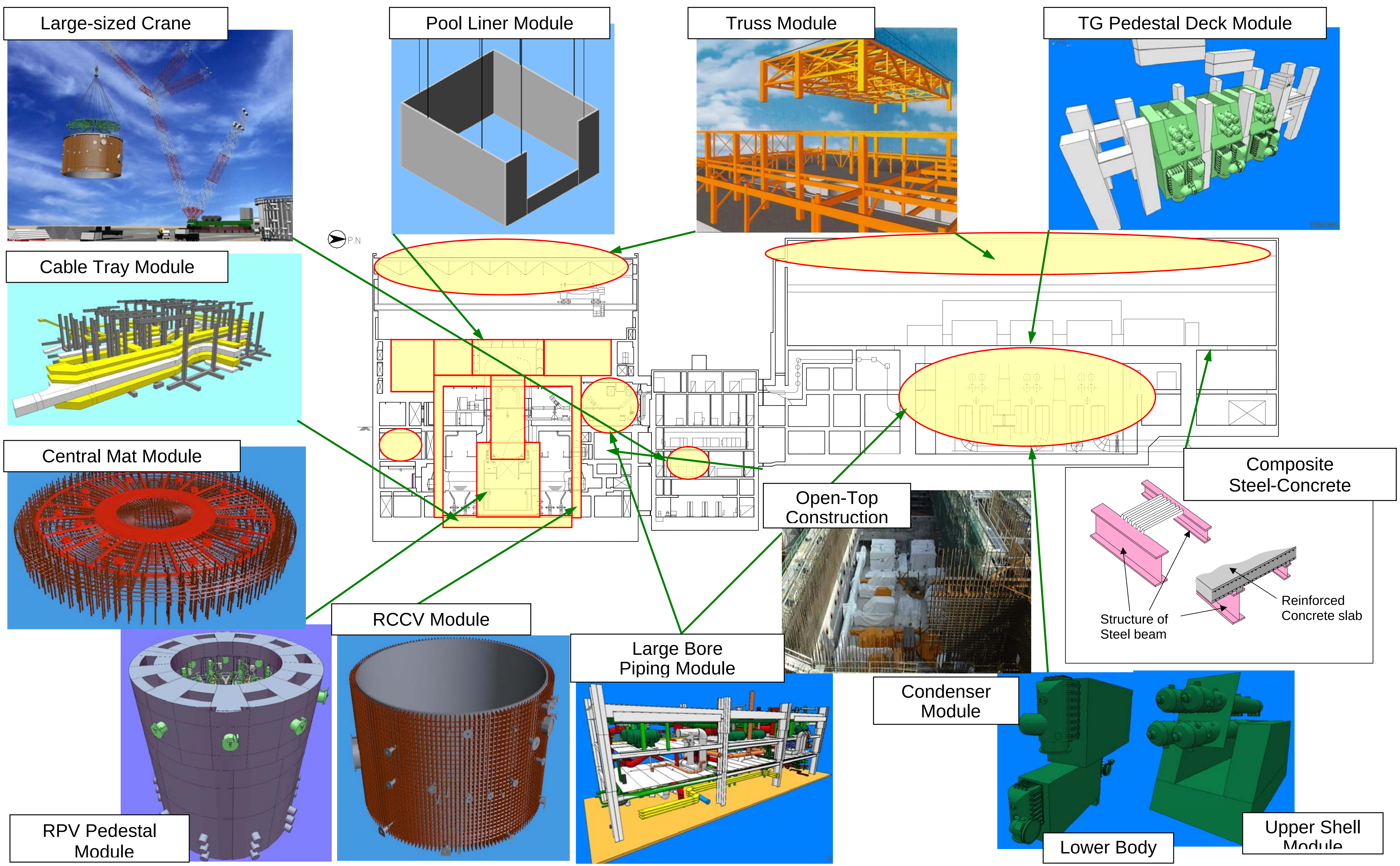


Figure 4.1-2 Principal Construction Method for ABWR

assembled into the RPV. Dryer, Steam separator and Top guide plate are fitted-up at the off-site shop to facilitate the installation at the jobsite.

The modularization of Bulk commodities into self-supporting, free-standing modules can significantly reduce the site population of the craft labor. Since the Bellefonte site is located at the bank of a navigable waterway, it is ideal to maximize the use of off-site modularization. However, when determining the extent and scope of modularization, the bulk commodities modules need to be carefully reviewed to achieve the proper balance between advantages and disadvantages of modularization. The advantages and disadvantages of modularization are as follows:

(a) Advantages

- Reduced Schedule (If Module is applied to Critical Path (CP))
- Reduced Field Work and Levelized On-site Manpower
- Increased Productivity and Quality under Factory Environment
- Increased Safety and efficiency at Ground Level Work
- Reusability of Module Engineering to the Nth Plants

(b) Disadvantages

- Increased Engineering for Modules
- Increased Temporary Support Steels
- Early Material Requirements
- Additional Transportation Costs (Large trailer truck, Barge)
- Increased Lifting/Rigging Requirements (Crane, Lifting Jig)

There are three levels of modularization; Prefabrication, Preassembly and Module, which are defined as follows:

- Prefabrication

  Joined materials to form a component part of a final installation

- Preassembly

  Joined components parts to create a sub unit

- Module

  Assembly of sub units to create an installation unit or assembly

The ABWR adopts prefabrication, preassembly and modules for bulk commodities in an optimized approach with the consideration of the advantages and the disadvantages as above. Figure 4.1-3 shows the different levels of modularization. For instance in the power block, 16% of prefabricated large bore piping can be preassembled and 14% can be modularized.

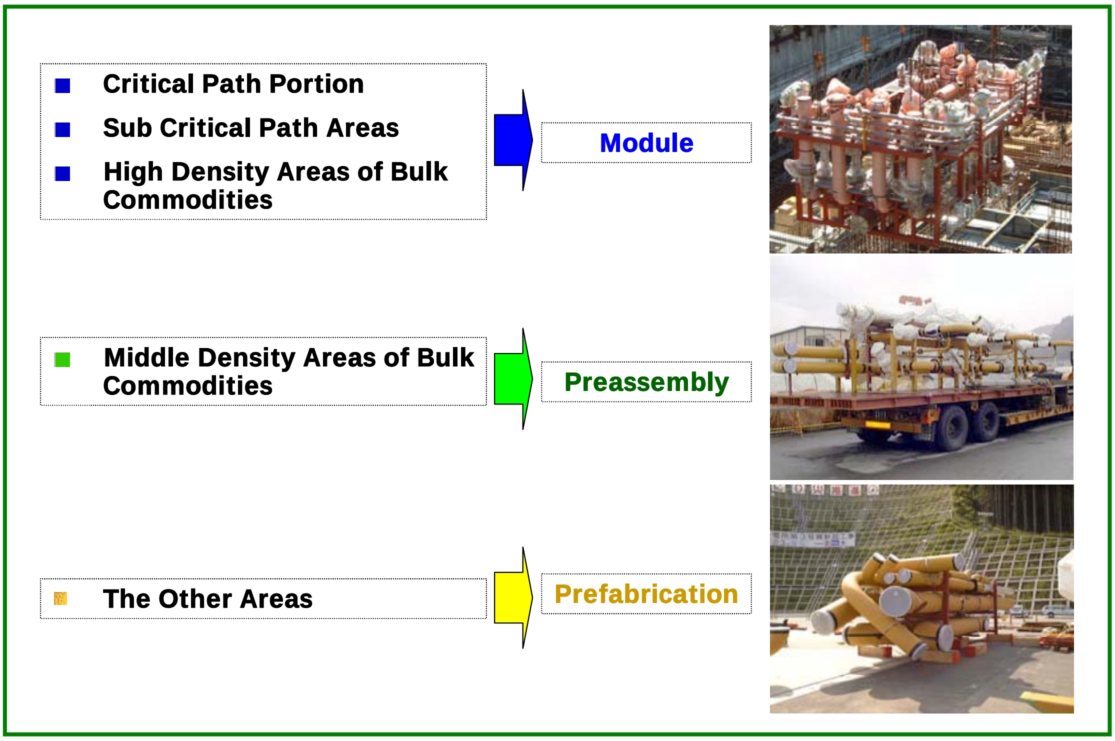


Figure 4.1-3 Modularization Levels

(2) Open-top construction

Open top construction is a construction/erection technique that involves integrating the construction of the building walls/slabs with the modules, equipment/mechanical and electrical commodities installation. The commodities are designed, procured and constructed with equipment and materials being installed in and/or loaded into their final installation spaces and elevations before those areas are fully enclosed by higher elevation slabs. In some cases even surrounding walls are not erected until the equipment is set (especially true when large-sized modules are utilized). When properly used this technique incorporates many of the advantages of modularization and pre-assembly to speed the construction process and reduce construction labor cost.

The Open top construction reduces temporary openings, which are utilized to carry in bulk commodities after the construction of the buildings in the conventional method.

(3) Composite steel-concrete structure for buildings

Composite steel-concrete structures consist of steel beams integrally joined to the concrete slab by shear connectors. This eliminates the time associated with placing rebar and formwork for the concrete beam. The composite steel structure supports the concrete pouring load without shoring slabs below, which eliminates the time associated with assembling/disassembling shores under the slab. The composite steel-concrete structure can be applied to all ABWR structures.

(4) Large-sized crane

The large-sized equipment of the ABWR such as the RPV, Condensers, the MSRs (Moisture Separator Reheater) are lifted "over the top" of the building (Open top construction) to avoid interfering with the building construction. The RCCV shell module will be approximately 1,000 ton in weight which is the critical load for the construction of the ABWR. The large-sized crane needs to have the capacity to lift the large equipment and modules into the building by the Open top construction method.

(5) 3D CAD for construction

Modularization requires more engineering for module design and also requires earlier engineering for bulk commodities which will be assembled into modules. The 3D CAD model is utilized to determine the scope and the boundary of each module with input from design engineers and construction engineers.

The Open top construction requires careful detailed planning to effectively coordinate the required simultaneous work activities of the civil/structural trades with the installation work being performed by the mechanical and electrical trades. Moreover, after the area is enclosed by higher elevation slabs, installation sequence and integrated construction schedule requirements with equipment, piping, HVAC ducts, electrical and instrumental commodities should be planned in detail to avoid conflicting between installation activities. The interactive installation simulation 3D CAD system linked to Time, Resource and Quantities (6D system) will be helpful to study the sequence and construction schedule. The site construction staff, superintendents, engineers, general foremen, foremen and crafts/labors can also possess common understanding of the construction sequence and schedule through the 6D system.

(6) Safety

Both Toshiba and Bechtel recognize the importance of a safety program intended to achieve zero accidents. Implementation of this program results in lower costs to the project through lower compensation premiums and lost productivity due to the accidents. A strong safety program is a prerequisite and essential to maintain the overall project schedule. (Refer to Appendix- Q5)

4.1.2.2 Yard construction plan

The organization of the construction yard facilities will be an important part in the success of erecting an ABWR NPP. It is suggested that all construction facilities be completed within a period of 13 months prior to erection of the plant in parallel with the site excavation of roads, parking areas, lay down areas, and the containment/auxiliary building footprint excavation. Completing these activities early will reduce the craft manpower needs to support both site facility erection and permanent plant facility erection at the same time. The project should realize increased schedule production by having these activities completed and not interfering with scheduled erection of permanent plant commodities.

The following construction facilities will be required to support non-manual site offices; safety functions on site, manual craft facilities for change and lunch rooms, fabrication facilities for all commodities required for on site fabrication as in piping, rebar, miscellaneous structural steel, welding, etc., as well as material warehousing facilities and modular assembly areas. Appendix I is provided to illustrate the location and area requirements for each of the construction site facilities for the yard construction plan.

Facilities considered in yard construction

- Material lay down areas
- Temporary underground utilities
  - Drainage
  - Power
  - Water
  - Communications
- Perimeter security fence
- Site road and heavy haul access areas
- Field construction offices
- Construction parking
- Construction warehouse
- Guard and time alley locations
- Concrete batch plant
- Testing facilities
- Safety and first aid facilities
- Fabrication shops
  - Carpenter
  - Piping
  - Electrical
  - Concrete formwork

  - Rebar
  - Bulk storage areas for gas, air, fuels, etc.
- Cable reel and cut yard
- Excavation spoils area
- Maintenance shops
- Modular site assembly platforms

Refer to Appendix J for an expanded discussion of the yard construction plan.

4.1.2.3 Differences of construction practices between U.S. and Japan

The construction of a power plant is performed with multiple and simultaneous installation activities. For example, civil installation is a sequence of rebar, embeds, forms and placing concrete. Piping is installed with a sequence of erect, line-up, tack weld and production weld. The first ABWR K-6 achieved the construction duration of 37 months from the 1st concrete to the fuel loading in Japan. The basic process to install components, such as civil, piping and electrical, would be the same between the U.S. and Japan. However, if there are any differences of construction practices in installation activities, even minor ones, the cost and schedule may be affected by the accumulation of the differences. US A/E companies and Toshiba made efforts to identify the differences of construction practices by means of reviewing construction photos, videos and discussing standard installation documents.

Some different practices were identified, but significant differences which may affect the cost and schedule were not found as a result of review and discussion.

The identified differences are shown in Appendix K. The more significant of these differences are as follows:

(1) Working-hours

Bechtel and Toshiba compared their typical daily schedule breakdown for an eight-hour work shift each other.

- A typical US 8 1/2 hour work day consists of 7 hours and 5 minutes of production work plus 55 minutes for stretching at beginning of shift, safety discussion, morning/afternoon breaks, and a 30 minute lunch period.
- A typical Japanese 9 hour work day consists of 6 hours and 45 minutes of production work plus 1 hour and 15 minutes for stretching at beginning of shift, safety discussion, morning/afternoon breaks, and a 60 minute lunch period.

(2) Inspection witness

- In the U.S., unless specific regulations require independent testing (apart in time and space), testing is done once with all pertinent parties involved.
- In Japan, inspections which are required to be witnessed by the government (METI: Ministry of Economy, Trade and Industry) are performed twice, with the Owner and the government separately.

(3) Direct hire/ Subcontracting

- Bechtel typically will direct hire 75% to 90% of the site manual workforce. The balance of the workforce will be by specialty subcontractors.
- Toshiba typically performs the work using almost 100% subcontractors.

(4) Scaffolding

- Scaffolds typically will be installed only in certain areas based on accessibility in the U.S. The electric power scissor lift is used in lieu of a scaffold whenever possible. All scaffolds are erected and inspected per safety requirements.
- In Japan, system scaffolds are used during the civil phase that are erected on both sides of the wall construction and are erected under the ceiling. In the Mechanical and Electrical phase of construction, tube and clamp scaffolds are generally used. All scaffolds are erected and inspected per safety requirements.

4.1.3 Project Schedule Assessment and Critical Path Analysis

4.1.3.1 Construction schedule evaluation

The construction schedule was evaluated by Toshiba in 2 stages.

First, Bechtel developed the construction schedule based on the quantities information provided by Toshiba and quantities information for the yard facilities developed by Bechtel. Bechtel reviewed with Toshiba the construction improvements, techniques and methods learned from recent Japan experience as well as any potential improvement from the past construction experience in the U.S. Bechtel provided to Toshiba a 44-month schedule duration from the first Reactor Building Concrete pouring to Fuel Loading.

Reference: Appendix Q, BECHTEL EVALUATION REPORT

At the second stage, Toshiba reviewed Bechtel's input and independently developed a more aggressive schedule to be achieved at the Bellefonte site. The review and evaluation by Toshiba is based on the input by Bechtel and the additional information supplied by other US A/E companies. Other information sources have been also investigated. These additional studies were also combined and verified with by Toshiba achievements in Japan. Toshiba concluded that the most optimum construction schedule achievable at the Bellefonte site should be 40-months from the first reactor building concrete pour to fuel loading. GE reviewed the construction schedule developed by Toshiba and also concluded that the 40-month schedule can be achieved at the Bellefonte site.

Toshiba schedule evaluation is as follows.

(1) Toshiba's review of Bechtel's evaluation

The actual schedule achieved in the construction of the FOAKE ABWR, K-6 in Japan was 37 months. Toshiba reviewed comprehensive aspects relating to the historical installation rates and the construction schedules in both Japan and the U.S. to identify the factors which make the Bellefonte schedule longer than those Toshiba experienced. Toshiba also performed the Visualized Work Process Analysis with multiple A/E companies in order to understand the differences of the construction schedule.

The critical path of Bechtel's 44-month schedule runs through the reactor building concrete structure, into the RB bulk commodities installations (Piping, Electrical) and then the reactor systems preoperational testing to fuel loading. What Toshiba has experienced in Japan is that the critical path does not run through the RB bulk commodities installations but Reactor internals (RIN) installation. The RB bulk commodities installations are shifted into the critical path because of higher unit rates and lower sustained rates.

(2) Historical construction schedules

Figure 4.1-4 below shows the actual construction duration of several BWRs (units over 800MWe) built in the U.S. and Japan respectively. Duration is measured from the 1st structural concrete pouring to fuel loading in the U.S., and is measured from the bedrock inspection of the reactor building to fuel loading in Japan. Though a few months adjustment may be necessary due to the differences in the duration definition, the construction duration in each country shows an opposite trend. The construction duration has increased significantly in the U.S. after the TMI incident. On the other hand, the duration has been decreasing steadily in Japan.

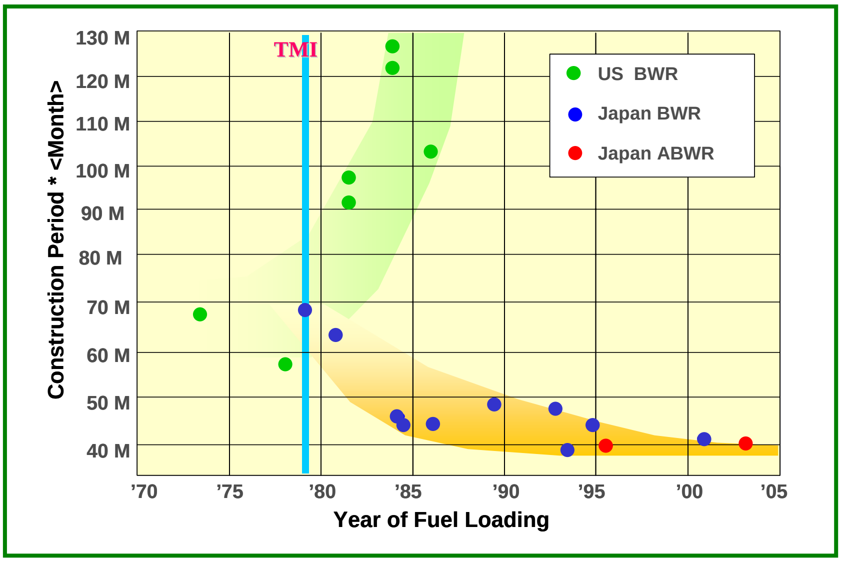


Figure 4.1-4. Trends in the Construction Duration in US and Japan

The Bellefonte ABWR can assume a lot of the construction advantages described in Section 4.1.2.1 which NPPs did not have in the past, with few of the construction uncertainties which have delayed the NPPs construction schedule.

(3) Historical installation rates

Toshiba and Bechtel discussed the historical unit rates, sustained rates and specific ABWR unit rates for commodities.

(a) Sustained rate

Figure 4.1-5 shows a trend of the structural concrete sustained rate in Japan as compared to the U.S.

The actual sustained rates per unit are plotted as a function of the year of fuel loading. The range of the sustained rate in Japan from 1970 to 1980 is 3,000 to 6,000 CY/month, which is similar to the range of sustained rates of the plants constructed in the U.S. However, in Japan, the sustained rate of structural concrete increased dramatically after 1980. The sustained rates have been improved to the range of 8,000 to 12,000 CY/month.

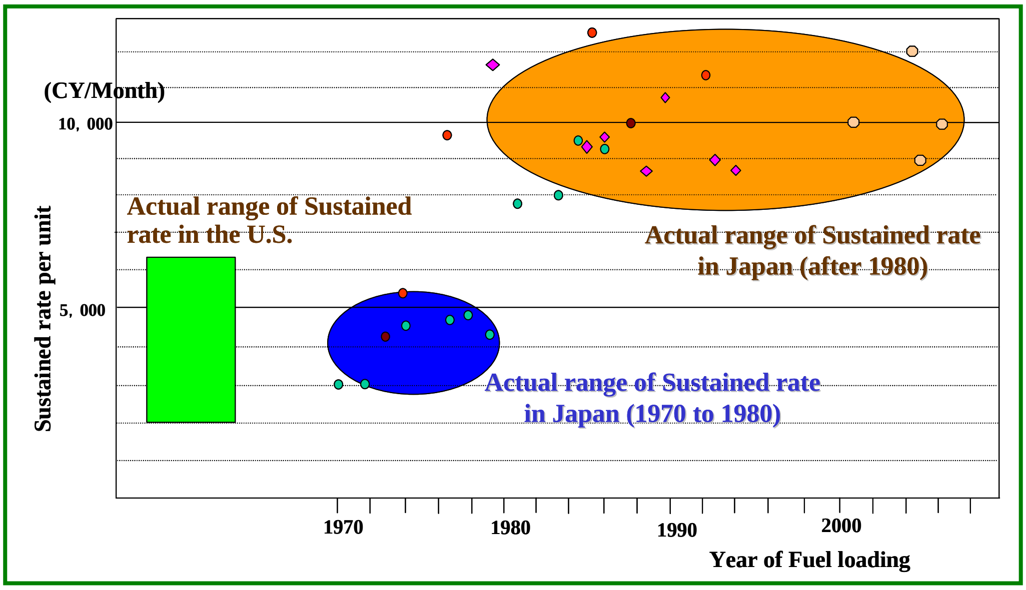


Figure 4.1-5 Actual Sustained Rate of Structural Concrete in Japan

Toshiba determined the reasons for the improvement of the sustained rates as follow

- Improvement of Construction equipment

  More efficient construction equipment was developed with larger capabilities, such as tower cranes, concrete batch plants, and concrete placement equipment.

- Large-sized crane

Large sized cranes were applied to install the large blocks of the containment vessel and/or the RPV. The large block method was also introduced to the civil work by using the large-sized cranes which were used for lifting larger assembled rebar blocks, metal deck blocks, assembled scaffold blocks.

- Metal decking method

The Open-top construction method for placing equipment and piping prior to placing higher slabs was applied. The metal deck method was also applied to install ceilings to reduce activities of supporting (shoring) ceilings, curing concrete, and disassembling the forms.

- Request for the short construction duration

Utility owners requested shorter construction schedules to save costs. The construction equipment and crafts/labors were mobilized to support a shorter construction schedule, which increased the sustained rate as a result. The 40-month schedule was evaluated based on the logics and the quantities provided by Toshiba for the Bellefonte ABWR. The resulting sustained installation rates are calculated according to the developed schedule. As an example, the sustained rate for concrete installation is 7,000 cy for unit one and common. The historical single unit nuclear experience is in the range of 3,000 to 6,000 cy per month as shown in Figure 4.1-5. The ABWBR rates were found to be higher than those previously achieved to date. However, the ABWR rates are evaluated to be achievable based on the following items:

i) Use of modularization; modularization is applied to the massive rebar area, where the concrete installation will be the critical path. Such modules are the R/B base mat module, the RCCV module, and the TG pedestal deck module. These modules are shown in Appendix H.

ii) Use of composite steel-concrete structure to the R/B, the C/B as well as the T/B, which eliminates the time associated with placing rebar and formwork for the concrete beam Design being completed prior to the start of construction allowing for the detailed preplanning of the activities

iii) Materials (like prefabricated rebar, structural steel) delivered to the site to support the construction process

Actual experience for the plant K-6 and K-7 in Japan have achieved sustained installation for concrete in excess of 10,000 cy per month. (The sustained rate curves in Appendix Q are based on unit 1, unit 2, and common facilities combined.)

(b) Unit rate

The required construction manpower at the jobsite has been steadily decreasing in Japan. The unit rates for piping and cable installation in Japan have a similar trend as the total manpower curve.

Reference: Appendix L, CONSTRUCTION MANPOWER TREND IN JAPAN

The piping unit rate in Japan was improved by:

- Increasing prefabrication, preassembly and modularization

  Pipes, fittings and valves are prefabricated into piping spools. Piping spools are assembled into preassemblies with support steels. Preassemblies can be integrated into large-sized modules. The piping unit rate can be reduced by increasing prefabrication, preassembly and modularization.

- Open Top construction

  Toshiba expanded the Open top construction method to include piping spools as well as the modules and preassemblies. The Open top construction method has reduced man-hours needed to move piping spools into the work places in the buildings.

The cable unit rate in Japan was improved by:

- Cable-pulling scaffold

  The Cable-pulling scaffold is attached to the cable tray after the installation of the cable tray. Electricians use the cable-pulling scaffold to set up and to pull cables by hand without erecting the scaffold on the floor.

- Cable-pulling space

  Cable-pulling space is reserved for each cable tray route to attach the cable-pulling scaffold. The cable pulling space is reviewed in advance when the 3D model of bulk commodities is prepared. A minimum 700mm space is reserved alongside the cable tray.

- Cable tray support

  The older design cable tray support had the shape of a frame, which enclosed the cable tray with structural tubing and/or channels. Cable tray supports have been improved by eliminating the support on one side of the cable tray, which makes cable-pulling and its set-up easier with better access to cable trays and allows cables to be placed directly into cable trays. The improved cable tray support is applied unless seismic/safety analysis requires the frame-shaped support.

(4) Visualized work process analysis

The unit rates have been improved in Japan as above mentioned. On the other hand, the unit rates expected in the U.S. are significantly higher than the unit rates in Japan. To identify the reasons for the unit rate differences, Toshiba discussed with US A/E companies, including Bechtel, Visualized Work Process Analysis (VWPA). The VWPA was conducted with the following steps as shown in Figure 4.1-6 (for a large bore piping as an example):

(i) Select a typical portion or component of a commodity

(ii) Illustrate several working sketches with a number of craftsmen

(iii) Develop hourly schedule of the individual craftsman

(iv) Analyze installation man-hours

The VWPA is typically applied to the following commodities:

- Large bore piping
- Small bore piping
- Cable

(5) Other A/Es study

Toshiba provided the same documents, ABWR CONSTRUCTION PLAN and ABWR QUANTITIES, etc. to multiple U.S. A/E companies and requested cost estimates in order to understand the unit rates. The unit rates obtained vary among the A/E companies, as expected.

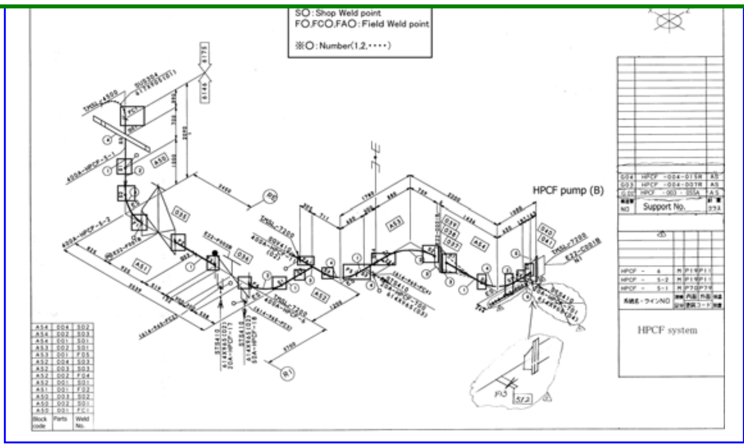
(6) Toshiba schedule evaluation

- Based on the achievements and from the information and knowledge Toshiba has accumulated, Toshiba has concluded that the 44-month schedule has room for improvement.
- Toshiba determined the unit rates achievable at the Bellefonte site and re-evaluated the construction schedule. The efforts by Toshiba were based on the results of the VWPA exercise, discussions with U.S. A/E companies and the information obtained from various sources. The Toshiba decision also includes Toshiba experience achieved in Japan. Table 4.1-1 shows the Bellefonte ABWR unit rates range, determined by Toshiba.

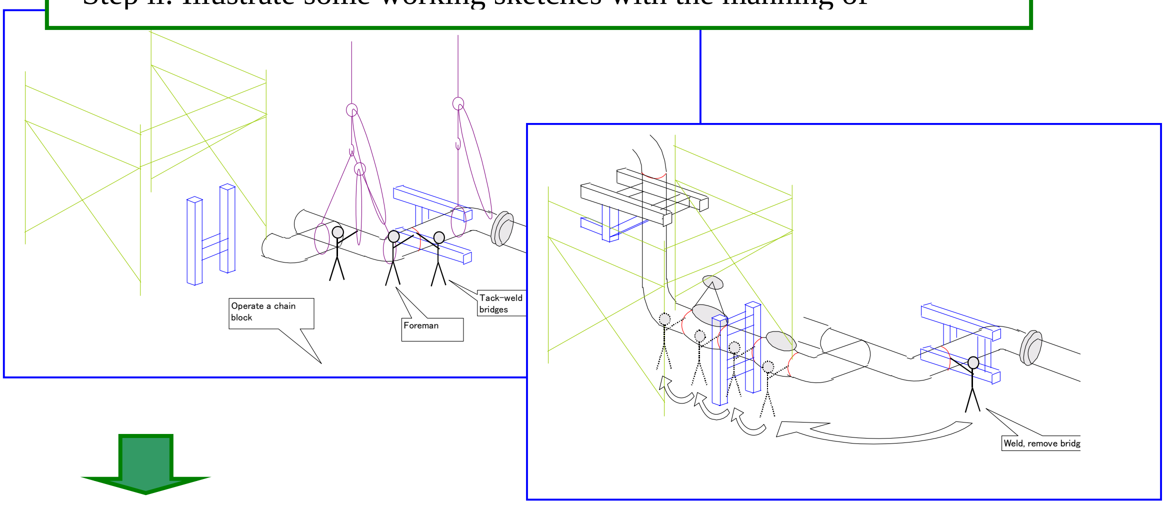
Table 4.1-1 Unit rates range Toshiba determined achievable for the ABWR at the Bellefonte site (relative ratio to the unit rates of 44-month schedule.)

Item	Toshiba unit rate adjustment range
Structural concrete	0.70-1.00
Large bore piping	
Small bore piping	
Cable tray	
Conduit	
Cable	

Step i: Select a typical part or component of a commodity



Step ii: Illustrate some working sketches with the manning of



Step iii: Develop hourly basis schedule with the number of craftsmen

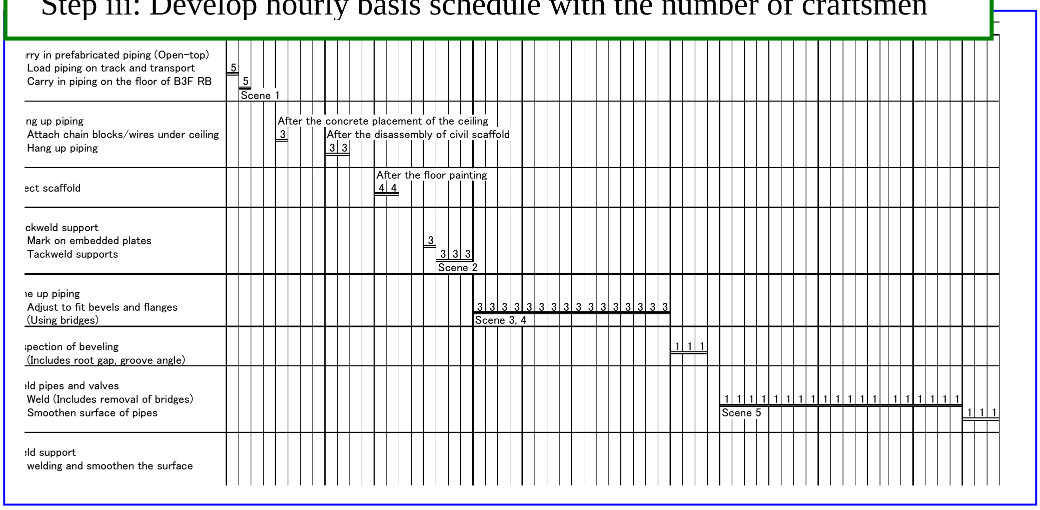


Figure 4.1-6 Visualized Work Process Analysis (ex. Large bore piping)

The Bellefonte ABWR construction schedule was re-evaluated using Toshiba's rates. The schedule evaluation results in a duration of forty months from the first reactor building concrete pour to fuel loading. (The start of Reactor Building related concrete construction to fuel loading of forty-one (41) months, because 1-month is needed to place the rebar before the first concrete pouring of the reactor building basemat). Prior to the start of Reactor Building concrete, thirteen (13) months of site preparation, including a significant amount of blasted and excavated rock, is required. Additionally the Turbine base mat concrete starts 4 months before the start of the reactor building concrete work. Following fuel loading, seven (7) months of Power Ascension testing, is scheduled to achieve Commercial Operations.

Figure 4.1-7 shows the Bellefonte ABWR 40-month Construction Milestone Schedule. Appendix M includes the Level 2 Construction Schedule, which was developed floor-by-floor and building-by-building for the 2-unit Bellefonte ABWR.

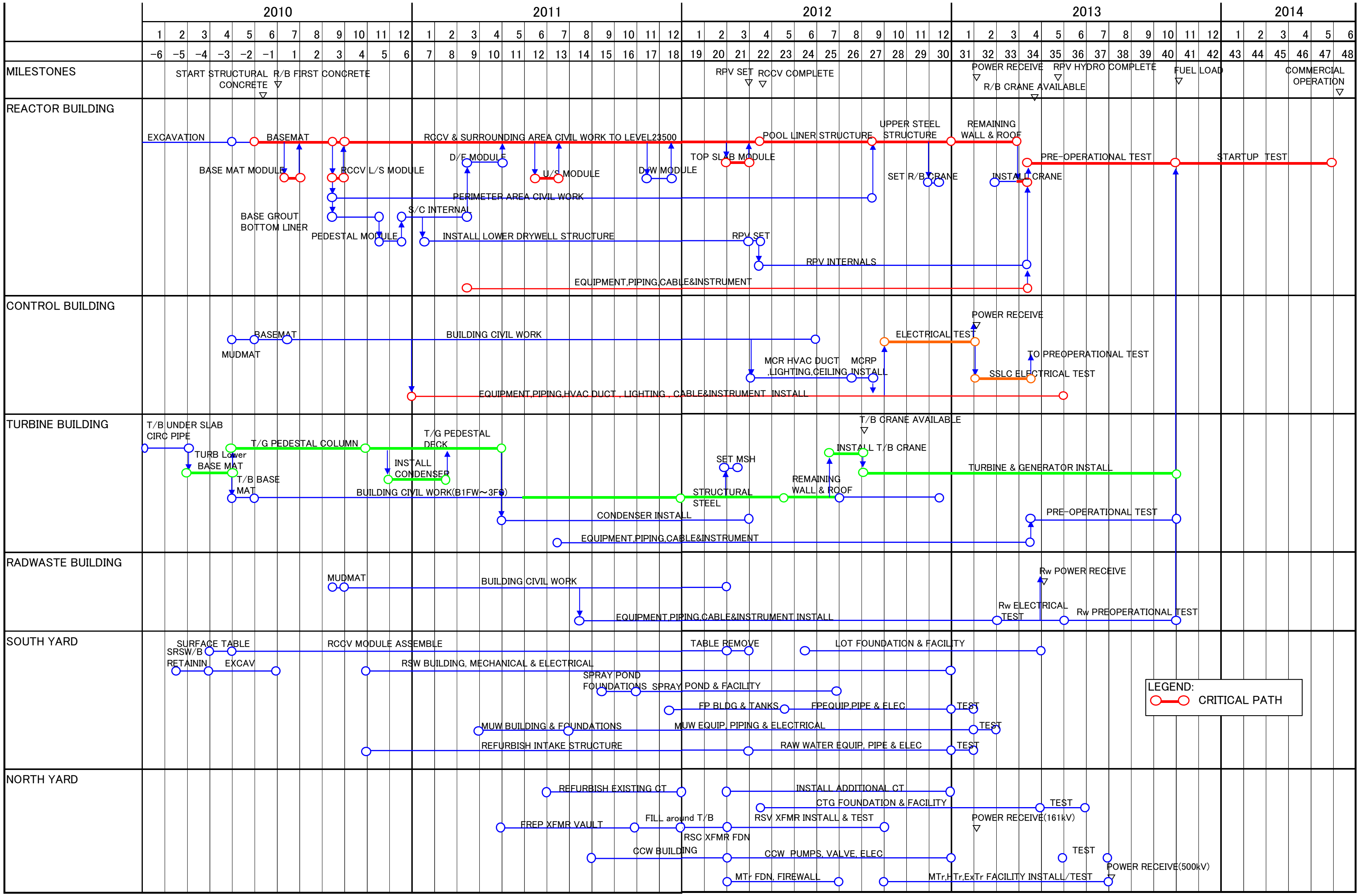


Figure 4.1-7 Bellefonte ABWR Construction Milestone Schedule

ID	Task Name	Start	Finish
1	**TVA-ABWR Joint Study**	**Mon 03/11/02**	**Mon 07/04/05**
2	DOE Solicitation of FY04 for Cost & Schedule Study	Fri 04/23/04	Mon 08/30/04
3	DOE Cost & Schedule Study	Thu 09/09/04	Mon 07/04/05
4	Other scope of Joint Study	Mon 03/11/02	Mon 07/04/05
5	**TVA Seismic & Transmission Study**	**Thu 09/18/03**	**Thu 07/28/05**
6	Transmission Study	Thu 09/18/03	Sat 07/31/04
7	Seismic Study	Fri 10/29/04	Thu 07/28/05
8	**Dominion Study**	**Mon 06/23/03**	**Mon 05/31/04**
9	Dominion Study	Mon 06/23/03	Mon 05/31/04
10	**Business Plan**	**Fri 07/18/03**	**Thu 06/30/05**
11	Develop Business/Finance Structure	Fri 07/18/03	Thu 03/31/05
12	Establish Business/Finance Structure	Fri 04/01/05	Thu 06/30/05
13	Develop Utility Partner	Fri 07/18/03	Thu 03/31/05
14	Establish Utility Partner	Fri 04/01/05	Thu 06/30/05
15	**TVA Decision for NOI**	**Fri 07/01/05**	**Thu 10/27/05**
16	Decision Process	Fri 07/01/05	Wed 10/12/05
17	Obtain Board Approval	Thu 10/13/05	Thu 10/27/05
18	**TVA Notice of Intent**	Fri 10/28/05	Fri 10/28/05
19	Site Specific Engineering	Fri 10/28/05	Wed 09/30/09
20	DOE Solicitation for COL and other Preparation Work	Mon 07/04/05	Wed 08/30/06
21	**COL Preparation Work**	**Mon 10/31/05**	**Thu 11/29/07**
22	COL Preparation Work	Mon 10/31/05	Thu 11/29/07
23	**TVA EIS Preparation**	**Mon 10/31/05**	**Mon 10/22/07**
28	**TVA Record of Decision**	Fri 11/30/07	Fri 11/30/07
29	**COL Work**	**Mon 12/03/07**	**Wed 09/30/09**
30	Filing	Mon 12/03/07	Mon 12/03/07
31	Staff Review	Tue 12/04/07	Fri 02/27/09
32	Publish NRC EIS	Fri 01/02/09	Fri 01/02/09
33	COL Hearing	Fri 02/27/09	Thu 07/30/09
34	Commision Decision	Thu 07/30/09	Tue 09/29/09
35	NRC Issue COL	Wed 09/30/09	Wed 09/30/09
36	**Procurement RPV**	Tue 04/01/08	Fri 03/30/12
37	**Pre-construction**	Mon 06/01/09	Wed 06/30/10
38	**Construction**	Thu 07/01/10	Wed 10/30/13
39	**Fuel Load**	Sat 11/02/13	Sat 11/02/13
40	**Startup Test**	Mon 11/04/13	Sat 05/31/14
41	**Start Full Power Operation**	Sun 06/01/14	Sun 06/01/14

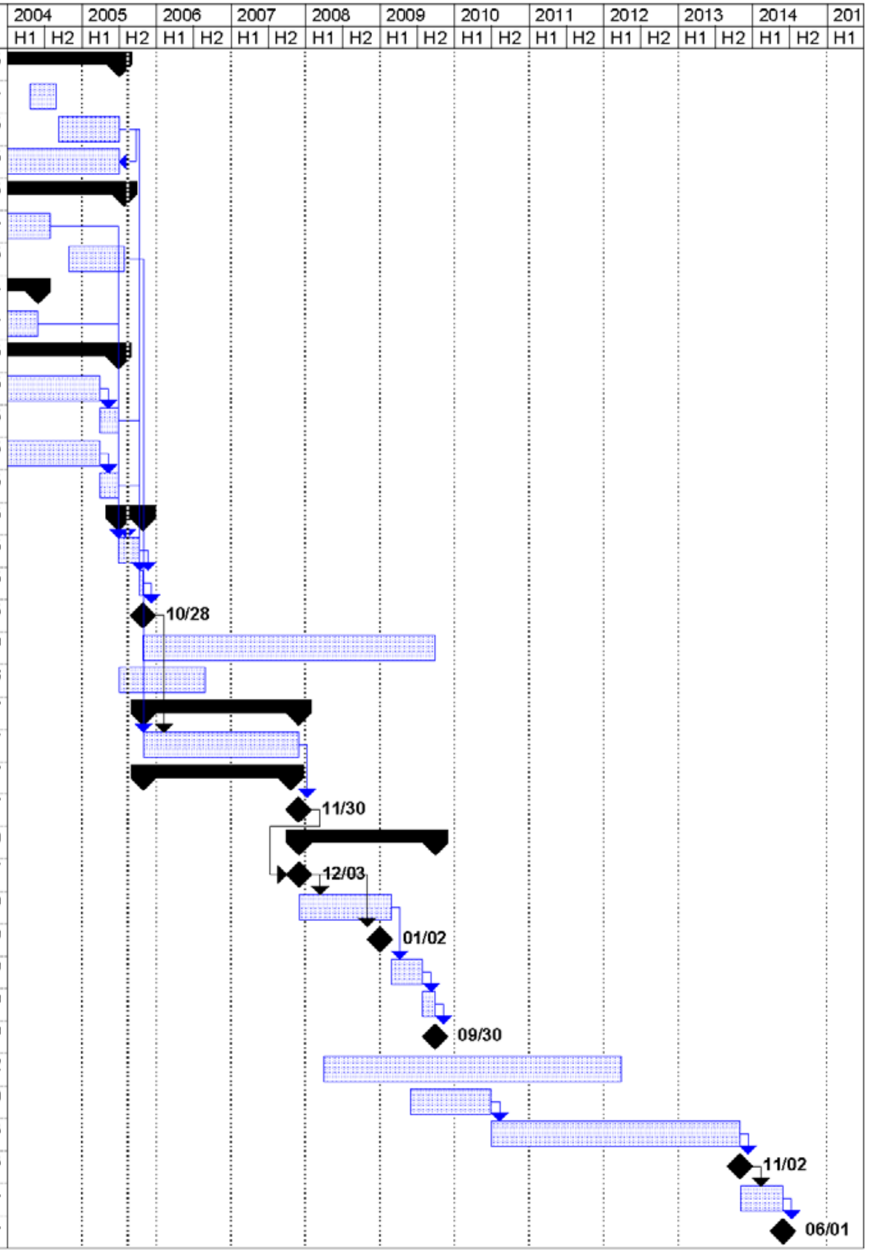


Figure 4.1-8 Project Summary Schedule

4.1.3.2 Preoperational testing schedule

Preoperational tests will be conducted prior to fuel loading in order to verify that plant systems are capable of operating in a safe and efficient manner compatible with the system designed. As soon as the preoperational test has been completed, the startup test begins, with fuel loaded, and extends to the full power operation.

The major process and the schedule of the preoperational test which will be on the critical path of the plant construction schedule is developed in accordance with the ABWR DCD and the regulations in the U.S.

The duration of the preoperational test from Energization (power receive) to fuel loading is evaluated as 9 months. The developed preoperational test schedule is shown in Appendix N.

4.1.3.3 Project schedule

Figure 4.1-8 shows a project summary schedule for the TVA ABWR at the Bellefonte site, which integrates the licensing process with the necessary engineering, construction and startup activities. The RPV procurement and fabrication schedule is described on the schedule as an example of the equipment which requires a long delivery time.

(1) Licensing schedule

The licensing process on the schedule in Figure 4.1-8 is identified as Combined Construction permit and conditional Operating License (COL) referencing ABWR Design certification without Early Site Permit (ESP) in accordance with 10 CFR 52. The period of COL preparation work including pre-application review by NRC is estimated at 13 months from TVA's Notice of Intent. The period of COL review by NRC, including technical review, environmental review, public hearings and commission decision is assumed to be 22 months.

In addition, this schedule assumes use of the Limited Work Authorization (LWA) process specified in 10CFR50.10 and 10CFR52.91. Before starting pre-construction work, survey, site cleaning and grading should be completed under the LWA.

(2) Procurement schedule

All long lead time equipment procurement were analyzed and found to support 40 months construction schedule. The forging of the RPV should be ordered approximately 4 years before the RPV is set on the base at the jobsite, before the COL is issued. Other equipment that needs to be ordered prior to the approval of COL are as follows:

- Reactor Internals
- RCCV Liners
- CRD Hydraulic Control Units

- ECCS Pumps
- RPV Pedestal
- Turbine and Generator
- Condensers
- MSV/CV
- MSR

(3) Engineering schedule

The site-specific engineering period is assumed to be approximately 47 months and will be completed before the start of placing structural concrete.

(4) Construction schedule

Pre-construction is the site preparation activities consisting of excavation for the power blocks, preparation of construction offices, construction utilities, concrete batch plants, and necessary construction warehouses and fabrication shops. The pre-construction period is planned at 13 months from site mobilization to the milestone of the first concrete pour for the reactor building.

4.1.4 Assessment of Plant Staffing

The manual /non-manual manpower requirements developed by Bechtel for the 44-month construction duration were reviewed by Toshiba.

It is Toshiba's assessment that the manual/non-manual manpower requirements are less than what was estimated by Bechtel for the 44 month construction duration. Toshiba has developed a level 2 schedule for the 40-month construction duration.

(1) Manual manpower requirements

Based on the one-year lag between units, the direct hire manual craft population approaches 4500 craft personnel at month 30 (excluding the subcontractors). This peak is primarily driven by pipe fitters who peak at nearly 1800, followed by the electricians who peak at 1100. These two crafts are considered to be the most critical resources need to achieve the work-off requirements.

Reference: Appendix Q, BECHTEL EVALUATION REPORT

(2) Non-manual manpower requirements

Non-Manual personnel (construction and startup) to support a 2 unit field organization requirement for an ABWR NPP will occupy a wide range of departments and departmental positions. It is estimated that at peak the ABWR project will employ approximately 750 field non-manual positions within the departments of:

- Management and Administration
- Supervision
- Engineering
- QA/QC
- Start Up
- IT
- Document Control
- Contracts
- Procurement
- Project Controls
- Safety
- Accounting, Payroll, Timekeeping

Reference: Appendix Q, BECHTEL EVALUATION REPORT

4.1.5 Bellefonte Area Labor Survey

The majority of the labor unions for the ABWR Project will be represented by the Chattanooga Building and Construction Trades Council. However, Operating Engineers Local #320 is located in Florence, Alabama; Pipe Fitters Local #498 is located in Gadsden, Alabama; Sheet Metal Workers Local #48 is located in Birmingham, Alabama; and Cement Masons Local #908 is located in Cape Girardeau, Missouri.

The following is a listing of the local unions whose jurisdiction covers the Bellefonte Nuclear Plant and are listed as participants in the collective bargaining agreements.

All of the local unions will have new collective bargaining agreements in place prior to the start of construction.

<Craft>

- Asbestos Workers
- Boilermakers
- Bricklayers
- Carpenters
- Electricians

- Iron Workers
- Laborers
- Millwrights
- Operating Engineers
- Painters
- Pipe Fitters
- Sheet Metal Workers
- Teamsters

The TVA system includes a significant, and historical, base of power plants that have allowed the craft unions in the area to establish large memberships to support year over year construction activity. Membership data collected indicates that within a 400-mile radius from the ABWR Project there would be an adequate supply of craft manpower to support the ABWR project. However, planned outages within the TVA system, as well as emerging workload related to construction of other industrial facilities in the region, represent significant competition for craft resources during the peak years 2011-2013. All this construction activity may create a strain on manpower availability within the region and will require the craft recruiting area for the ABWR Project to reach beyond 400 miles. This situation will require the Project to evaluate the need for economic incentives, such as per diem, housing allowances, etc., to attract travelers (these cost are currently excluded from this study).

As a result of the design of new generation nuclear power plants with faster construction schedules that utilize pre-assembled and modularized components, the profile of the construction worker needed to build this new generation plant is mobile, and well trained to work with new technology. While the challenges facing craft staffing for the ABWR Project are formidable, the critical issues that need to be addressed are summarized below:

- Assessment of the craft skill requirements needed to work on the ABWR Project.
- Development of a Local, Regional and National Recruiting and Training Program.
- Negotiation of a Nuclear Project Labor Agreement (PLA).

Reference: Appendix O, BELLEFONTE AREA LABOR SURVEY

4.1.6 Opportunities for Further Schedule Reductions

The Bellefonte ABWR 40 month construction schedule was based on the logics and the quantities developed from Toshiba's actual construction experience in Japan. The

40-month schedule has its critical path running through the installation of bulk commodities (concrete, large bore piping, and cables).

The following items are raised for consideration for potential further schedule reduction.

(1) Optimized modularization for U.S.

In general, modularization is applied in the study based on the modular approach in Japan, such as composition of modules, quantities of modules, scope (boundary) of modules, and on-site/off-site classification of modules. However, there are a few differences between U.S. and Japan in factors affecting modularization, such as wage rate ratio between the off-site facilities and the jobsite and transportation methods(e.g. river/sea). More study may be able to optimize modularization applied to the ABWR project in U.S. and it may reduce the schedule.

(2) Optimized construction process

The level 2 construction schedule is developed based on the standardized process of bulk commodities installation floor by floor, i.e. (a) equipment, (b) large bore piping, (c) small bore piping, cable trays and HVAC ducts, (d) conduits, instruments and cables. An optimized construction process and schedule, which should be developed room by room at the detail plan stage, may raise the productivity and reduce the schedule, because each room has its own optimized process.

(3) Improved installation rates

Installation unit rates for the Bellefonte ABWR are evaluated to estimate the on-site jobhours. Sustained rates are also evaluated to verify the construction schedule for the Bellefonte ABWR. It is believed that unit rates and sustained rates in the US can potentially be improved to approach those achieved in Japan.

(4) Applying new technologies

The following new construction technologies may be able to reduce the construction schedule.

Table 4.1-2 Construction Technologies for Further Schedule Reduction

ITEM	DESCRIPTION
Prefabricated Floor Panels	Manufactured prefabricated floor panels that can replace the cast in place flooring
Adopt the most cost effective mechanical rebar connector	Use of grouted splices or bar lock splice coupler
Concrete composite technologies	Advanced concrete admixtures are used to achieve increased strength and workability. Technology includes self compacting concrete(SCC) , high performance concrete (HPC), and reactive powder concrete(RPC).
High deposition rate welding	Deposition Rate Welding Specialized versions of traditional welding processes, including GMAW, GTAW (orbital welding), flux cored SAW, and strip clad welding, that have higher deposition rates than their predecessors.
Robotic welding	Layout piping to facilitate space for automated welding.
Positioning applications in construction (GPS and laser scanning)	Global Positioning System (GPS) is worldwide radio navigation system used to determine longitude, latitude, and altitude. Use of “Indoor GPS” (laser scanning) for process control inside fabrication facilities is being developed
Cable splicing	Eliminate the need to pull cables through adjacent modules
Cable pulling	Advancements in lubricants for cable pulling

4.2 COST EVALUATION

4.2.1 Overall Plant Cost Summary

4.2.1.1 Introduction and summary of result

A major concern for U.S. utilities as they face the decision of purchasing a new nuclear power plant is the uncertainty associated with the cost and construction schedule of the plant. The major goal of the study which the team tried to provide was to quantify this uncertainty by bringing in the experience of actual construction of ABWR plants in Japan and Taiwan. As described previously, the first ABWR, Kashiwazaki Kariwa Unit-6 was actually completed in 37 months from the first reactor building structural concrete pouring to fuel load. This completion schedule of 37 months included various first of a kind tests and removal of associated test equipment. Since this first ABWR completion in 1996, both Toshiba and GE have accumulated further ABWR construction experience, efficiency enhancements, modernization and improvements in the BWR construction methods. Such enhancements and improvements lead to cost reduction, shorter construction periods, and most of all decreasing the uncertainties associated with the cost and schedule. A major contribution to this study is the application of the actual detailed construction process of the ABWR and the evaluation of its use at the Bellefonte site.

The following steps have been taken in order to achieve the goal of quantifying the cost and schedule uncertainty:

(1) A detailed plant concept of the ABWR at the Bellefonte site has been developed by Toshiba and GE based upon the DCD and FOAKE project design, incorporating the improvements and detail design achieved in Japanese ABWR plants and Lungmen. New improvements achieved both in Japan as well as those achieved by GE for the Lungmen ABWR project were reviewed by GE and Toshiba in order to verify that they would be applicable to Bellefonte and meet the U.S. requirements.

(2) Based on the plant concept reviewed by GE and Toshiba, Toshiba developed detail quantity information for the Bellefonte ABWR plant, using detail design information for the Japanese ABWR plants.

(3) Bechtel developed a preliminary design for the yard facilities specific to the Bellefonte site for the purpose of estimating yard construction material quantities. All the quantities for equipment and bulk commodities other than the yard facilities were provided by Toshiba. (Refer to Section 4.2.1.2 for details of the work split.)

(4) Bechtel evaluated overall construction cost, considering required man-hours, wage rates based on labor survey and other cost factors including distributable costs.

For further understanding of the U.S. construction practice, Toshiba collected information from multiple U.S. architect engineering companies and other available information sources (e.g. DOE and other industry reports). Toshiba finally evaluated all the information obtained from multiple sources including what Bechtel performed to estimate the total costs for the project so that the costs presented in this report are not that of a single U.S. contractor.

(5) To enhance the credibility of the evaluation results, GE also performed its own evaluation based on the quantity information they estimated independently. The quantity information upon which the GE estimate was based was compared against the quantities developed by Toshiba. Thus, the ABWR at TVA Bellefonte EPC cost estimate can be characterized as the most definitive and complete estimate ever done for a nuclear power plant prior to start of construction in the U.S. Such estimation and evaluation results were compared and reviewed by GE and Toshiba.

The following results were obtained. Details of the results are described in the following parts of this chapter.

- Toshiba and GE have good agreement on the plant concept and the quantity information for the Bellefonte ABWR.

- The overall evaluations were performed independently by Toshiba and GE, and both reached a unified estimation. As mentioned before, GE has come to this estimation with an independent quantity, engineering and construction estimation. Toshiba used its quantity information and performed its own engineering estimation. Such estimation was based upon Toshiba's assessment of information obtained from U.S. A/E companies and other available sources.

All such estimation results were extensively discussed among, GE, Toshiba, and other team members. As a result, Toshiba and GE agreed to present the following cost estimate for the study.

<u>Cost estimate agreed and determined by Toshiba and GE.</u>

Since the two major plant vendors with significant plant construction experience performed the estimation independently and the results were a close match, the plant costs determined by Toshiba and GE are considered to be very credible. Table 4.2-1 and Table 4.2-2 summarize the plant costs in more detail.

This report provides the EPC price to TVA (i.e. GE/Toshiba's price) and schedule for construction of a two unit Advanced Boiling Water Reactor (ABWR) power plant at TVA's Bellefonte plant site. This information is useful in demonstrating the economic viability of advanced nuclear plants, prior to a decision to add generating capacity. GE/Toshiba's price includes provisions for standard commercial terms and conditions, and a project contingency.

The study is based on actual construction experience in Japan and Taiwan modified by a preliminary engineering design specific to the Bellefonte site, the material quantities needed to construct the plant, and current market conditions related to materials, supplier prices, and local labor market.

Table 4.2-1 Bellefonte ABWR EPC Overnight Costs[1] Summary in 2004 Dollars

Plant capacity	Scope	$/KW
Base Output (1,371MWe)	Entire Plant	1,611
	Power Block	1,443
Uprate Output (1,465MWe)	Entire Plant	1,535
	Power Block	1,377

- Uprate case is evaluated in Chapter 6 "Additional Plant Enhancement Options"
- Builder's risk, property and liability insurances and import duty are not included in the above costs. The ballpark estimate for the insurances and import duty is approximately equivalent to $20/KW in the case of EPC Overnight Cost of $1,611/KW for Entire Plant, but could vary based upon specific terms and conditions.

The EPC costs developed in this study are indicative prices based on mutually agreeable terms and conditions and site conditions for a firm fixed price offering.

(1) Description of nuclear power plant for this study

- Reactor Type: Advanced Boiling Water Reactor (ABWR) (Twin units)
- Site Location: TVA's Bellefonte Alabama site
- Electricity Output: Base output: 1371MWe (Net)

[1] EPC Overnight Cost: Overnight costs are those costs that would occur if the entire project could be completed in a single day. Overnight costs do not include the time-related cost effects of inflation and interest. In addition, EPC stands for Engineering Procurement and Construction and EPC cost does not include owner's cost.

Table 4.2-2 Bellefonte ABWR EPC Overnight Cost Estimate in 2004 Dollars for the base output (EEDB Account[2])

($ million)

<table>
<tr><th>Code</th><th>Description</th><th>Equipment and Material</th><th>Labor</th><th>Total</th></tr>
<tr><td>21</td><td>STRUCTURE and IMPROVEMENTS</td><td>515</td><td rowspan="6">938
Manual
Labor</td><td rowspan="9"></td></tr>
<tr><td>22</td><td>REACTOR PLANT EQUIPMENT</td><td>910</td></tr>
<tr><td>23</td><td>TURBINE PLANT EQUIPMENT</td><td>607</td></tr>
<tr><td>24</td><td>ELECTRIC PLANT EQUIPMENT</td><td>253</td></tr>
<tr><td>25</td><td>MISCELLANEOUS PLANT EQUIPT</td><td>89</td></tr>
<tr><td>26</td><td>MAIN COND. HEAT REJECT SYS.</td><td>38</td></tr>
<tr><td>91</td><td>CONSTRUCTION SERVICES</td><td rowspan="3">327</td></tr>
<tr><td>92</td><td>ENGINEERING and H/O SERVICE</td><td rowspan="2">741
Non manual labor</td></tr>
<tr><td>93</td><td>FIELD SUPER. and F/O SERVICE</td></tr>
<tr><td colspan="2">Total</td><td>2,739</td><td>1,679</td><td>4,418</td></tr>
</table>

- This table gives a cost of $1,611/KW.

[2] EEDB: The Energy Economic Data Base (EEDB) Program is sponsored by the U.S. Department of Energy (DOE) for the purpose of developing current technical and cost information for nuclear and comparison electric power generating stations. The EEDB contains a variety of nuclear and coal-fired power plant technical data models. Each of these data models is a complete and detailed conceptual design for a single unit, commercial, steam electric, power generating station located on a standard hypothetical Middletown site. A major effort for the Sixth Update (1983) has been the updating of the system design descriptions and selected engineering drawings for the technical data models. This update took the form of revising and expanding the system design descriptions and engineering drawings contained in the Base Data Studies, to include the technical information developed and recorded in the first five EEDB updates. The results of the update effort are contained in this EEDB Program Technical Reference Book.

- Commercial Operation: Unit-1: 2014, Unit-2: 2015

(2) Basic assumptions of cost calculation

- The EPC costs under this study include provisions for standard commercial terms and conditions, and a project contingency. Thus, the EPC cost presented in this study represent all inclusive costs, excluding owner's costs. The all inclusive EPC costs, however, would require adjustment to specific terms and conditions as applied to a specific contract. Unless otherwise specified, the EPC costs and its components in this report are expressed in fourth quarter 2004 dollars.

- In addition to the EPC costs based on the original plant concept (as described in Task-1), EPC costs based on an uprated power output in the enhanced plant concept reviewed in Task-3 of this study (Ref. Chapter 6 of this report) are presented. The enhancement includes a power uprate to 1465MWe (net).

- Since the purpose of this study is to evaluate site specific EPC costs, the above EPC costs include not only the cost for the power block, but also yard facilities based on the detailed site survey and use of existing facilities. In a general study to compare economics of nuclear power plants by each different design, a cost for the power block is sometimes used in order to eliminate site-specific parameters. For this purpose, Table 4.2-1 summarizes the costs for a power block. The power block includes the reactor buildings, turbine buildings, control building and radwaste building for a two-unit plant.

(3) Other key items incorporated in the evaluation

- Bellefonte labor survey

  For preparation of the cost data in this report, a labor survey around the Bellefonte site area in Alabama was conducted by Bechtel. It should be noted that a comparison of wages identifies a problem for the ABWR Project. Four (4) out of five (5) of the key crafts for the ABWR Project (Pipe Fitters, Electricians, Carpenters, Laborers and Iron Workers) are paid a total wage and fringe package that is significantly lower than TVA's Watts Bar Nuclear Plant. This condition will hamper the ABWR Project's ability to recruit high quality craft both locally and regionally. A Project Labor Agreement (PLA) would provide the best opportunity to negotiate competitive wages, hours, terms and conditions of employment appropriate for the ABWR Project. Reference Appendix O, Bellefonte Area Labor Survey, for an expanded discussion of this topic.

- Site Survey

A detailed site survey (including surrounding area to the site) was performed to determine which existing facilities at the Bellefonte site, where two PWR units were partially constructed and then cancelled, could be utilized to the maximum extent possible.

- Adoption of the most advanced construction technology of U.S. and Japan

In the U.S., there has not been any new commercial nuclear construction initiated for over 2 decades, while Toshiba has been continuously involved in new nuclear construction in Japan as a general contractor and major equipment supplier. Because of Toshiba's continuous involvement in nuclear construction in Japan, Toshiba was able to improve construction and installation management technologies and processes that have been applied to this study. In this study, Toshiba applied the most advanced construction technologies to achieve a shorter construction period and lower construction cost compared to conventional nuclear power plants (which are explained in detail at Section 4.2.3.2. (1)(b)). This study adopts Toshiba's improved construction technologies to the maximum extent possible, in addition to some advanced features of recent U.S. fossil power plant construction, such that the construction costs of the ABWR at the Bellefonte site is credible and competitive.

- Optimization of construction process management

The construction management technologies (which are explained in more detail in Section 4.2.3.2.((1)(b)) provide methods to manage a construction project. Toshiba evaluated U.S. nuclear construction history of construction and observed several factors which contributed to significant increases in a construction cost and schedule. With the construction management technologies experienced by Toshiba, potential cost over run can be avoided or can be minimized.

- Minimization of regulatory risk

Pursuing the Bellefonte project under 10CFR52 (one step licensing) will stabilize the licensing process and minimize the licensing difficulties of the past. The ABWR is already an NRC certified design. All the improvements have been reviewed with GE and their licensing risks evaluated. Proposed design changes which were determined to be against NRC regulations or which would present unacceptable licensing risks were eliminated. Previous construction of the ABWR in Japan and at Lungmen will assist with the ITAAC process. Now, it has been acknowledged that most of those factors have been eliminated because of the regulatory changes (10CFR52, etc.) and construction technology improvements.

- Application of U.S. codes and standards

In the evaluation of equipment costs, ASME (American Society of Mechanical Engineering) and other applicable U.S. codes and standards were applied. Global sourcing of the equipment with U.S. codes and standards provides the opportunity of procuring equipment at more competitive prices.
The delivery team intends to apply U.S. products and equipment to the maximum extent possible. In this study, the EPC costs are based on U.S. products and equipment except:

- When there are no U.S. domestic supply sources, and
- When there are significant cost and/or schedule advantages to use imported products.

- Consideration to DOE Nuclear Power 2010 program[3]

This study provides an additional step toward construction of new nuclear power plants in the U.S. which is a goal of the DOE Nuclear Power 2010 program. The ABWR project at the Bellefonte site helps and provides great employment opportunities.

4.2.1.2 Roles and responsibilities of cost estimating team

The Bellefonte ABWR cost estimate was prepared by the following members of the ABWR team. The roles and responsibilities of the team members are as follows:

(1) Toshiba

- Lead the cost estimation
- Provide lessons learned from experiences in Japan - including construction methods and innovative construction management technologies
- Proceed with preliminary engineering for Bellefonte ABWR and provide plant concept reflecting latest ABWR technologies with support of GE
- Provide equipment and engineering pricing for the ABWR at the Bellefonte site

[3] DOE Nuclear Power 2010 program: The Nuclear Power 2010 program is a joint government/industry cost-shared effort to identify sites for new nuclear power plants, develop and bring to market advanced nuclear plant technologies, evaluate the business case for building new nuclear power plants, and demonstrate untested regulatory processes leading to an industry decision in the next few years to seek NRC approval to build and operate at least one new advanced nuclear power plant in the United States.

- Provide quantity data for estimating costs of installation and civil works
- Collection, analysis and evaluation of construction cost data from U.S. A/E companies
- Develop a total plant cost for review with GE. Finalize and determine with GE the overall cost estimate of the ABWR at the Bellefonte site

(2) GE

- Provide plant design enhancement concepts from Lungmen design and recent bid for an ABWR in Finland
- Provide overall cost estimate based on Lungmen and recent bid for an ABWR in Finland, plus other information from GE data base
- Review of the cost data provided by Toshiba and evaluate against GE database from Lungmen and Fin-5 bid
- Finalize and determine with Toshiba the overall cost estimate of the ABWR at the Bellefonte site

(3) Bechtel

- Perform a preliminary design of the yard facilities and develop quantities of the yard facilities
- Perform a labor survey
- As one of A/Es, provide Bechtel's historical and contemporary cost and schedule data to assist Toshiba in overall analysis.
- Provided a cost estimate of equipment of the yard facilities

4.2.1.3 Cost evaluation scope

(1) EPC scope definition

Principle: The scope of the cost study includes all EPC costs except for owner's cost. Fuel cost is not included in EPC cost. It is intended that the existing facilities at

Bellefonte will be used to the maximum extent possible, but most of the facilities require some adjustment or additional work. Such additional costs are categorized as owner's cost. The major existing facilities which are incorporated into the Bellefonte ABWR are listed in Table 4.2-4. (Refer Appendix P for all the details of the existing facilities).

The detailed split of scopes between EPC scope and owner's scope is described in Appendix P "Total Facility List"

(2) Owner's cost and other cost scope

Items in Table 4.2-5 are categorized as owner's cost or other cost which are not included in EPC scope in this Study.

(3) Commissioning service account

As described in Table 4.2-3 EPC Scope "Commissioning Service", the following costs will be offset by revenue from power generation during start up tests prior to the commercial operation of the plant. It is assumed that TVA will take the power generated during the start up tests at a reasonable rate or sold to other spot buyers at an avoidable cost (fuel and variable maintenance costs of marginal fossil power plants). The Commissioning Service account will be established and managed to pay off the following costs under the responsibility of EPC team without additional funding by TVA.

- Start-up training program and manual provided by Toshiba/GE (including its subcontractors)
- Required costs by EPC Team to support the start-up testing
- Consumables until turn over of the plant to TVA

Equivalent fuel cost (including contribution to spent fuel fund) during start-up testing. (payment to TVA)

4.2.1.4 Estimating process

The cost evaluation has been conducted in accordance with the process described in Figure 4.2-1, based on the plant concept under the Task-1 (Chapter 3) and the construction schedule under the Task-2 (Section 4.1):

Table 4.2-3 Items not Included in the EPC Scope

Total Scope	Description
Existing facilities (Appendix P)	Several existing facilities at the Bellefonte site (e.g. cooling towers) are used. Cost to connect to the existing facilities is included. Refurbishment costs of the existing facilities are not included.
Preparation of COL	Costs for the COL application are part of Owner's cost.
Initial core fuel	Fuel cost, Fuel Design cost or Fuel loading cost are not included in EPC cost.
Transmission Upgrade	Transmission upgrade is owner's cost
State and local tax	Taxes are not included for purpose of this study
Builder's risk, property, liability Insurances, Import Duty	Builder's risk, property and liability insurances and import duty are not included in the costs in Table 4.2-1. The ballpark estimate for the insurances and import duty is approximately equivalent to $20/KW in the case of EPC Overnight Cost of $1,611/KW for Entire Plant, but could vary based upon specific terms and conditions.
Commissioning Service (Start up tests after Fuel Load)	Training Program provided by Toshiba/GE, costs by EPC Team to support start-up tests, consumables and fuel cost during the start-up tests will be off-set by selling the power which is generated during the start-up tests. The Commissioning Service account would be separately established and managed under responsibility of the EPC team without additional funding requirements to the owner.
TVA Staffing	Staffing cost until commercial operation is covered under owner's scope
Financing Cost	Financing cost is not included in EPC costs
Permits and licenses	Any permits and licenses needed for operating power plant are not included in EPC cost.

Note; TVA has no plans to remove the components and facilities from the site which will not be used.

Table 4.2-4 Major Existing Facilities

Item	Description
Cooling Towers	Natural Draft Type
Auxiliary Facilities	Auxiliary Boiler Switch Yard
Intake Facilities	Intake Pumping Station Intake Channel Skimmer Wall
Others	Construction Space Service Facilities Ponds Barge Dock

Table 4.2-5 Owner's Cost

Owner's site preparation costs
River water system to tie in point for spray pond
Security infrastructure
River water system to tie in point for MUW building
Transmission tower (Main transformer)
Transmission tower (Auxiliary transformer)
Cooling tower refurbishment
Switchyard upgrade
Intake structure refurbishment
Yard drainage pond refurbishment
Sump collection pond
Site/facility upgrades and office setup
Equipment in operation training building
Warehouse (Permanent)
New fuel storage space (Initial core)
Access road
Parking lot
Landscaping
Yard lighting (outside of the power block)
Communications system
Machine shop refurbishment/equipment
Warehouse and utility, clearing ; tree transplanting
Radiological environmental monitoring program
Barge dock
House boiler refurbishment
Chemical treatment pond
Mobilization costs
Const. power and potable water refurbishment
Sewage plant upgrade
Meteorological monitoring
Simulator
Information technology
Spare parts
Emergency preparedness
Station staffing
Other owner's regulatory scope
NRC licensing review and inspection fee during construction
Environmental impact
Preparation and approval of licensing documents

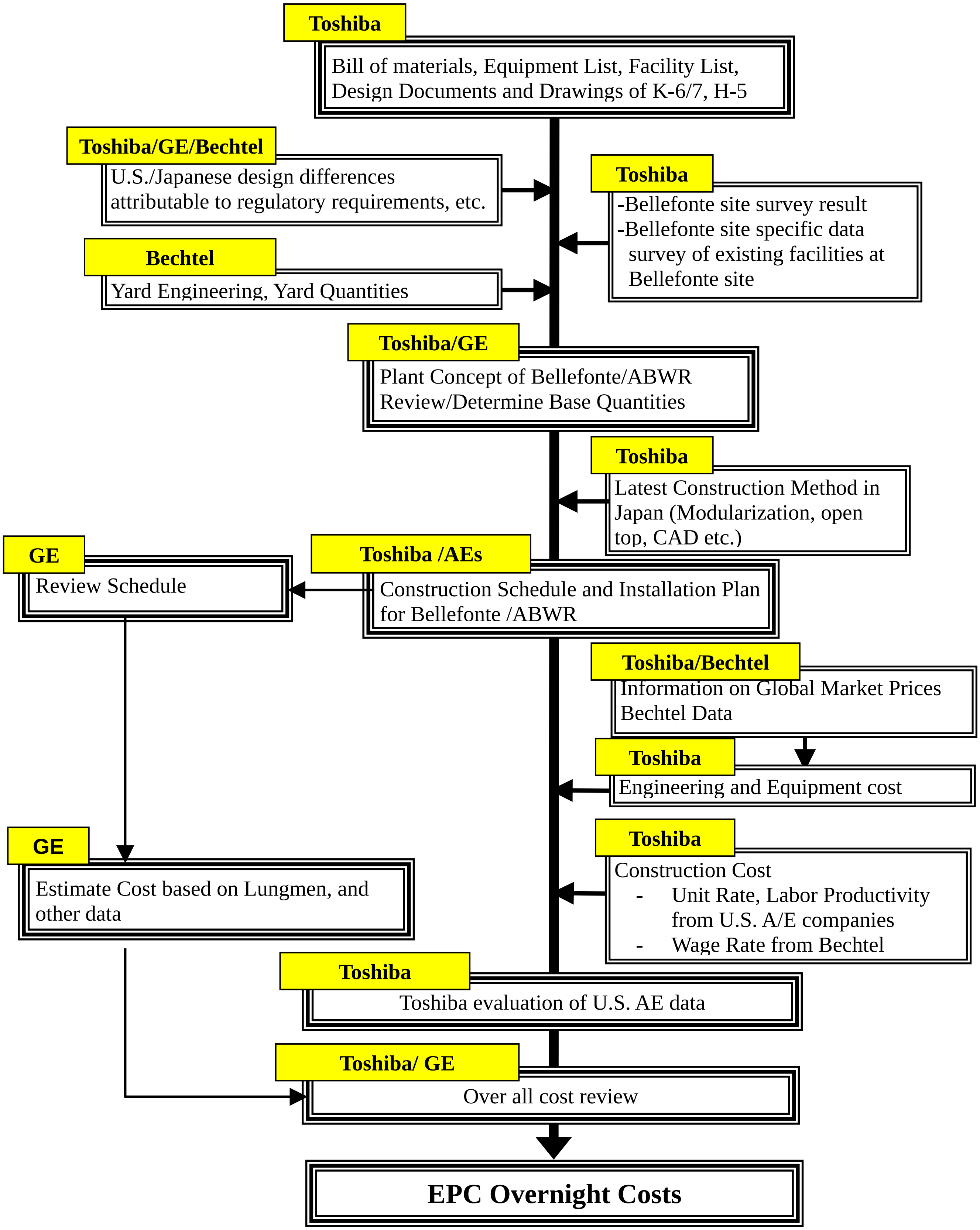


Figure 4.2-1 Block Diagram of the EPC Cost Estimating Process

4.2.1.5 Applicability of the study result to further ABWR construction

In this study, the overall costs of the ABWR at the Bellefonte site were evaluated. The costs of follow on ABWR units beyond Bellefonte 1 and 2 are expected to decrease because of several factors. Following are some of the factors that affect cost of the follow on ABWR units.

(1) Learning curve and improvement of productivity

Being the first new construction after 20 years from last construction of nuclear power plant in U.S., there is still room to improve the productivity in the cost estimate developed for the ABWR at the Bellefonte site.

By accumulating construction experience and construction planning, construction sequences can be optimized. Furthermore, improved modular design can be maximized and more practically interfaced with construction planning and sequences. Further improvement of productivity can be gained through learning curve of craft labor. Toshiba's experience in productivity improvement is shown in Appendix L.

In order to achieve what has been realized in the past decades during the absence of the construction of new nuclear power plant in the U.S., following may be proposed.

- Extensive negotiations with the unions to explore potential for improved working conditions and establishing most effective working procedures including work assignments and flexible working hours.
- Establish and control of the most effective construction plan to minimize any waiting time of the craft workers. A mechanism is important to prevent a domino effect of delays of the construction schedule which will give an impact to other segment of the construction schedule.
- Introduction of craft labor incentives to improve productivity

(2) Elimination of certain engineering costs

The EPC costs for ABWR at the Bellefonte site include certain engineering costs (e.g. new smaller turbine building design and construction sequence planning) which result from being the first ABWR project in U.S. For follow on ABWR units, such initial engineering costs are not necessary.

(3) Equipment costs

Equipment costs for the ABWR at the Bellefonte site include engineering costs to test equipment for U.S. projects (e.g. equipment qualification). Such engineering costs will not be necessary for follow on units.

(4) Economy of multiple units

For a single unit ABWR project, the costs of common facilities cannot be shared and all materials and equipment will be procured for single unit instead of two. Better economy will be achieved if multiple units are ordered. The most cost effective procurement is possible, if multiple ABWR units are expected and common procurement is initiated (even at a different site).

4.2.2 Equipment and Material Cost

4.2.2.1 Summary

Equipment costs and material costs are based upon estimates obtained from various equipment manufacturers. The equipment and material costs were reviewed and finalized with GE.

Results of the evaluation of equipment and material costs are as follow:

STRUCTURE AND IMPROVEMENTS	515M$
REACTOR PLANT EQUIPMENT	910M$
TURBINE PLANT EQUIPMENT	607M$
ELECTRIC PLANT EQUIPMENT	253M$
MISCELLANEOUS PLANT EQUIPT	89M$
MAIN COND. HEAT REJECT SYS.	38M$

4.2.2.2 Evaluation process

(1) Equipment in the power block

Toshiba and GE evaluated the cost for equipment in the power block as follows:

Equipment cost in Japan (Experience)

←Identification of scope (existing facilities eliminated)

←Determine supply sources (country of origin)

U.S. supply sources

Japanese supply sources

Other supply sources

←Price adjustment of Japanese supplied products due to change of codes and standards to U.S. codes and standards (2004)

←Inquiries for global sourcing

Specification document was prepared by Toshiba and request for quotation was issued to vendors. Responses from vendors were collected (in 2004 dollars).

←Equipment costs were compiled

←Reviewed with GE.

↓

Determined ABWR at Bellefonte equipment cost

(a) Identification of scope (existing facilities eliminated)

- It is intended that the existing facilities at the Bellefonte site will be used to the maximum extent possible, but most of the facilities require some adjustment or additional work. Such additional costs are assigned to owner's cost.
- The detailed scope split between EPC scope and owner's scope is described in Appendix P "Total Facility List".
- Identification of supply sources (countries of origin): Equipment and materials

will be sourced mainly in the U.S. except for those equipment and materials which are not available in the U.S. or are significantly cost competitive if sourced outside. The equipment listed in Table 4.2-6 is sourced in Japan because the sole sources exist in Japan and because of the reliability of the equipment.

Table 4.2-6 Equipment supplied by Japanese

Item
RPV (Reactor Pressure Vessel)
RIN (Reactor Internals)
RIP (Reactor Internal Pump)
Seal-less FMCRD (Seal-less Fine Motion Control Rod Drive)
RIP/CRD Control System

(b) Inquiries for global sourcing through actual contact with vendors

- Toshiba has a database for Japanese ABWR equipment. However, it is anticipated that the Japanese equipment prices are generally more expensive than in the global market place because Japanese ABWR equipment is based on unique Japanese codes and standards and prevailing requirements of Japanese utility companies. Except for the items listed in Table 4.2-6, Toshiba developed specifications for ABWR equipment based on U.S. codes and standards and sent requests for quotation to most of the potential vendors including U.S. (and non-U.S. suppliers). This global sourcing process has resulted in more competitive prices as compared to Japanese equipment prices.

- In order to obtain competitive pricing information, Toshiba also asked TVA to issue a letter explaining that TVA is seriously studying the ABWR Bellefonte project. Toshiba explained to the vendors the potential of the ABWR Bellefonte project.

- Toshiba obtained cost estimates of equipment and materials for more than 80 items from multiple suppliers.

- When requesting pricing information, the following U.S. regulatory documents, U.S. codes and standards were applied:

  - 10CFR50 / 10CFR21
  - Regulatory Guides
  - Standard Review Plan
  - DCD of ABWR
  - ASME / ANSI
  - IEEE
  - NFPA codes
  - Building Code which should be considered at the Bellefonte site
  - Local regulations

- Toshiba's cost estimation
  - Due to the limitation of time allowed in the study, it was not practical to obtain cost estimates for all equipment and materials. Therefore, Toshiba requested the vendors to provide cost estimates for representative items. Toshiba made a best effort to estimate equipment and materials in the same category.
  - As an example, Toshiba received cost estimates for pumps in 3 different sizes in the same category. Using those cost, Toshiba extended the estimate to 10 different sizes of pumps. Toshiba fully utilized its own database for estimation process.

(c) Final cost evaluation based on the results of the above investigations

- Based on Toshiba's investigation as described in a) and b) above, Toshiba developed a cost estimation of equipment and materials.
- For the items not listed in Table 4.2-6, if non-U.S. price of equipment is more competitive, the price of such non-U.S. product is selected for the cost estimates. Estimated percentage of these product is 13%, which includes turbine, generators, I&C and in core monitoring equipment.

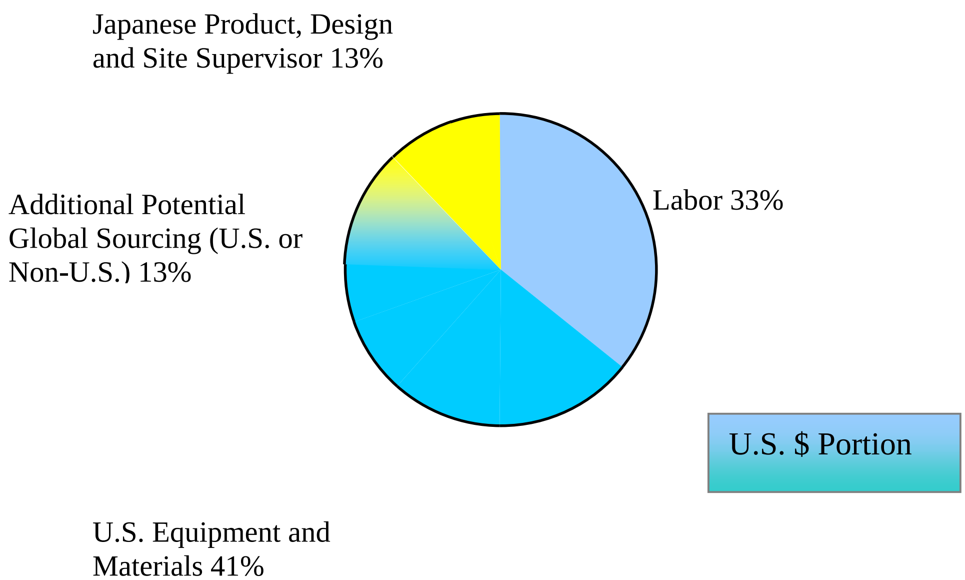


Figure 4.2-2 Cost Breakdowns by Origin

(d) Reference to GE database of Lungmen and other data

- GE has a database for procurement of equipment for ABWR. GE developed the database through the experience of Lungmen ABWR project and bid for ABWR in Finland. Using this database, GE evaluated cost information for Bellefonte ABWR (taking into account U.S. specifications and escalation)

- Toshiba provided GE with the values of existing facilities that can be used. GE incorporated such input from Toshiba for the Bellefonte ABWR cost estimate.

(2) Equipment in yard facilities

Costs for equipment in yard facilities were mainly developed by Bechtel through its historical database and direct contact (in the form of RFQ) with potential suppliers of equipment. Toshiba and GE reviewed the equipment costs for all these items and compiled the cost data.

(3) Bulk material cost

Costs for bulk material such as piping, cable and duct were evaluated by Toshiba utilizing their in-house database and direct contact with potential suppliers of each material (in the form of RFQ) with appropriate price adjustment for deployment in U.S.

GE participated in the overall cost review with Toshiba for the bulk materials and Toshiba and GE determined the equipment and material cost.

(4) Module assembling costs

- The assembly cost for modules was evaluated for both on-site modules and off-site modules.
- Toshiba contacted potential suppliers of assembling services in the U.S. and obtained cost information for off-site modules. (Full cost of off-site module is categorized as equipment cost)
- Because on-site modules are assembled at job site, Toshiba evaluated labor hours of the module based on the quotation of U.S. A/E companies. (Costs of on site modules are split into both equipment and labor cost)
- Technical explanation on module assembling is described in Section 4.1.2.1

(5) Other cost

(a) O&M cost

- Radwaste treatment systems are different between the U.S. and Japan. In the U.S., some of the radwaste treatment systems are not capitalized but expensed in the O&M account under an appropriate leasing arrangement of the equipment. This system is the reverse osmosis system which treats laundry drains and high/low conductivity waste water. This is the same arrangement as applied by TVA at Browns Ferry. The equipment and installation cost of the reverse osmosis system is not included in the EPC cost.
- Just for reference purposes, the cost of the above-mentioned is approx. $10M if capitalized.

(b) Salvage cost

- This study incorporated cost savings by salvaging (e.g. re-sale of used construction equipment in the market, following completion of the project). The cost savings amounts were evaluated through past experience.

- The following items are considered to have a value after the construction
  - Large Cranes
  - Purchased tools and construction equipment

(6) Commodity price spike incorporated for 2004 dollars

Some commodities experienced a price spike during 2003 and 2004 in comparison with previous years. This is partly due to very strong demand from China. The EPC costs in this study are based on 2004 dollars and as such price spikes have not been eliminated completely. Therefore, 2004 commodity prices are overstated in this report. As an example, Figure 4.2-3 shows producer price index for "Iron and steel" and "Nonferrous wire and cable". Considering that the actual order of major equipment for the project will be after 2009, the extraordinary price spike is anticipated to end before that time.

4.2.3 Construction Cost

4.2.3.1 Summary

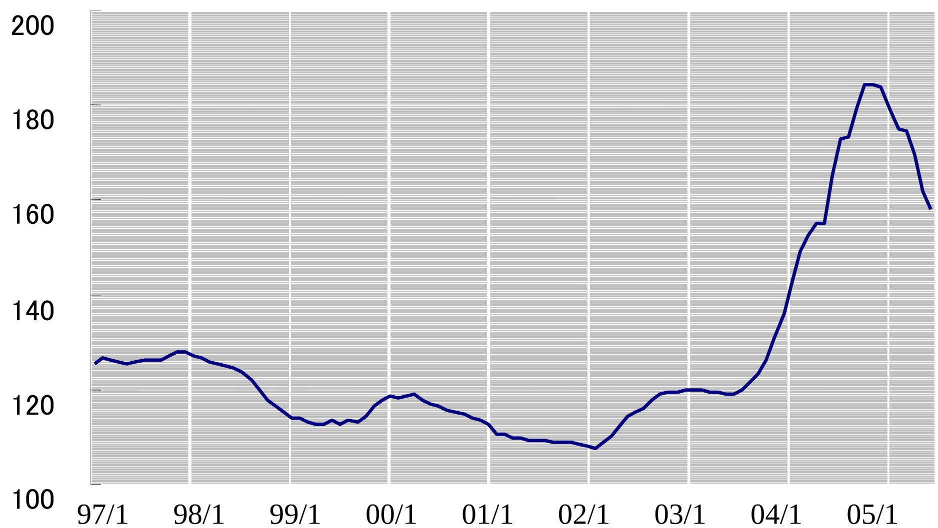
- Toshiba has taken the lead in the construction cost evaluation. Toshiba collected information on U.S. construction business and related issues from U.S. A/E companies including Bechtel, and from various documents. Toshiba evaluated the construction costs based on the information obtained.

- Bechtel and other A/E companies provided Toshiba with information on construction costs, including direct labor costs, indirect labor costs and wage rates. Bechtel also performed labor survey in surrounding area of the Bellefonte site.

- Based upon the information obtained from Bechtel and other A/E companies as well as the information from various documents, Toshiba incorporated and evaluated several elements to improve productivity. Elements such as finalizing the design prior to commencement of construction work and proven Japanese construction technology (open top method and advanced modularization program) were incorporated.

- Toshiba analyzed detailed construction processes with the A/E companies. The detailed analysis includes the analysis of productivity difference between U.S.

Group: Metals and metal products **Item:** Iron and steel
Source: Department of Labor, Bureau of Labor Statistics



Group: Metals and metal products **Item:** Nonferrous wire and cable

Source: Department of Labor, Bureau of Labor Statistics

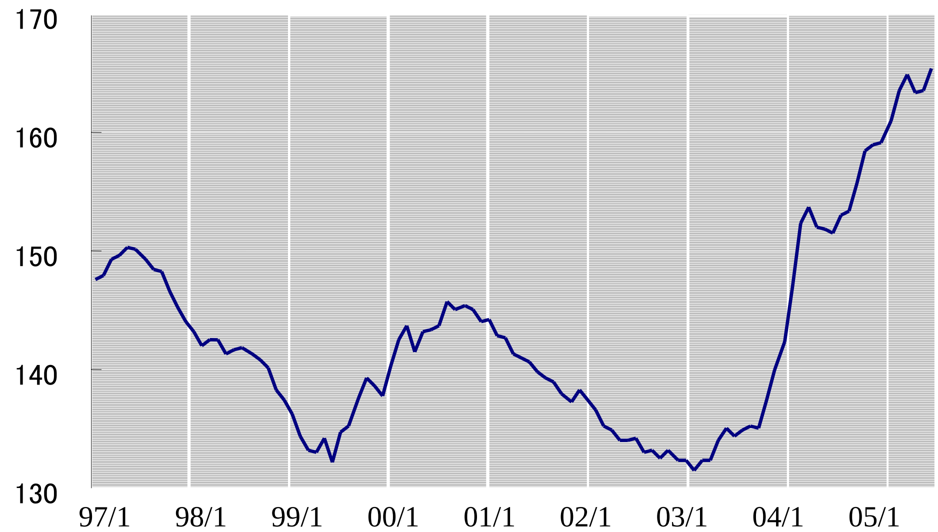


Figure 4.2-3 Producer Price Index-Commodities

and Japan, using Visualized Work Process Analysis (VWPA)[4], crew system and union practices.

- Through the extensive discussions with A/E companies and based on the information obtained from them, Toshiba determined the most appropriate and achievable unit rates[5]. In estimating the labor costs, Toshiba utilized wage rates Bechtel developed for the Bellefonte site area.

GE independently evaluated unit rates and construction costs for the Bellefonte project and exchanged the cost information with Toshiba. GE and Toshiba have found that the result of the independent evaluation of the construction costs (both manual labor and distributable) are in an acceptable range and agreed on these costs as follows:

Manual Labor Cost:	938M$
Equipment and material construction services and Field service and field office service:	327M$

4.2.3.2 Evaluation process

(1) Estimating manual labor Cost

(a) Estimating unit rate

Toshiba had U.S. A/E companies estimate construction costs based on the quantities provided by Toshiba. Bechtel provided the quantities for the yard facilities. The unit rates vary among the A/E companies.

As a result, it was found that average unit rates in Japan are significantly less than unit rates in the U.S..

Toshiba further improved the unit rates due to completion of design and application of new advanced features of Japanese innovative and sophisticated construction technologies (to be presented in later part of this report) including,

---

[4] VWPA : Focusing at a typical process of a certain installation scope, a method of analyzing installation time and number of workers required as well as location of each workers using punch or cartoon. Toshiba uses VWPA in installation work planning in Japan

[5] Unit rate represents the number of labor-hours required to install one unit of work (e.g. a cubic yard for concrete, a linear foot for piping)

- Completed design document
  - Completed design at the start of construction
  - 3D design including conduits, instrumental tubing, and embeds
  - Minimum rework by design changes
- Licensing under 10CFR 52
  - Certified design (DCD)
  - No impact from change and/or new regulations
  - Predictable Inspection program (ITAAC)

In addition, Toshiba and U.S. A/E companies conducted VWPA, a work process analysis. VWPA focused on a typical process of several installation work scopes. Under VWPA, work procedure, installation time and number of workers as well as location of each worker (craft/labor manning) were analyzed by each work process component to develop a detailed hourly schedule (or further detailed schedule, as necessary). Figure 4.2-4 is an example of the VWPA, installation of large bore piping.

Toshiba conducted VWPA in various areas including civil works, piping installation and electrical works. As an example, piping installation work was reviewed on large bore piping and small bore piping. Based on the detailed review of each component of the work, it was concluded that the procedures used in Japan and U.S. were not much different for large bore piping installation work. In case of small bore piping, the required man-hours in the U.S. are less than in Japan. However, the Japanese unit rates are significantly better.

It is reasonably assumed that the difference of the unit rate does not mean difference of each work process, but that the difference comes from other factors.

GE performed an independent estimate of unit rates to determine the total manual labor hours.

Toshiba and GE conducted joint reviews of total manual labor hours for the project and confirmed that they are in good agreement. Thus, the final construction costs were agreed and determined by the two parties. The unit rates Toshiba concluded applicable and achievable for the Bellefonte project are approximately 20% more than the Japanese rates.

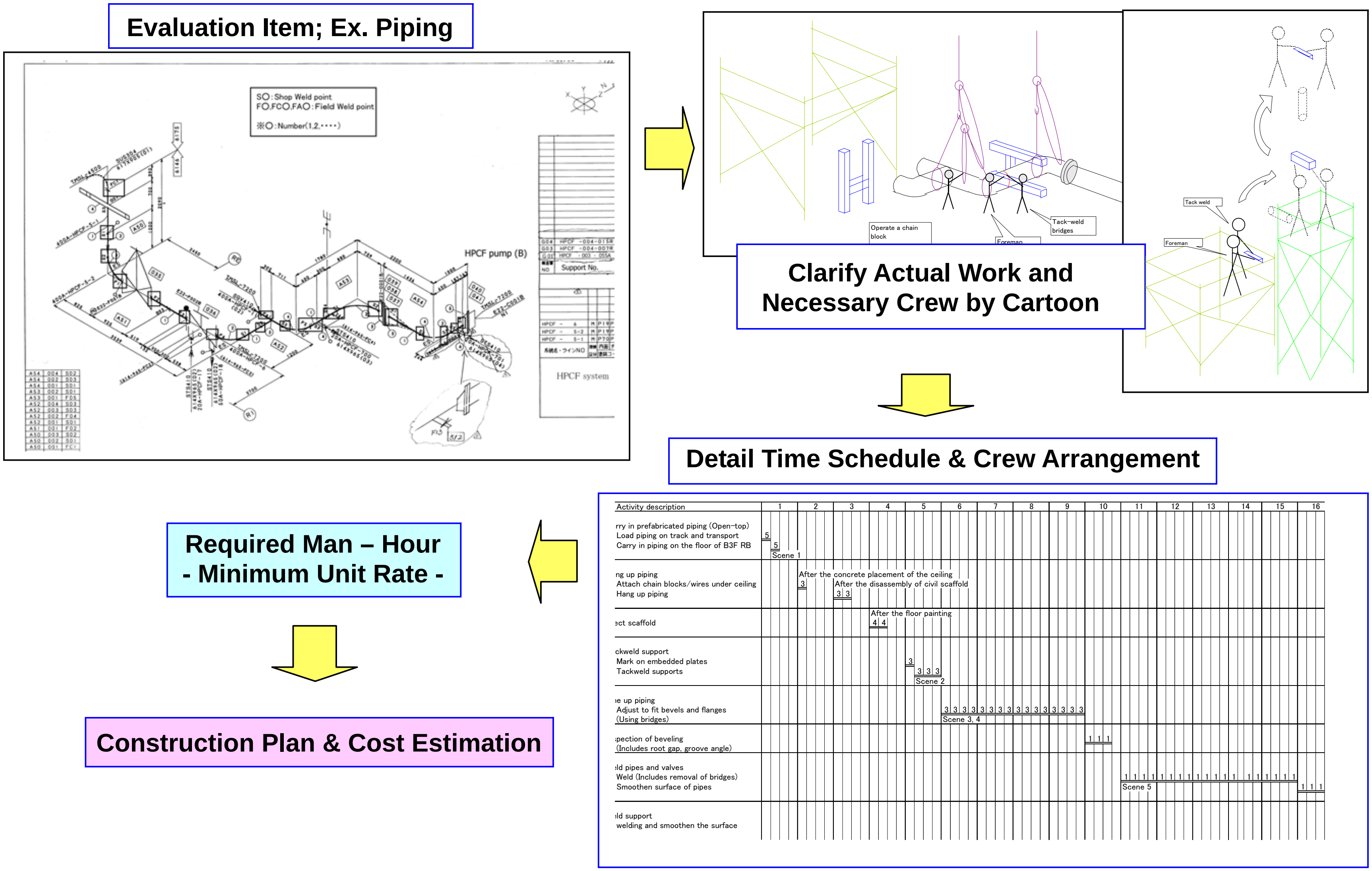


Figure 4.2-4 VWPA: Visualized Work Process Analysis - Large Bore Piping

(b) Introduction of Innovative Construction Technology of Toshiba

In the past, nuclear power plants have been continuously constructed in Japan and innovative construction technologies to reduce construction cost and schedule have evolved. Toshiba was instrumental in developing, verifying and demonstrating e such innovative technologies.

In this study, Toshiba applied these innovative technologies for the ABWR project at the Bellefonte site. Several examples of these innovative technologies are as follows (refer to Section 4.1 "Construction Schedule")

- Modularization

Aggressive module construction methods have been applied to RCCV installation process, one of the critical paths of construction activities. RPV internals are pre-assembled at the manufacturing plant and shipped to the construction site. The condensers are pre-fabricated at a manufacturing plant (including the cooling tubes). Off-site fabrication contributes to improve the first time quality and eliminates several work steps at the job site. Bulk commodities are installed in modules (piping, cable tray etc.) off-site (close to the construction site) for less work at the job site.

- Advanced module and open top construction method

Through integrated construction planning and management of delivery of large equipment as well as module engineering and construction, efficient control of equipment deliveries to the job-site are realized. A number of temporary openings are significantly reduced. Equipment and Bulk commodities (piping, cable trays, etc.) are moved to the installation location prior to the ceiling placement.

- Building composite structure

Girders and beams are integrated into the structural steel so that separate work for girders and beams can be eliminated. Due to the elimination of the work for girders and beams, the installation work of embeds becomes efficient.

- Deployment of very large-sized crane

The heavy components or modules such as RPV, Condenser and MSHR can be lifted by a very large-sized crane through open top, eliminating the needs for preserving temporary construction openings.

- 3D-CAD

In past construction projects, support for small piping, instrumentation , control systems and conduits（embedded，exposed） were designed and managed at the field engineering offices. Toshiba developed all its designs into 3D-CAD and integrated this with an interactive simulation system. This allowed a linkage to the construction schedule, manpower resources and material and equipment quantities (now 6D system). This is essential to optimize the construction sequence and schedule.

(c) Estimating composite wage rate

The wage rates were based on a labor survey (of the local unions) conducted by Bechtel in the Bellefonte area. It provided the hourly base salaries and fringe benefits for each of the different crafts performing the work. Bechtel uses a crew mix approach common in the industry to arrive at the effective wage rates, so that for concrete work, for example, a representative crew mix of carpenters, cement masons, laborers, etc. is used with a weighting of the individual salaries and fringes.

Additionally, the following journeymen to apprentice ratios are assumed:

Boilermaker:	90/10
Carpenter:	90/10
Cement mason	100/0
Electrician	90/10
Ironworker:	85/15
Laborer:	90/10
Operating Engineer:	90/10
Pipefitter:	90/10
Teamster:	100/0

The planned work week for the crafts is five, eight hour days (5 -8's) plus working every other Saturday plus 5% unscheduled overtime with 60% of the workforce on the day shift and 40% on the back shift (adding a shift differential premium for craft on second shift), was applied.

Finally, published Workmen's Compensation Insurance rates and State and Federal Unemployment Insurance as well as FICA taxes were added to the wage rates.

Eventually, the composite wage rates were calculated through bill of quantities determined in the Task 1 of this study and identification of respective crew teams by each work scope. The wage rates include an allowance for the premium portion for overtime.

The calculated composite wage rates (in 2004 value) are as follows

Concrete:	$30.61 (per man-hour)
Structural and other civil:	$32.90
Piping:	$34.70
Controls and instrumentation:	$36.43
Electrical Bulks:	$41.38
Manual construction distribs:	$29.58
Manual start up distribs:	$38.65

(2) Field Non- manual (NM) and Distributable

(a) Estimating NM labor

The non-manual job hours are based on a staffing plan which is based on a ratio of 1 superintendent for every 50 craft, 2 field engineers for every superintendent and 1 QC person for every 100 craft. Twelve engineers were included for 2 years to prepare packages. All departments were based on the 40-month (first reactor building concrete to fuel load) schedule. Additionally Toshiba optimized the number of positions to execute the project.

Non-manual wage rates are based on industry standards from the NECESS survey. Payroll additives are based on the Bureau of Labor Statistics for management/technical personnel and are calculated as 39% on all wages. Relocation and per diem costs were developed for the Bellefonte area and a 20% field non-manual labor turnover over the life of the project was assumed.

(b) Distributable costs

Distributables are classified and evaluated respectively as 1) temporary construction facilities/ utilities /services, 2) construction tools equipment and supplies, and 3) distributable craft labor.

- Temporary construction facilities / utilities /services

The temporary facilities (offices, warehouses, fab shops) are estimated based on historical costs on a $/sf basis adjusted for U.S. deployment. Other facilities /utilities are factored from current projects or priced from our historical data base including sewage treatment facilities, and temporary toilet facilities. The remaining costs are based on the site population and are priced from our historical data on a cents/job-hour basis adjusted for U.S. deployment, this would include temporary power, clean up and scaffolding. Other items are individually priced out such as guard services where we are able to identify both the quantity required and the duration need.

- Construction tools equipment and supplies

Small tool, consumable and safety equipment are price on a $ per craft hour from Toshiba's historical database adjusted for U.S. deployment. Rental of construction equipment durations were calculated on a rental plan quantifying the use of such equipment based on the Milestone Summary Schedule and the quantities required to execute the scope of the project. For the rental cranes, earthmovers, air compressors, welders, etc., monthly rental rates along with monthly fuel and maintenance costs were established by Bechtel Equipment Operations Company, which specializes in leasing heavy construction equipment. In the case of the large-sized cranes to pick the major heavy lifts (Demag 888) it was found to be more cost effective to purchase the crane. It was assumed that it could be resold for 50% of its value at the end of the project assuming additional needs for this size of crane. Salvage value for resale after job use or completion is also built into the cost estimate for small tools and construction equipment at a resale value of approximately 20% of original price.

- Distributable craft labor

Distributable labor job hours were developed from historical ratios between direct and distributable job hours

(3) Cost for module installation

Through past construction experiences in Japan, Toshiba improved technologies for module design, applicability and level of modular integration for the purpose of cost reduction and shortened construction schedule. Toshiba's technologies are described in more detail in Section 4.1.2.1.

Besides the modular design technology, optimization of module application has been thoroughly reviewed and understood through the construction experiences. An optimized modular construction is different from site to site and Toshiba evaluated factors such as productivity and wage rate at the prefabrication facility and job site as well as the transportation costs of each component, spool or module. Then, Toshiba determined levels of modular integration of each f component and spool. The optimization process requires significant level of construction expertise and experiences.

Through extensive discussions with various U.S. A/E companies indicated that the labor costs at the job site are more expensive than in pre-fabrication facilities.

Therefore, for the basis of this cost evaluation, Toshiba assumed more modules and improved level of integration at Bellefonte ABWR project than in Japan. (Ref. Section 4.1.2.1 for applicability of module technology)

4.2.4 Engineering and Project Administration Costs

4.2.4.1 Summary

Toshiba and GE evaluated Engineering and Project Administration Costs considering DCD/FOAKE, construction designs in Japan and Lungmen, as well as the Bellefonte site specific designs.

The engineering and project administration costs are reflected in design work collaboration between GE and Toshiba, as discussed in Chapter 5, Project Deployment Model.

4.2.4.2 Scope of engineering and project administration costs

The scopes categorized in Engineering and Project Administration Costs are as follows:

- Plant Arrangement / Layout

- Mechanical and Piping
- I&C and Electrical
- DCIS
- Simulator
- HVAC
- System Integration / Performance
- Project Management
- Home Office Support Services (Cost and Scheduling, Finance, Sourcing/Contracts, Quality assurance, IMS, Configuration Management, others)

For reference, due to the advanced design of the ABWR, its construction at multiple locations and certification in the U.S., the following engineering work already has been performed to support the COL application:

- Basic design (general document, plant heat balance, system design description, P&ID, logic diagram, general arrangement, single block diagram, etc.)

4.2.4.3 Key assumptions

There are several U.S. ABWR design documents applicable for the Bellefonte ABWR project such as DCD, FOAKE and Lungmen design documents. Japanese advanced design features will also be incorporated into the U.S. ABWR design documents. As discussed in Chapter 5, Project Deployment Model, GE and Toshiba will share the documents and work together to develop the design of the ABWR at the Bellefonte site. The incremental design work scope required for the Bellefonte ABWR will be as follows:

- Changes from DCD (refer to Chapter 3)
- T/B, S/B and RW/B design
- Yard facility engineering

Since the Bellefonte ABWR is a twin plant project, the incremental engineering cost for the second unit is significantly lower than the first unit. In other words, incremental design costs for the second unit are limited to:

- Project Management
- Home Office Support Services (Cost and Scheduling, Finance, Sourcing/Contracts, Quality assurance, IMS, Configuration Management, others)
- Interface between common facilities (RW/B, S/B, RSW/B) and the second unit, where the symmetrical location or construction planning is not possible

Taking those factors into consideration, Toshiba and GE judged that the engineering costs for the second unit of the ABWR twin plants is 25% of that of the first unit.

Figure 4.2-5 shows the relationship of design costs for Bellefonte ABWR compared to other new designs.

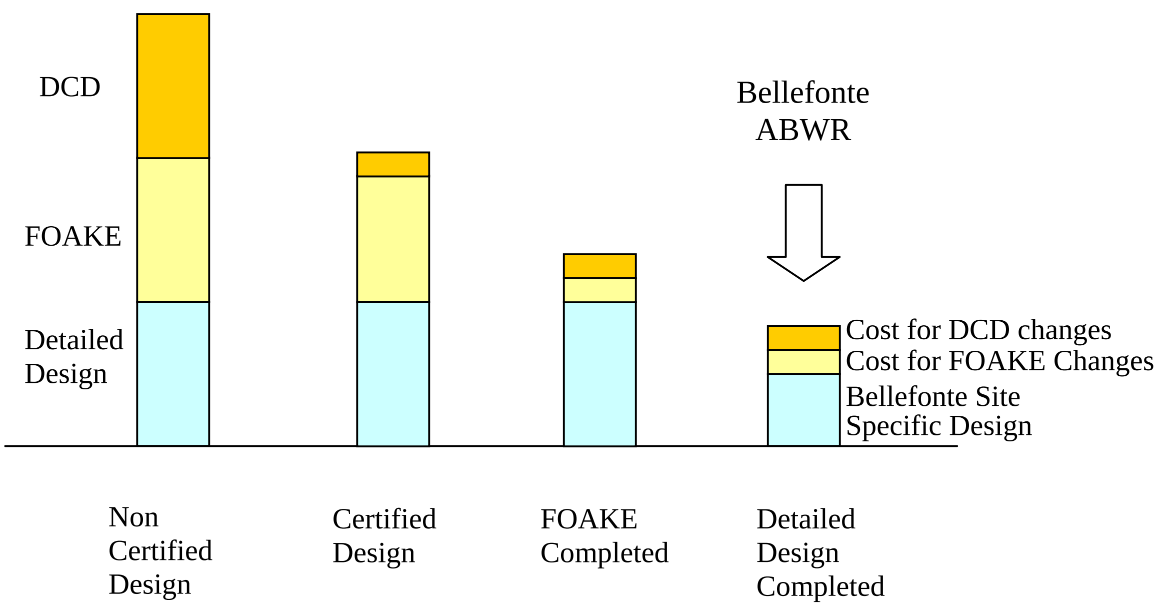


Figure 4.2-5 Bellefonte ABWR Design Cost

4.2.5 Construction Lag Costs

4.2.5.1 Summary result

In this study a 2-year lag time between the 2 units was assessed in addition to the base case of a 1-year lag time. An evaluation of the impact for the 2-year lag time to the cost was performed in the following areas:

- Permanent Plant Equipment
- Construction
- Engineering and Project administration

The result is summarized in the Table 4.2-7 below. In the case of the 2-year lag, the construction cost will be slightly reduced by eliminating the second heavy lift crane. The total project cost for the 2-year lag time, however, will increase. This is due to the loss of the advantage of simultaneous manufacturing of equipment for both units or storage costs for second unit equipment materials at one time which offsets the cost saving by eliminating the second heavy lift crane.

Table 4.2-7 Construction Lag Cost Evaluation Result

<table>
<tr><th colspan="2">Items</th><th>Impact to Cost
1-year lag versus 2-year lag</th></tr>
<tr><td rowspan="2">Permanent Plant Equipment</td><td>Equipment</td><td rowspan="2">+++</td></tr>
<tr><td>Bulk material</td></tr>
<tr><td rowspan="7">Construction</td><td>Large-sized crane</td><td>- - -</td></tr>
<tr><td>Medium-sized crane</td><td>+</td></tr>
<tr><td>Small cranes & equipment</td><td>- -</td></tr>
<tr><td>Direct labor</td><td>(- Potential)</td></tr>
<tr><td>Indirect manual labor</td><td>(- Potential)</td></tr>
<tr><td>Field non-manual labor</td><td>++</td></tr>
<tr><td>Site temporary materials and equipment</td><td>++</td></tr>
<tr><td rowspan="2">Engineering and Project administration</td><td>Engineering</td><td>No impact</td></tr>
<tr><td>Engineering and project administration</td><td>++</td></tr>
<tr><td colspan="2">Total</td><td>+++</td></tr>
</table>

(Notes) +++: Increase over 10MM$, ++: over 1MM$, +: less than 1MM$
- - -: Decrease over 10MM$, - -: over 1MM$, -: less than 1MM$

It is concluded that the 1-year lag construction schedule is more cost effective than the 2-year lag construction schedule.

This conclusion is drawn by the above assessment in the areas of EPC Overnight Cost and is reinforced by considering areas of other costs that constitute total capital cost at commercial operation.

4.2.5.2 Lag cost evaluation and assumption

(1) Permanent Plant Equipment

The cost estimate of this study is based on the 1-year lag time. It minimized the procurement cost by common engineering, sourcing materials, manufacturing, QA inspections, testing, creation of temporary tools and administration of purchase orders at the vendors shop.

The 2-year lag time may lose the advantages of the 1-year lag time because some vendors may have a different order control for extended lag. When equipment for the 2 units is manufactured, storage costs and associated interest cost for the additional year will be required. Equipment cost is approximately one third of the total plant cost. It is concluded that a significant cost savings for equipment for the 1year lag time will be achieved relative to the 2-year lag time. The cost impact for procuring bulk materials may not be as great as equipment since these materials are usually procured in large quantities regardless of the lag time.

(2) Construction

- Large-sized crane

One advantage to the 2-year lag is the elimination of the need for the second heavy lift crane. Upon setting the unit 1 reactor pressure vessel (month 21) the heavy lift crane can be disassembled, relocated to unit 2 and reassembled in time to start the setting of unit 2 modules in month 24.

- Middle-sized crane

To complete the heavy lifts on unit 1, which consists of the reactor building and turbine building truss modules and overhead cranes, a temporary semi-heavy lift crane could be utilized. The temporary crane would be shipped to the site, erected in unit 1 to make the final lifts and disassembled and demobilized over a 7-month period.

- Small cranes & equipment

Another advantage to the 2-year lag is the elimination of additional cranes and other equipment, which would be required in unit 2 should a shorter lag time duration be used.

- On site labor

With regard to on site labor, the 2-year lag, while adding Field Non-Manual (FNM) man-hours, has the potential advantage of cascading the experienced labor from unit 1 to unit 2. This is desirable because experienced labor will incorporate unit1 lessons learned resulting in more productive second unit. This will also keep the peak labor force lower and more manageable adding additional confidence that the overall schedule can be maintained.

(3) Home office engineering and project administration

Engineering and project administration man-hours vary depending on the overall project duration. The longer duration resulted in the increase of such man-hours.

(4) Other benefits

In addition to the discussions associated with EPC Overnight Cost as identified above, there are other benefits to the 1-year lag. They are savings of owner's cost, escalation during construction, interests during construction and potential loss of revenue associated with another year duration.

4.2.6 Uncertainties and Contingency Assessment

4.2.6.1 Summary

The delivery team has analyzed major causes of significant costs and schedule over runs in the U.S. commercial nuclear power construction in order to identify an appropriate level of uncertainty and contingency for the Bellefonte ABWR project.[7]

The ABWR is the only design certified by the NRC with extensive construction and operating experience. Therefore the risk to overrun the cost and schedule is minimized compared to other new reactor designs. Some of the risks within the scope of the study are listed in Table 4.2-8.

4.2.6.2 What is included or not included in the study

[7] A cost contingency is included in the project price. This contingency is proprietary. It has been established based on standard terms and conditions and considering the risks listed in Table 4.2-8

Table 4.2-8 summarizes some of the more significant risks which must be independently reviewed based on the actual terms and conditions to be negotiated. Therefore, it is not appropriate to discuss these in detail in the absence of applicable terms and conditions.

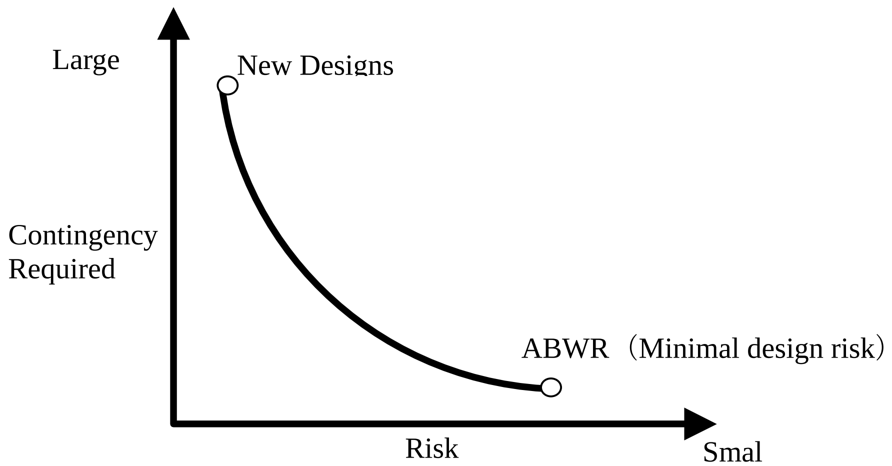
The EPC costs developed in this study are indicative prices based on mutually agreeable terms and conditions and site conditions for a firm fixed price offering. However, contingencies may need adjustment in accordance with the terms and conditions actually negotiated. The following should be considered to evaluate appropriate contingencies.

- The ABWR detailed design has been completed. Construction experience has been accumulated in Japan and Taiwan. Uncertainty and associated risks are limited. There are no additional costs required to develop or verify newly designed equipment performance.

- There are, however, challenges for the nuclear industry to resume constructing nuclear power plants in the U.S. Therefore, the ABWR retains the advantages of offering a fixed price contract based on the completed and readily available detailed design.

Toshiba has demonstrated it competencies in the construction arena to 1) plan detailed construction sequences and manage them, 2) recover delays during the construction period to minimize the impact and 3) provide a supply chain management integrated with detailed construction and inspection plan. These competencies accumulated by Toshiba will minimize the risks associated with construction work including ITAAC.

The ABWR project at the Bellefonte site is the most credible option to minimize the risks and uncertainties for near term new nuclear deployment. Figure 4.2-6 conceptually illustrates a comparison of uncertainty between the ABWR and other new reactor designs. The ABWR at the Bellefonte site will become the 7th unit worldwide.



With Toshiba's involvement in construction management, the ABWR risk component is reduced even further.

Figure 4.2-6 Uncertainty Comparison: ABWR and New Reactor

Table 4.2-8 Examples of Risks and Uncertainties to be Reviewed with Actual Contractual Terms and Conditions

Risk Item	
Market related risks	Exchange Rate
	Material/equipment escalation
	Labor rates
	Non-project strike or labor dispute
Schedule over run or additional cost increase to recover delays	Delay of equipment delivery
	Design Changes
	Regulatory Changes
	Scope adjustment
	Force Majeure（natural disaster etc.）
Other major items depending on the terms and condition including	Limit of liability Insurance coverage Liquated damages Security type requirement (Performance bond etc.)
Performance Warranty	

4.2.7 Opportunities for Further Cost Reductions

The results presented in this study could be improved by further detailed evaluations, technology transfer programs, and contractual schemes which could be applied through the process of detail engineering and construction preparations. As a result the study cost and schedule numbers can be viewed as a realistic starting point and may be reduced by detailed evaluations considering the following factors.

(1) Current price spike in the market

(2) Large yard facilities at the Bellefonte site

(3) U.S. construction productivity

(4) Competitive bids at the contract stage

(5) Contingency reduction on future projects

(6) Government support

Each of these factors is described briefly below:

(1) Current price spike in the market

As shown in Figure 4.2-3, the recent Chinese economy boom increased the global market price of many raw and manufactured materials, such as steel, between 2004 and 2005. Since the cost assessment for the study was performed beginning in August of 2004, the influence of the price spike is included in this study. This price spike affected the equipment and material cost in this study.

However as Figure 4.2-3 also shows, this increase in material price is stabilizing and by the time actual procurement for future plants occur, prices could be expected to be de-escalating.

(2) Large yard facilities at the Bellefonte site

Use of existing facilities at the Bellefonte site resulted in some inefficiencies in the plant lay-out. In order to connect to existing facilities, primarily associated with the circulating water system, additional material quantities were required. A green field site would not necessarily require these extra costs. At the Bellefonte site, these additional costs are offset by utilizing the existing facilities.

The major factors contributing to the increases in the yard construction costs are listed below:

(a) Additional Ultimate Heat Sink (UHS)

(b) Additional mechanical cooling tower and circulation water piping and cables

(c) Longer main circulation water piping and cables

(d) Longer auxiliary piping and cables including safety system

(3) U.S. construction productivity

Construction productivity evaluated as Unit Rate is the dominant factor for the construction period and cost.

It is believed that nuclear plant construction productivity in the U.S. can potentially be improved to that achieved in Japan.

One significant opportunity for increased productivity in the U.S. is increased use of modularization to reduce the field installation work. As described in Chapter 4.1, modularization for the Bellefonte ABWR was optimized based on the experience of Japanese ABWR. Further extension of modularization scope with less fieldwork could further reduce the total cost.

(4) Competitive bids at the procurement stage

The cost estimated in this study was based on the actual quotation from multiple equipment and material sub-suppliers, however these costs are quoted as "study". Accordingly, it is anticipated that bid prices at the actual procurement stage could be lower. An example is electronic online bidding or use of multiple project agreements for procurement of materials, equipment and construction services.

(5) Contingency reduction on future projects.

The estimated cost presented in this study is a fixed firm price including standard commercial terms and conditions and a project contingency. For future projects, this contingency could potentially be reduced by removal of uncertainties due to construction experience and negotiations of terms and conditions.

(6) Governmental supports

The recently passed U.S. Energy Bill contains some incentives available to Private utilities that are not available to TVA e.g. tax credit.

4.2.8 Conclusion

The construction cost evaluation performed as part of this study incorporates specific parameters at the Bellefonte site. This cost evaluation is the only comprehensive and detailed evaluation among new nuclear deployment cost studies conducted in recent years.

The overall EPC costs to TVA concluded in this study are 1,611$/KW (1371MW), 1535$/KW (1465MW). They are based on the experienced construction scope and schedule of ABWR plants in Japan. The results have been reviewed by GE and compared against GE's worldwide construction experience including its on-going ABWR project experience in Taiwan. Toshiba and GE agreed on the results of this study.

The ABWR is the only design certified by the NRC with extensive construction and operating experience. Therefore the risk to overrun the cost and schedule is minimized compared to other new reactor designs.

Toshiba has demonstrated its competencies in the construction arena to 1) plan detailed construction sequences and manage them, 2) recover delays during the construction period to minimize the impact, and 3) provide a supply chain management integrated with detailed construction and inspection plan.

The ABWR detailed design has been completed. Construction experience has been accumulated in Japan and Taiwan. Uncertainty and associated risks are limited. There are no additional costs required to develop or verify newly designed equipment performance. Therefore, the ABWR retains the advantages of offering a firm price based on the completed and readily available detailed design.

4.3 FUEL MANAGEMENT AND FUEL SUPPLY PLANS

4.3.1 ABWR Core and Fuel Description

The fundamental characteristics of the ABWR core and the associated fuel are described in this section. The ABWR core is similar to existing BWR cores and can accept fuel bundles that are applicable to GE BWR/4-6 with minor mechanical modification for fit up in the reactor. The ABWR core configuration is presented in Figure 4.3-2. Fuel experience in other GE BWRs is applicable to the ABWR core. The fuel bundle geometry within the channel for application to ABWR is identical to an application to a GE BWR/4-6. The following key characteristics are noted:

- The bundle pitch (N-lattice) is increased by 100 mils (i.e., 6.1" vs. 6.0")
    - Provides ~1% improvement in CSDM vs. C-lattice deriving from increased bypass gap width.
    - Reduces the magnitude of the void reactivity coefficient which has a favorable impact on core stability.
- Favorable system response to Anticipated Operational Occurrences (AOOs) resulting in low OLMCPR
    - Supports high bundle power.

The ABWR specific characteristics noted above provide for excellent core performance, particularly when coupled with advanced fuel such as GE14.

The GE14 fuel design (Figure 4.3-1) is well suited for application to the ABWR as it has excellent power producing capability and its performance has been proven in reload application. GE14 is an advanced 10x10 fuel design with Zircaloy ferrule spacers providing for high critical powers and part length fuel rods for excellent thermal hydraulic characteristics. As the key components in GE14 do not change when applied to the ABWR, the excellent performance achieved in the existing fleet is applicable. The lead exposure of GE14 is ~57 GWd/MT bundle average while its 10x10 predecessor (GE12) has achieved exposures of 68 GWd/MT (note that the key components are identical). Application of GE14 to the Bellefonte ABWR will result in confidence in reliability, with performance that is superior to the existing fleet.

4.3.2 Fuel Cycle Analysis

In order to establish a fuel cycle projection to determine fuel cycle costs associated with initial and reload cycles, two different Energy Utilization Plans (EUPs) were analyzed. The first EUP, referred to hereafter as "Option 1", consists of 2-year cycle lengths for all cycles.

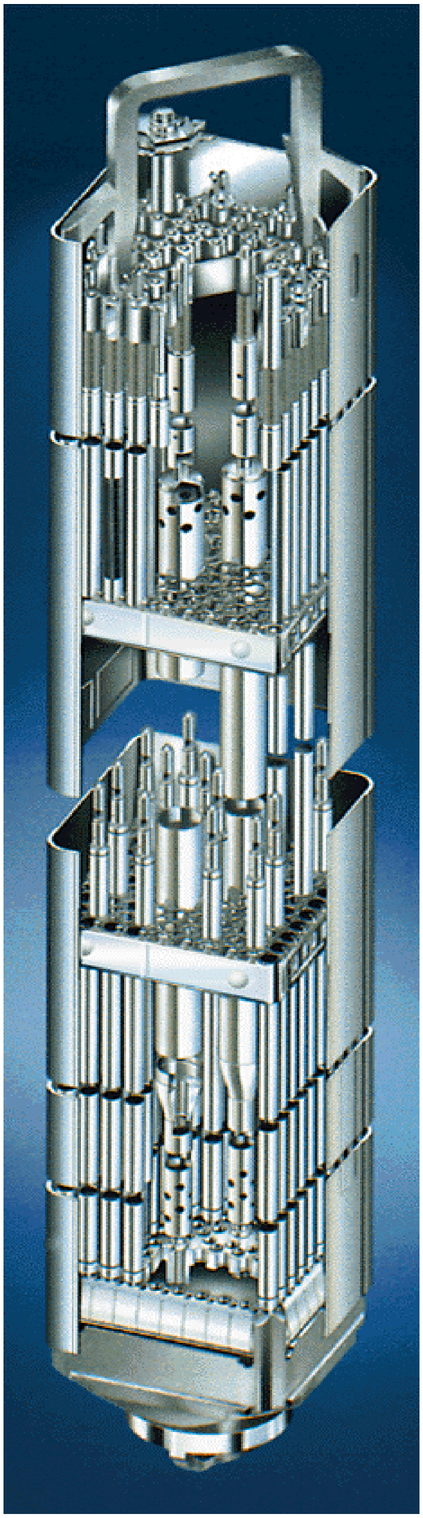


Figure 4.3-1 GE14 Bundle Configuration

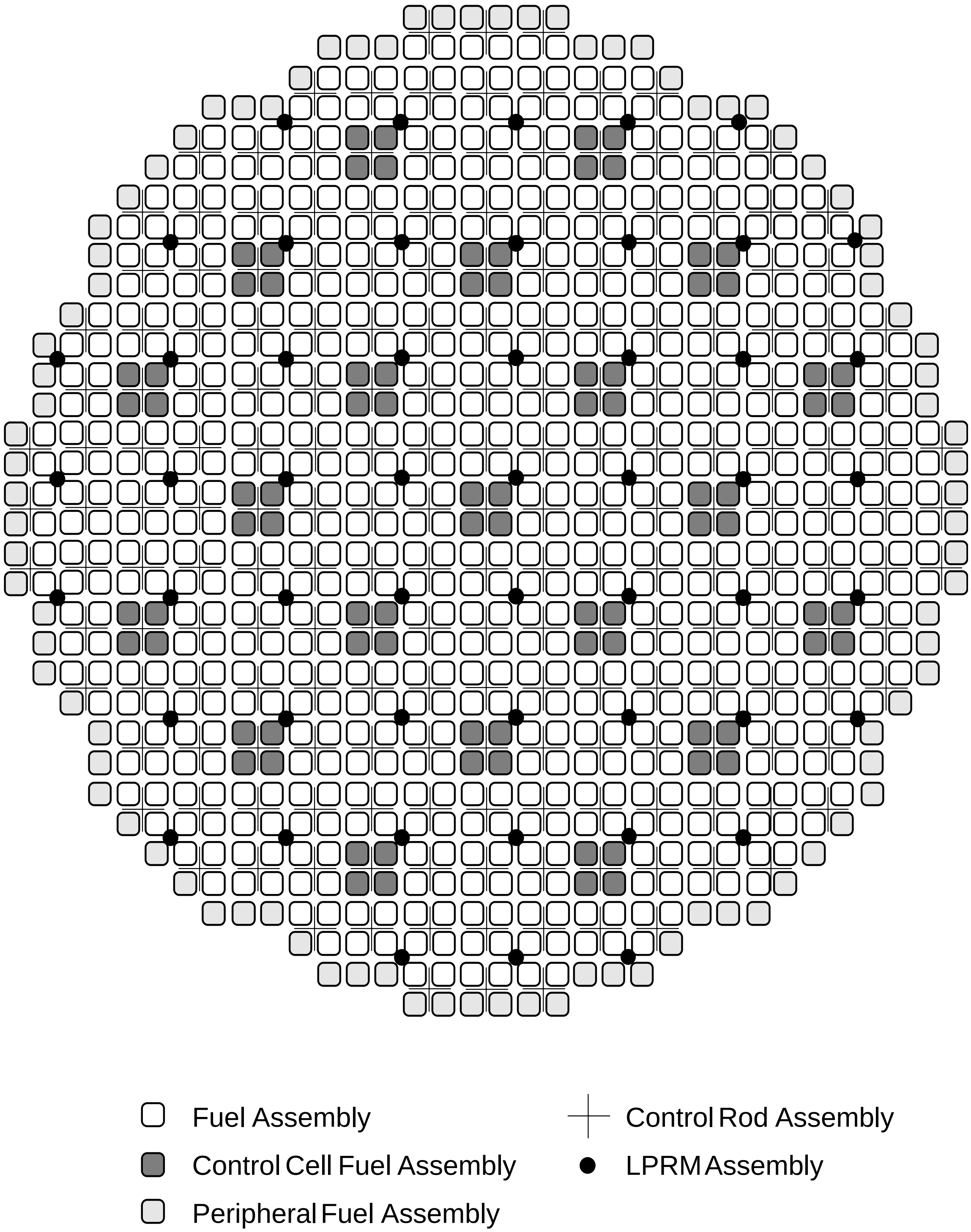


Figure 4.3-2 ABWR Core Configuration

The second EUP, referred to hereafter as "Option 2", consists of an initial 1-year cycle and 18-month second and third cycles. All subsequent cycles are 24 months long. The following table summarizes both EUPs:

Table 4.3-1 Energy Utilization Plans

	OPTION 1		OPTION 2			
	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Thermal Power Rating, MWth	3992	3992	3992	3992	3992	3992
Refueling Interval, months	24	24	12	18	18	24
Operating Capacity Factor, %	0.96	0.98	0.96	0.98	0.98	0.98
Cycle Length, EFPD	677	691	326	512	512	691
Outage Lengths, days	25	25	25	25	25	25
Target Cycle Energy, MWd	2,701,786	2,758,073	1,302,989	2,044,104	2,044,104	2,758,073

All cycles demonstrated compliance with reactivity design limits (hot excess and cold shutdown margin), thermal limits (MFLCPR and MFLPD) and exposure.

In Option 1, the equilibrium cycle was first designed to establish target bundle enrichments for the initial cycle. The initial cycle was then designed to have as many enrichment streams in the core as the equilibrium core in order to reach equilibrium as quickly as possible and to achieve a high initial core discharge burnup. The second cycle was designed with similar bundles to the equilibrium bundles. Cycle 3 and subsequent cycles all utilize the equilibrium bundle designs. Table F-1 of Appendix F summarizes the fuel utilization for Option 1.

In Option 2, since the initial cycle is a 1-year cycle, it is not feasible to load bundles of enrichment levels comparable to the equilibrium bundles as was done for Option 1. Instead, the initial cycle is loaded with lower enrichment suitable for 1-year cycles. The transition to 2-year cycles is then performed gradually by having cycles 2 and 3 operate for 18-months. Although an explicit calculation was not performed, it is expected that the fourth cycle can be transitioned to a 2-year cycle with a batch size comparable to the equilibrium batch size. Table F-2 of Appendix F summarizes the fuel utilization for Option 2.

The fuel designs for both options along with the core loadings and the performance characteristics are described in detail in Appendix F.

An equilibrium fuel cycle evaluation was performed using the fuel design GNF2. A detailed description of the GNF2 Fuel is included in Appendix F along with a performance comparison to GE14.

4.3.3 Schedule and Licensing Considerations

Assuming TVA's board of directors approves the preparation of a Combined Operating License Application (COLA), several key milestones must be met in order to assure commercial operations by 2014. The following figure illustrates these key milestones.

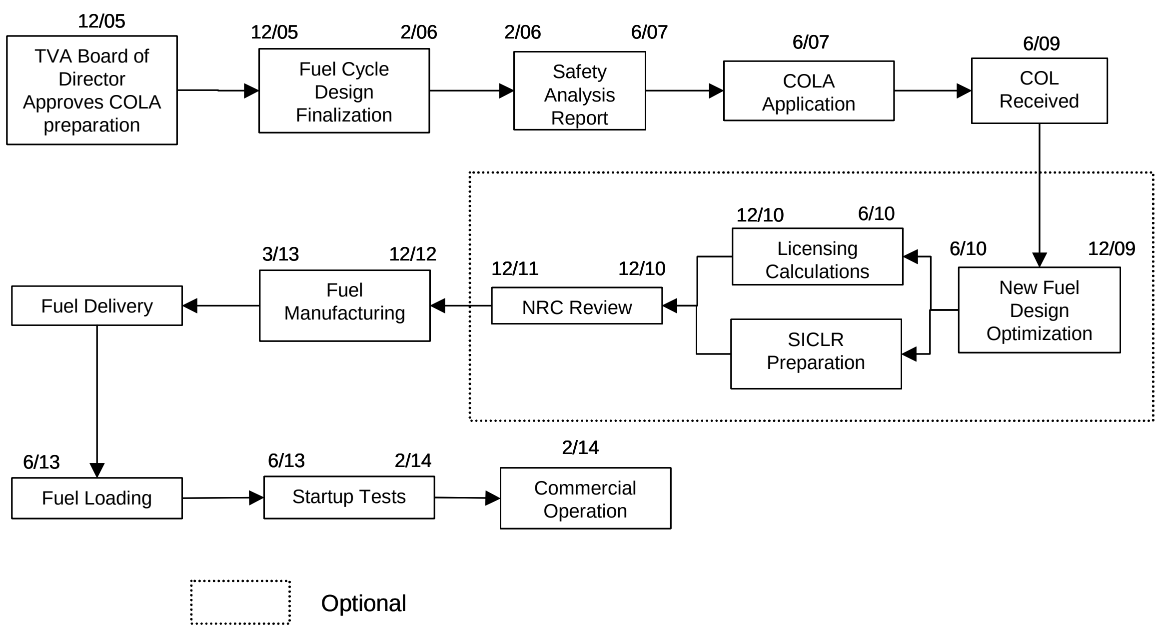


Figure 4.3-3 Integration of Fuel Design Schedule

The fuel design has been developed as described in Section 4.3.2. However, additional preparations to perform the Safety Analysis Report (SAR) are required as shown in the schedule. The COLA would be submitted in mid 2007 with an expected approval in mid

2009. With the current schedule, the final core design would be completed approximately 7 years prior to Fuel Load. Therefore, since significant time would have elapsed, new fuel designs (e.g., GNF2) are expected to be available. This would warrant an optional fuel design optimization step as shown in Figure 4.3-3 (inside the dashed line box). The licensing approach, relating to core and fuel, are described in the following paragraphs.

4.3.3.1 Conventional approach

The conventional approach is characterized by the development of a Reference Core design, based on the most current fuel bundle design (GE14), to support FSAR safety analyses and this core is then actually loaded (including the nuclear design of the bundles and core loading pattern). In this approach, the Energy Utilization Plan and Design Basis would be established in early 2006 to support detailed design work that would initiate in 2006. Sufficient multi-cycle analysis would then be required to satisfy the requirements of a Release Category fuel cycle resulting in an Initial Core Reference Loading Pattern. During FSAR preparation, all of the references cited in the FSAR (e.g., GESTAR II) would require review and their applicability confirmed. It is judged that this approach has the lowest uncertainty related to achieving and maintaining an issued COL. Accompanying this approach, however, is the likelihood of absorbing some excess fuel cost (the magnitude is difficult to forecast at this stage). The sources of this excess cost can arise from insufficient study of potential core design options for the Reference Fuel Bundle (GE14) and/or fuel efficiency differences between the Reference Fuel Bundle (GE14) and Fuel Designs available at the time of Fuel Load (i.e., GNF2). GNF2 is expected to have 6 years of operating experience, in Reload quantities, at the time of the Bellefonte ABWR Fuel Load.

4.3.3.2 Alternate 1 – Supplemental initial core licensing report

One possible alternative is to proceed as described above but then to provide a Supplemental Initial Core Licensing Report (SICLR) in much the same way as is done for Reload cores with the SRLR. This would provide a mechanism to update the nuclear design of the Reference core and perhaps support a change in product line. It is expected that a change in fuel product from the original FSAR would require a similar scope of engineering work as that related to a reload fuel transition. The key consideration is whether there exists licensing flexibility to adopt such a process; it is conceptually very similar to what is routinely done for reload cores. For reload cores, the SRLR is not reviewed by the U.S. NRC. However, due to the uncertainty of the U.S. NRC's feedback to this approach, a one-year review period was included in the schedule. Note that the USNRC review can take a total of 2 years before it could impact the fuel manufacturing schedule and so it can be viewed that there exists significant schedule margin to support a change in Initial Core fuel design.

4.3.3.3 Alternative 2 – FSAR revision

Another approach to achieve the same design flexibility as described above with the SICLR is to simply plan for a revision to the FSAR (this step is designated as "licensing calculations" in Figure 4.3-3). The timing would support the overall project schedule and experience with reload licensing could be used as a template. In an approach such as this, it would be desirable to obtain agreement from the U.S. NRC that the processes used to develop the Reference FSAR are fundamentally approved as part of the initial review and any subsequent revision is automatically approved if the Reference processes and criteria are followed (much in the same way as GNF licenses new fuel designs with Amendment 22 to GESTAR II).

4.3.3.4 Summary

The conventional licensing approach is judged to have relatively low uncertainty but also relatively low flexibility. The alternatives described above have been developed to improve flexibility, but also introduce some uncertainty as to the requirements the U.S. NRC would institute (early agreement on the approach should be considered). Overall, the preferred approach will depend on the balance of economic benefit vs. the cost (additional licensing analyses) and the associated licensing uncertainty.

4.3.4 Fuel Supply Plans

4.3.4.1 Overview

This fuel supply plan was drafted for TVA's potential twin unit ABWR plant at its Bellefonte site in Hollywood, Alabama. There are two potential fuel supply options for the plant:

(1) The Isaiah Project Plan

The Isaiah Project Plan is the preferred option, which suggests that the Bellefonte plant can be fueled most economically by low-enriched uranium (LEU) derived from the U.S. government's stock of surplus highly-enriched uranium (HEU). The concept of the U.S. government donating surplus HEU to be recycled into fuel for new nuclear power plants (the Isaiah Project) was first proposed by USEC in 2003, and has been met with interest at the federal level. It builds on several HEU to LEU programs that have been successfully implemented over the past decade. This option is described in greater detail in Section 4.3.4.3.

(2) The Traditional Plan

The traditional plan is the less economical option, which outlines a more customary approach for providing the Bellefonte plant with LEU by enriching natural uranium. Two Global Nuclear Fuel (GNF-A) fuel management plans (Options 1 and 2) were evaluated to formulate cost estimates. This option is discussed in greater detail in Section 4.3.4.4.

4.3.4.2 Cost summary

The Isaiah Project Plan provides an initial core cost savings of approximately 60% -75% compared to the traditional plan (Option 1 or 2). The estimated fuel costs and fuel cycle costs of each initial reactor core and typical reload for the TVA Bellefonte ABWR under the potential options outlined above are detailed in Appendix F.6.1, F.6.2 and F.6.3, respectively.

4.3.4.3 Isaiah project plan

(1) Overview

The Isaiah Project is a proposal to address vital U.S. energy security, nonproliferation and national security objectives. It involves the construction of a limited number of new, advanced nuclear power reactors fueled primarily or exclusively by uranium recycled from the nation's stockpile of surplus HEU and nuclear warhead material. During an Isaiah reactor's projected 60 years of operation, the uranium equivalent of more than 2,000 nuclear warheads could be eliminated.

The initial amount of HEU assumed in this analysis is the 17.4 metric tons (MT) of surplus U.S. HEU that the National Nuclear Security Administration (NNSA) has indicated may be available for recycling into LEU fuel. This material makes up about ten percent of the 174.3 MT of HEU that the U.S. government has declared surplus military material, no longer needed for defense purposes. Following the downblending process, the 17.4 MT of HEU is expected to yield enough LEU fuel for several initial reactor cores, depending on reactor type.

Recycling surplus HEU through the Isaiah Project would be a cost-effective way for utilities to fuel new reactors. In this way, it supports the Administration's energy security initiatives, in particular DOE's Nuclear Power 2010 program, by helping to stimulate private sector support for the construction of the first new U.S. nuclear power reactors in 25 years.

Equally important, the program helps to eliminate NNSA's stockpile of surplus HEU and advances the Administration's nonproliferation objectives. Over the past decade, nuclear power plants have proven to be the most effective means of eliminating weapons-grade nuclear material. At the same time, international concerns surrounding the safety of worldwide stocks of HEU have been growing. Successful implementation of the Isaiah Project in the United States offers the President an opportunity to advance his February 2004 initiative against weapons of mass destruction (WMD) proliferation by challenging other nations to build reactors similar to that of Isaiah, thereby eliminating their own stockpiles of HEU.

The Isaiah Project would be a partnership between the U.S. government and the nuclear power industry. There would be five primary stages to the program:

(a) HEU supply

The U.S. government would supply weapons-grade HEU to be recycled into fuel. This enables NNSA to reduce its HEU security and storage costs, while advancing DOE's Nuclear Power 2010 program by providing incentives for new reactor construction.

(b) Formation of consortium

An Isaiah Consortium, which would be comprised of a group of nuclear industry fuel providers, would manage and finance the recycling of the HEU into LEU fuel (e.g., natural blend stock procurement, downblending, transportation, storage, etc.). The Isaiah Consortium would include USEC, the U.S. Government's Executive Agent for the U.S.-Russian HEU Agreement, and build upon a ten-year history of successfully managed and implemented HEU to LEU recycling programs involving U.S. and Russian warhead material.

(c) Downblending of HEU

Following U.S. government delivery of the weapons-grade HEU to the Consortium, the HEU would be downblended using natural uranium provided by DOE. The resulting LEU would be distributed between the U.S. government and a utility(s) in the manner described below.

(d) Possession of LEU by U.S. government

The U.S. government would take possession of the down-blended LEU fuel, less a percentage of LEU equal in value to the Isaiah Consortium's cost of managing and financing the recycling of the HEU into LEU fuel (recovery cost).

(e) Receipt of LEU by utility

The first utility or utility group(s) to commit to building one or more new reactors would be eligible to receive the recycled LEU fuel from the U.S. government. Because the U.S. government would be donating both the HEU and potentially additional natural uranium (depending on reactor type), the initial core of an Isaiah reactor would be effectively subsidized.

TVA's Bellefonte ABWR would be a strong Isaiah Project candidate. In addition, other new Isaiah nuclear plants, using ABWR or another advanced reactor technology, could be constructed by other utilities that wish to take advantage of the Isaiah program. Furthermore, the U.S. government's success in implementing HEU to LEU programs with the participation of private companies such as USEC suggests that the U.S. government could expand the Project beyond the initial 17.4 MT of HEU if desired.

The U.S. government would transfer weapons-grade HEU to a nuclear fuel industry group (the Isaiah Consortium) to be recycled into fuel (Figure 4.3-4). The initial amount of HEU involved would be the 17.4 MT of excess U.S. HEU that NNSA is considering making available for recycling. This material makes up ten percent of the 174.3 MT of HEU that the U.S. government has declared surplus military material, no longer needed for defense purposes. Once downblended, the 17.4 MT of HEU is expected to yield enough LEU fuel for several initial reactor cores depending on reactor type. For TVA's Bellefonte ABWR, the Isaiah Consortium recovers its processing costs by retaining a percentage of the downblended fuel, leaving enough LEU fuel for two initial cores. Additionally, approximately 25 percent of each initial core will require 0.711 percent natural uranium fuel from DOE inventory.

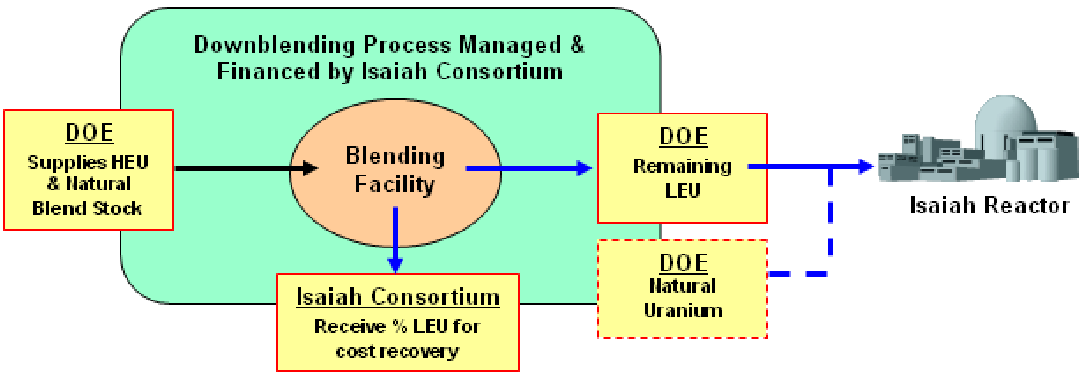


Figure 4.3-4 The Isaiah Consortium

The Isaiah Consortium would manage and finance all HEU processing activities, including transportation, HEU purification, downblending, LEU fuel storage, etc. A domestic company that can blend down HEU to LEU would be a member of the Isaiah Consortium so that this Consortium would be directly involved in the downblending process.

The Isaiah Consortium would then provide LEU fuel to the U.S. government while retaining a percentage equal in value to its processing costs. Lastly, the U.S. government would provide LEU to TVA for its new reactors upon commencement of commercial operations. This scenario is anticipated to result in significant fuel cost savings for TVA because the U.S. government will provide the LEU resulting from downblending and the natural uranium needed for the initial core at no cost. As is standard in this type of deal structure, TVA would be responsible for arranging for fabrication.

(2) Price estimates

The Isaiah Project is expected to provide new reactor owners with a very attractive means of securing initial reactor fuel cores. A competitive price for the initial cores could be achieved due to the U.S. government's donation of the necessary HEU and natural uranium. If the U.S. government supplies TVA Bellefonte ABWR with these without charge, the only remaining cost would be fabrication. The estimated costs of the Isaiah Project to TVA and the U.S. government are located in Appendix F.6.1, due to its proprietary nature.

(3) Isaiah project advantages

(a) Isaiah consortium supports program success

The HEU to LEU process is a proven success story. Over the past decade, several large programs have been implemented to recycle nuclear warhead material into reactor fuel:

- U.S.-Russian Megatons to Megawatts program to date has recycled 231 MT of HEU (equivalent to more than 9,200 warheads) into LEU fuel and will recycle a total of 500 MT of HEU by the end of 2013.
- USEC-DOE program is recycling approximately 65 MT of U.S. HEU into LEU fuel.

An Isaiah Consortium should be comprised of members who have gained considerable knowledge and experience managing HEU to LEU recycling programs. This experience will translate into lower HEU processing costs, resulting in lower pass-through costs for the new reactor owners. One of the primary reasons for the success of these HEU to LEU programs is that the HEU-derived fuel has been introduced into the U.S. market in a measured, controlled manner. If the Isaiah Consortium consists of parties with previous HEU-to-LEU experience, then it could serve as an entity that has sufficient customers and contracts in place to ensure that U.S. HEU sales do not negatively impact the domestic nuclear fuel market.

If a successful experience with the TVA Bellefonte ABWR leads the U.S. government to free up more surplus HEU for follow-up projects, the Isaiah Consortium could also provide additional fuel to TVA for Bellefonte ABWR scheduled refueling.

(b) The Isaiah project supports key administration policy objectives

In addition to providing the most economical supply of fuel for new reactors, the Isaiah Project is the best way to support several key Administration energy security, nonproliferation, and national security policy objectives:

- Enables NNSA to achieve its goal of eliminating excess HEU and minimizing storage and security costs.
- Advances DOE's Nuclear Power 2010 program by providing incentive to the private sector for construction of new reactors.
- Ensures that U.S. HEU sales do not negatively impact the domestic nuclear fuel market.
- Advances the President's February 2004 initiative to strengthen international efforts against WMD proliferation by challenging other nations to build Isaiah reactors.

(4) TVA Bellefonte ABWR project would be a strong Isaiah project candidate

The current time schedule for a decision on whether to construct the Bellefonte ABWR plant enables it to be a strong candidate for the first two Isaiah Project cores. In addition to the considerable economic benefits involved, TVA participation in the Isaiah Project would also make it more attractive to local residents. According to opinion surveys, the recycling of HEU into LEU fuel is a concept that is strongly supported by the public as a major benefit of nuclear power. Bellefonte participation in the Isaiah Project would also encourage participation by other utilities as project partners and potentially lead to the construction of additional ABWR plants by other utilities.

4.3.4.4 The Traditional plan

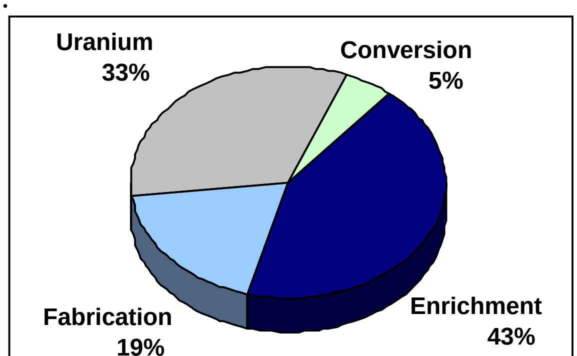
(1) Overview

Based on the fuel management plans from GNF-A, USEC has developed projections of total fuel cycle costs, including fuel costs for both initial core and typical reloads. In addition, several potential financing options have been identified which will help reduce the total cost of the fuel.

In connection with the assessment of the interagency agreement between DOE and TVA, these options will be examined at a high-level in order to develop cost estimates. However, USEC will not develop specifications for specific procurements by TVA.

(2) Nuclear fuel market pricing and trends

Front-end nuclear fuel costs can be broken into four components: U_3O_8 production, the conversion of U_3O_8 to UF_6, enrichment, and fabrication. The ultimate price for fuel is influenced by supply and demand conditions and price movements across each of these interdependent markets. In 2004, the global front-end fuel cycle market was estimated to be around $9.4 billion by revenue, which was distributed across the four market segments as follows:



Source: USEC Marketing & Sales. Based on published annual average market prices and assumes 4.0% enriched product assay and 0.30% tails assay (The Ux Consulting Company, LLC, http://www.uxc.com/ & Nuclear Market Review, TradeTech, LLC)

Figure 4.3-5 Front-end Nuclear Fuel Market Costs

A prudent fuel cycle risk management strategy would combine various optimal pricing mechanisms and contractual arrangements with several supply partners across each of these market segments. A competitive pricing mechanism would also consider base price escalation and market-related pricing.

(a) U_3O_8

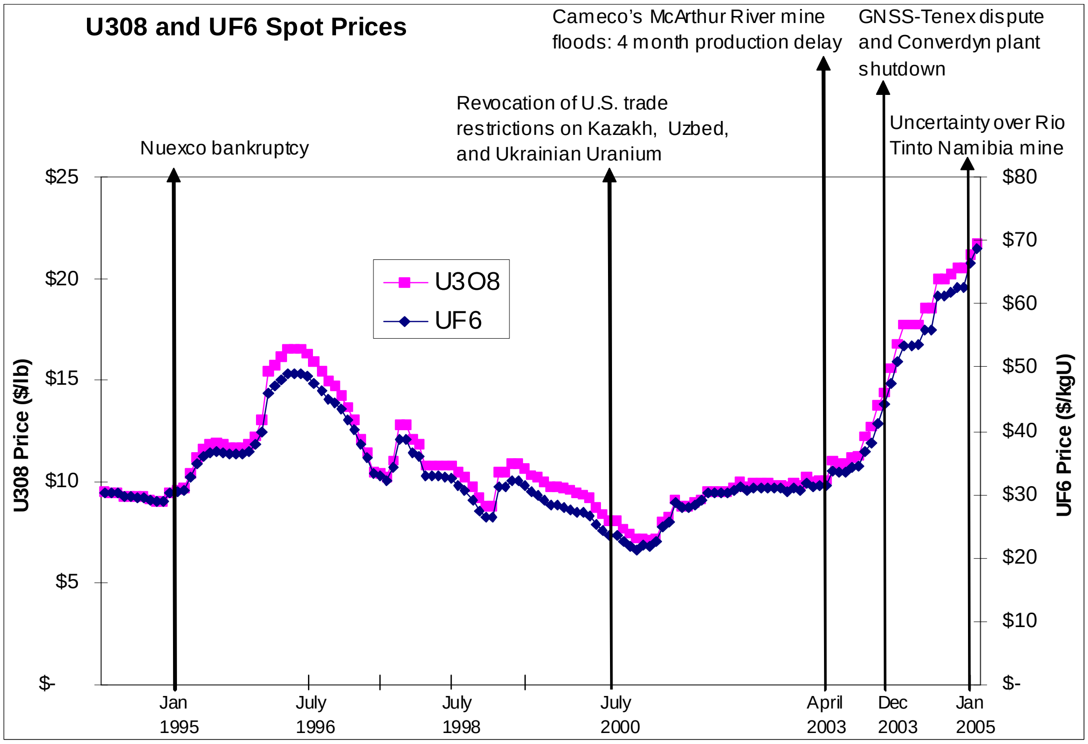
The long-term U_3O_8 market experienced significant upward price pressure in 2003 and 2004 as a result of supply disruptions and a change in the perception of market supply levels. As seen in Figure 4.3-6, U_3O_8 prices have seen volatility over the last decade. Cameco's McArthur River Mine Flood of 2003 precipitated an increase in price while additional events continued the upward pressure on price.

In November of 2003, Tenex terminated its uranium contract with GNSS for 2004 and beyond. However, GNSS had supply agreements with many U.S. customers from 2004 through 2009, leaving these customers with unfilled requirements that had to be filled quickly.

Another major market development in 2004 was the uncertainty surrounding the decision by Rio Tinto, owner of the Rossing mine in Namibia, to make the major capital investments required to extend operations past 2007 despite firming prices in the U.S. dollar. As the market began to rise in 2004, Rossing and other uranium producers reported that they were not seeing corresponding price increases in home currencies due to a weakening U.S. dollar. Uranium prices have continued to rise into early 2005 while the market continues to await a final decision from Rio Tinto on whether to invest in Rossing's development.

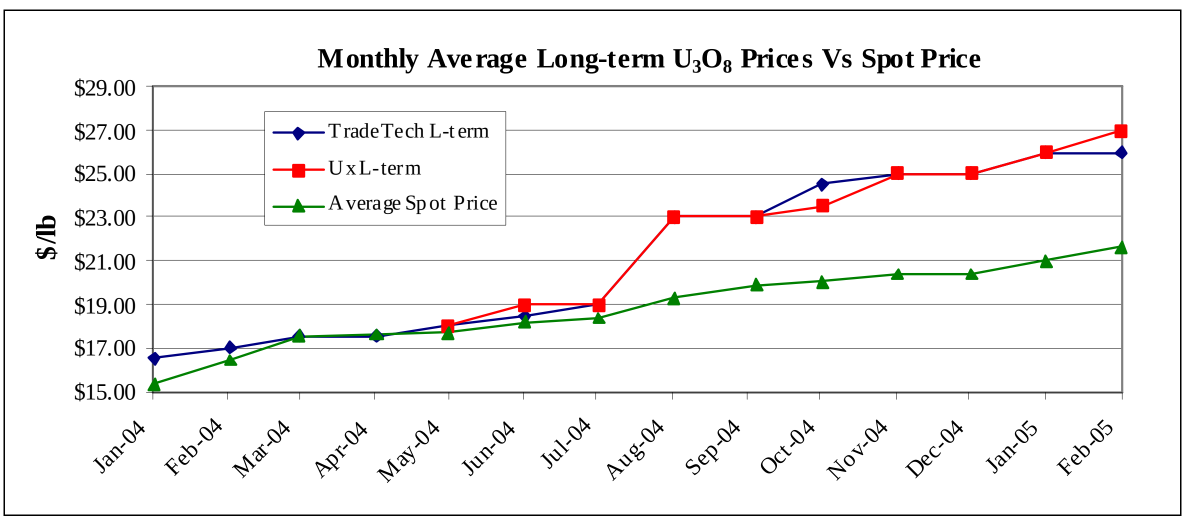
Market fundamentals for uranium production appear poised to support rising prices as projections of existing supply continue to remain short of requirements. Base uranium production in 2004 was about 60 percent of reactor requirements and has been supplemented by secondary sources such as inventory draw downs and the feed component associated with the blending down of HEU to LEU. The upward price pressure implied by the market fundamentals, a shrinking spot market, and the unwillingness of some producers to make long-term sales commitments has resulted in a market where some buyers are prepared to pay a significant premium to lock in future or long-term prices (currently in the $26/lb to $27/lb range). This is significantly above the historical range of spot prices shown previously in Figure 4.3-6.

Historically, the difference between spot uranium and long-term prices has been in the $1/lb to $2/lb range. In the current market, however, long-term uranium prices are trading at almost a $5/lb premium to spot prices, which reflects uncertainty over future supply and the unwillingness of some major suppliers to make long-term commitments. Figure 4.3-7 highlights the significant increase in published long-term uranium prices over the past year and their current premium to spot prices.



Sources: Nuclear Market Review, TradeTech, LLC; USEC Marketing & Sales

Figure 4.3-6 U_3O_8 and UF_6 Spot Prices



Sources: The Ux Consulting Company, LLC, http://www.uxc.com/; Nuclear Market Review, TradeTech, LLC

Figure 4.3-7 U_3O_8 Long-term and Spot Prices

On a positive note, rising prices have also generated worldwide interest in additional uranium supply. This is evidenced by plans for significant expansion at Olympic Dam in Australia as well as several exploration programs being launched in Canada and Australia. In addition, several so-called "junior" uranium companies have recently entered the market and pose an interesting dilemma for the nuclear fuel buyer- the need to encourage uranium production beyond the small number of current uranium "mega-projects", while managing the risk associated with contracting with smaller and potentially less experienced operators.

In the near term, enrichers with the operational capacity to reduce tails assays (primarily Western gaseous diffusion plant operators) are doing so in order to reduce feed requirements and optimize LEU production costs. In addition, reactor operators are reducing the tails assays of enrichment orders so as to reduce the quantity of uranium they must purchase in the marketplace. Tails assay reductions like these can reduce uranium requirements by 10 to 15 percent.

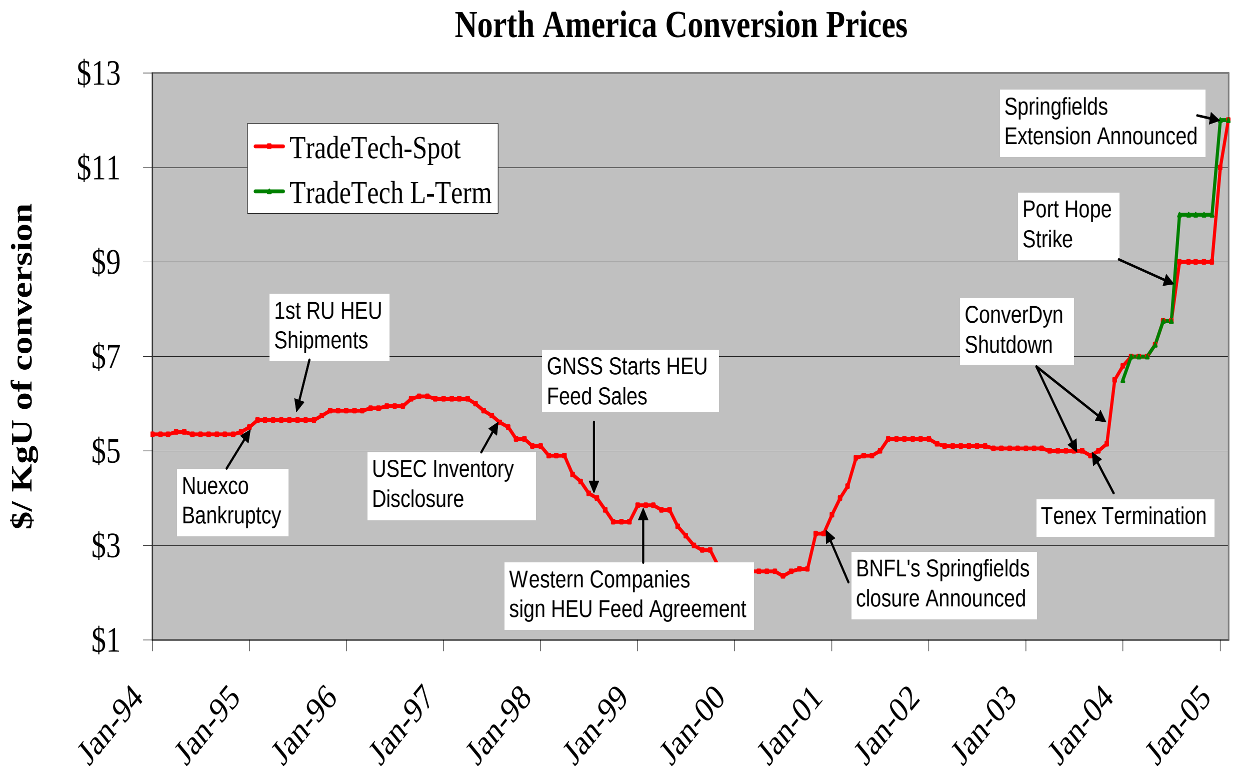
(b) Conversion and UF_6

Over the last year, there has also been significant upward pressure on the price of conversion with current spot and long-term prices reaching $12/KgU (figure 4.3-8). This represents a 70 percent increase in price over year ago levels and with upward pressure on U_3O_8 prices, has led to significant escalation in UF_6 feed prices (Figure 4.3-9).

ConverDyn's uranium conversion facility in Metropolis, Illinois was shut down in December 2003 following a chemical release and remained closed until mid-April 2004. ConverDyn notified its customers that it would be two years before its target working inventory could be replenished and that production for 2004 would only be 9,000 MTU/UF_6 compared to the normal level of 13,000 MTU/UF_6. ConverDyn subsequently notified the industry that production for 2005 was expected to be 11,000 MTU/UF_6 as compared to the normal production level of 13,000 MTU/UF_6.

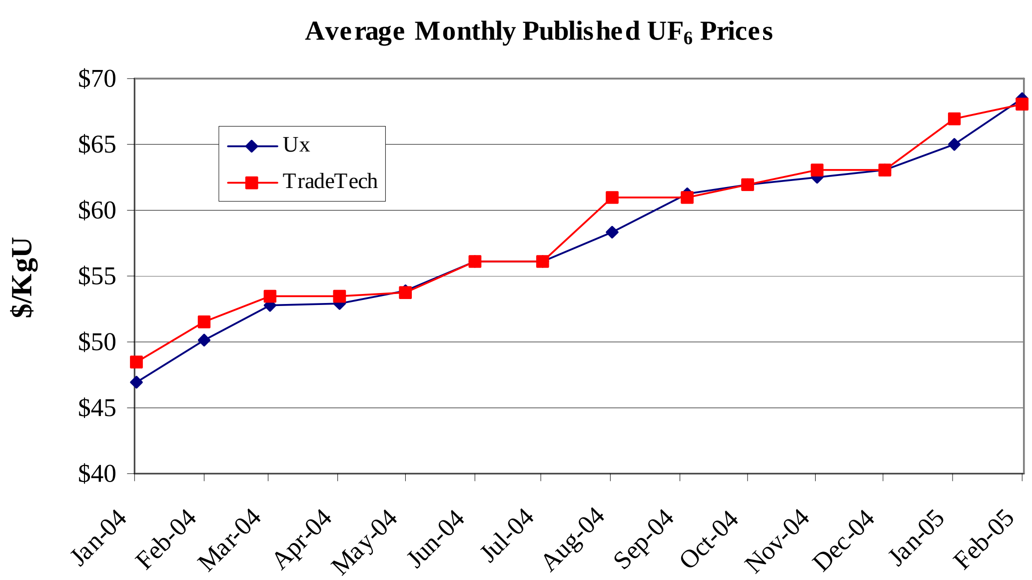
Additionally, Cameco's Port Hope conversion facility experienced a strike by its hourly workers from the end of July through the end of September 2004. These two events in late 2003 and 2004 added much uncertainty to this small but critical part of the fuel cycle, which over the years had not been given a lot of attention.

The conversion market also faces long-term supply concerns. As with the uranium production market, the existing conversion capacity in operation today is about 10 percent below reactor requirements when supplies of UF_6 from the blending down of HEU are taken into consideration to meet the gap between production and requirements. The announcement by BNFL of the closure of the Springfield's conversion facility in early 2001, allegedly for reasons unrelated to low conversion prices, did not significantly impact the conversion market at that time because it was not focused on long-term supply issues.



Sources: The Ux Consulting Company, LLC, http://www.uxc.com/; Nuclear Market Review, TradeTech, LLC

Figure 4.3-8 Conversion Prices



Sources: The Ux Consulting Company, LLC, http://www.uxc.com/; Nuclear Market Review, TradeTech, LLC

Figure 4.3-9 UF_6 Prices

The disruption of the short-term market, potential supply disruption from the Port Hope strike, and increasing industry awareness of long-term security of supply issues have altered the fundamentals of the conversion market and have driven prices higher. A recent agreement between Cameco and BNFL to supply UO_3 to Springfield's facility for conversion will extend the plant life at least 10 years to 2015 and reduce immediate supply concerns. However, a major European market participant continues to voice industry concern over the need for additional conversion capacity, particularly in Europe, to offset a geographical imbalance with North America. Although conversion is a small cost of producing LEU, close proximity to enrichment facilities to reduce transportation costs is an important consideration. The requirement of a new plant supports the maintenance of strong pricing as current or higher price levels are required to establish acceptable economics for a facility, particularly in Europe where the weakness of the U.S. dollar to the Euro must be overcome.

(c) Impacts of the U.S.-Russia HEU agreement on conversion and UF_6 prices

In February 1995, the Nuexco Trading Corporation, which was the world's largest uranium trader, filed for bankruptcy protection under U.S. laws. Although this triggered a significant increase in U_30_8 spot market activity, the conversion market remained stable with the spot conversion price trading in a narrow range of $5.50/KgU to $5.85/KgU.

During 1995, Russia delivered about 6 MTU of HEU under the US-Russia HEU agreement, none of which entered the market due to technical, legal and political constraints. As such, the demand for conversion and hence, prices were not impacted by HEU shipments throughout 1995 and 1996. In 1997, excess inventories of UF_6 from the HEU agreement and other secondary sources of UF_6 in the marketplace, together with low demand in the market, were factors that contributed to the decline of the conversion market.

In 1998, the fall in conversion prices was exacerbated when Tenex commenced sales of the natural feed component of HEU through its partially owned U.S. based subsidiary GNSS. Then in 1999, after several years of negotiations, the Russian Federation and a Western consortium, (made up of Cameco, COGEMA, and Nukem) finally reached a commercial agreement for sale of the natural uranium feed component of HEU. This further depressed demand for conversion services and negatively impacted prices.

Prior to 2001, the U.S.-Russia HEU Agreement precipitated several key events that had a sustained negative impact on the conversion market. In contrast, conversion has experienced a sustained upswing since 2001. As mentioned in the section "U_3O_8", effective January 2004, Tenex's termination of its HEU feed contract with GNSS due to disagreement over the terms and conditions has led to a further spike in conversion prices.

(d) Enrichment

Separative Work Units (SWU) account for the largest share (over 40 percent) of front-end nuclear fuel supply costs. Figure 4.3-10 provides a historical perspective of SWU price movements over the last decade and the key events that made an impact on prices in the industry. These events are examined in greater detail below.

i) USEC Portsmouth Gaseous Diffusion Plant (GDP) closure

In June of 2000, USEC, the sole U.S. domestic producer of enriched uranium, announced that it would cease uranium enrichment at its Portsmouth, Ohio GDP by June 2001. The decision was made on the basis of global enrichment overcapacity, the availability of supplies of HEU from dismantled nuclear weapons, and market share lost to European producers seeking market expansion at discounted prices. At the time the Portsmouth GDP closure was announced, spot SWU and long-term SWU prices had fallen to historic and unsustainably low levels of $80 and $83 respectively.

ii) Trade case announcement

In December 2000, the U.S. Department of Commerce (DOC) announced that it would investigate unfairly priced imports into the United States of enriched uranium from Europe. In petitions filed with the DOC and the U.S. International Trade Commission (ITC), USEC charged that its European competitors, Eurodif S.A., through its U.S. sales agent Cogema, and Urenco, Ltd., were selling enriched uranium into the U.S. market below their cost of production and benefiting from unfair government subsidies in their home markets. Since it was claimed that this activity had materially injured the domestic enrichment industry, an investigation was sought to ensure fair trade practices and if necessary, impose duties upon future imports of enriched uranium from France, Germany, the Netherlands and the United Kingdom.

iii) Portsmouth GDP closes

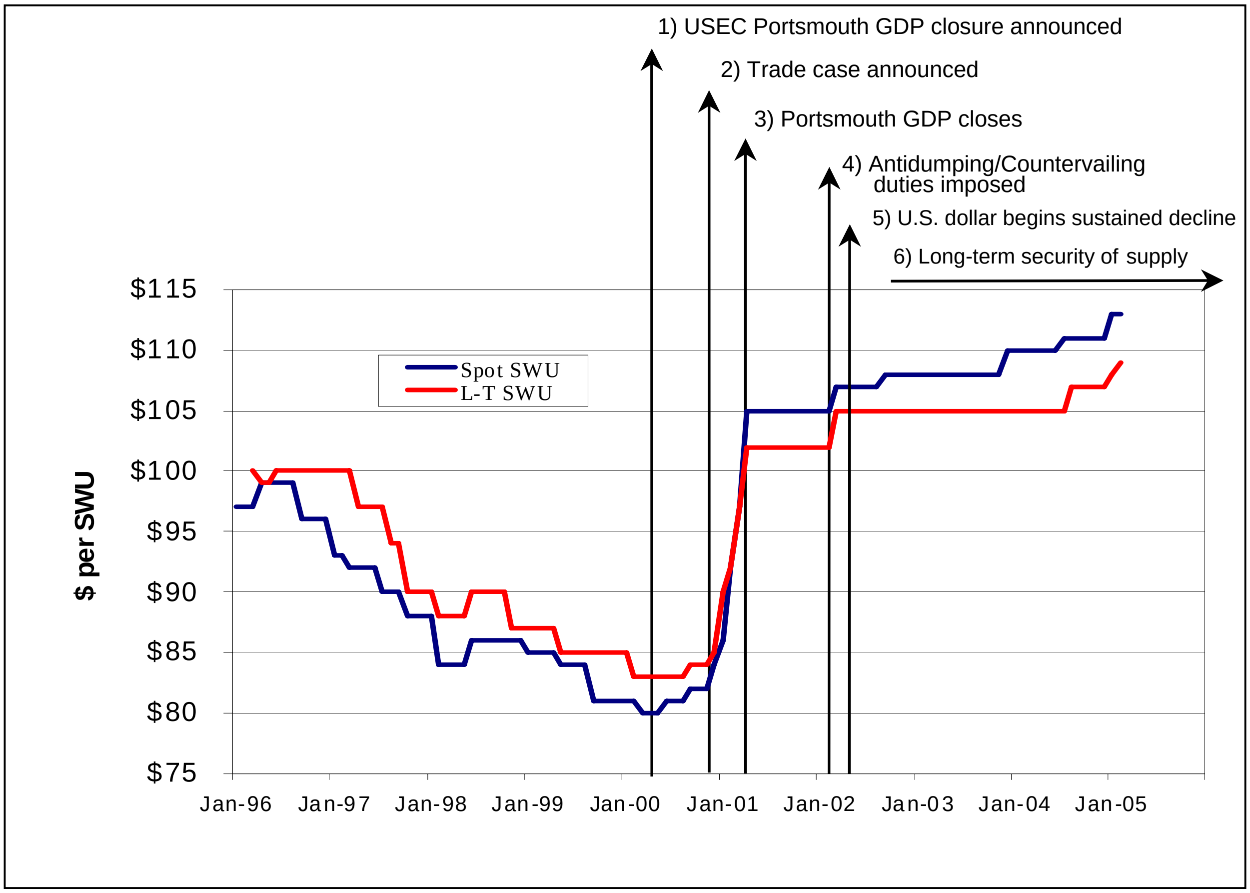
The Portsmouth GDP in Ohio ceased production of enriched uranium in May 2001. With this closure, U.S. enrichment operations were consolidated at USEC's Paducah, Kentucky GDP facility and excess capacity available to the U.S. market was effectively reduced.

iv) Antidumping/Countervailing duties imposed

In January 2002, the ITC unanimously ruled that LEU imports from Europe had materially injured and/or threatened to materially injure USEC Inc. In February 2002, the U.S. government began collecting duties on imported enriched uranium from Eurodif and Urenco equivalent to 53.50 percent of the value of Eurodif SWU and 3.72 percent of the value of Urenco SWU.

v) Exchange rate trends

Like other commodities markets, uranium and enrichment contracts are typically denominated in U.S. dollars. As such, exchange rate trends have significant impacts on



Sources: Nuclear Market Review, TradeTech, LLC; USEC Marketing & Sales

Figure 4.3-10 SWU Prices

pricing. When the U.S. dollar weakens, foreign suppliers' contractual unit prices in U.S. dollars must rise in order to compensate them at a given foreign currency unit price. The reverse is true when the U.S. dollar is strong. In the period prior to mid-2002, the U.S. dollar was strong and to some extent contributed to price discounting by European competitors. However, after mid-2002 and after a policy shift by the U.S. government to allow a weakening of the dollar, exchange rates shifted by over 60 percent to provide an advantage to U.S. producers. This change supported higher long-term SWU prices in U.S. dollars.

vi) New enrichment capacity/long-term security of supply

The closure of the Portsmouth GDP, plant aging concerns related to existing gaseous diffusion facilities, and concerns over the competitiveness and exposure to high electric power prices for gaseous diffusion operations led to the development of three new enrichment plant projects. Both USEC and Areva have efforts underway to replace existing GDP operations with centrifuge based facilities. In addition, Urenco is leading a consortium to build a new enrichment facility in the U.S. The result of these initiatives, particularly in the U.S. market, is a rationalization of market prices based on the realized prices required to support the capital requirement of new facilities ($1.2 to $1.5 billion for the U.S. plants, and $3 billion for the French plant).

The critical role these new enrichment plants will play in providing a long-term, secure fuel supply for the existing reactor fleet (including extensions to the 60 year projected lifespan for much of the U.S. fleet) and future reactor fleets (which show increasing prospects for being built), economically justifies sustained higher SWU prices within the nuclear fuel cycle.

(e) Current enrichment outlook

Average long-term and spot published SWU prices for February 2005 were $108.50/SWU and $112.50/SWU respectively (Figure 4.3-11). Compared to U_3O_8 and conversion, SWU prices have been relatively stable over the past year, having increased approximately 3 percent. Most analysts predict sustained upward pressure in the near term.

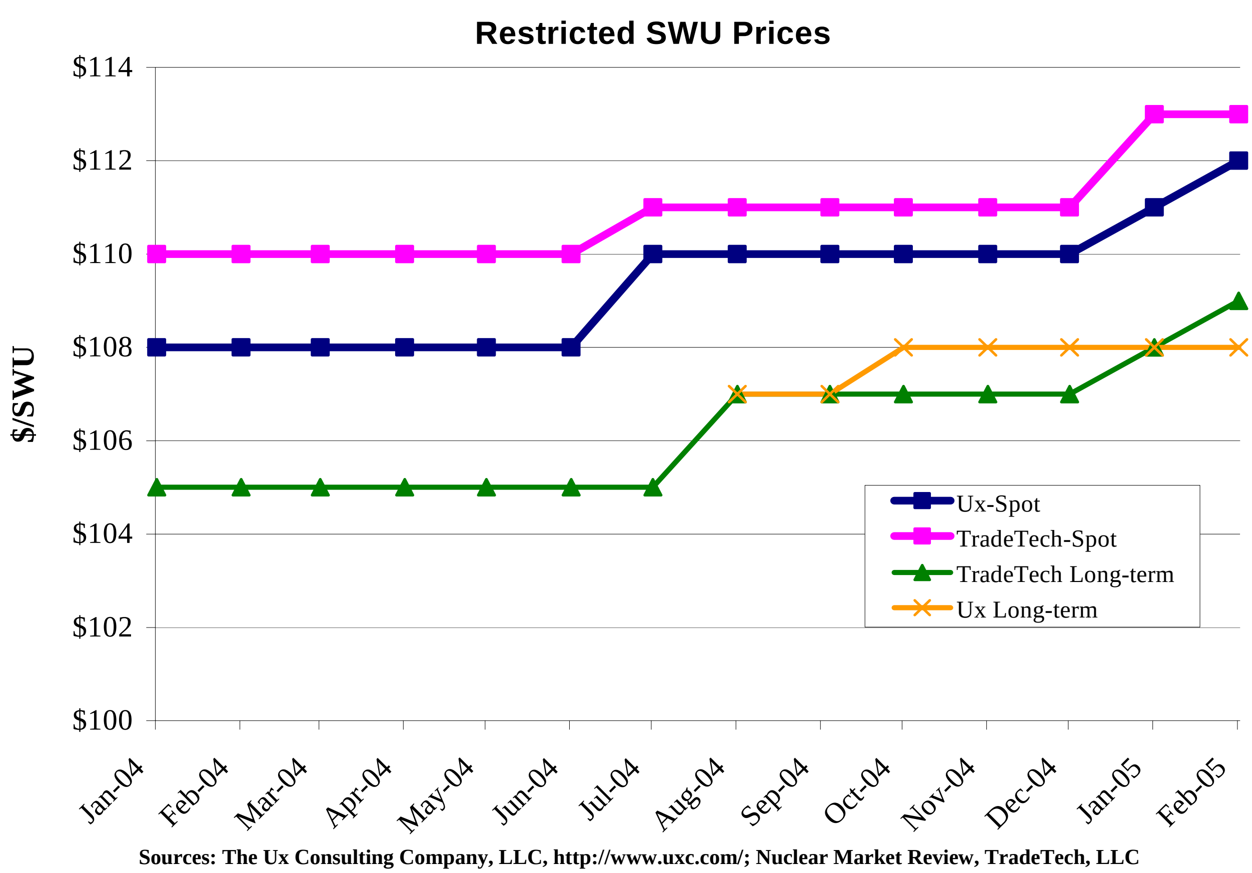


Figure 4.3-11 Restricted SWU Prices

Rising uranium prices and the falling U.S. exchange rate are among the key reasons for this bullish outlook on SWU prices. Indeed, the significant increase in uranium and conversion prices has placed a premium on feed for enrichment, with utilities demanding lower tails assays in contracts where the utilities are obligated to supply natural uranium. This has led to increased demand for SWU relative to current uranium feed stocks, which places additional upward pressure on SWU prices.

Most buyers are fully dependent on mid to long-term contracts with primary enrichers, who continue to avoid selling spot SWU/EUP (enriched uranium product) into the market. The availability of secondary supplies is also low. These constraints on short-term enriched uranium supply are reflected by the $3/SWU to $5/SWU premium of spot prices relative to long-term prices.

(f) Fabrication

After the enrichment stage, enriched UF_6 is transported to a fuel fabrication plant where it is converted to uranium dioxide (UO_2) powder and pressed into small pellets, which are inserted into fuel rods, usually made of a zirconium alloy or stainless steel. The rods are sealed and made into fuel assemblies for use in the core of the nuclear reactor.

Fuel fabrication for the bulk of installed nuclear capacity is undertaken by a number of competitors including GNF-A (a joint venture of GE, Hitachi, and Toshiba Corp), Westinghouse, Areva/Framatome, and Mitsubishi Heavy Industries. Such suppliers are often involved in collaborative R&D programs with large utilities to improve fuel fabrication design and efficiency.

Although the cost of nuclear fuel fabrication typically amounts to less than 20 percent of the front-end fuel costs, significant cost savings and efficiency enhancements across the entire nuclear fuel cycle rely on advances in nuclear fuel technology and in particular the more efficient utilization of fuel. Such advances will have ripple effects on the entire uranium fuel supply sector, as well as on the management and disposal of spent fuel.

(g) Conclusion

Supply and demand conditions and price movements across the four key components of the nuclear fuel cycle (U_3O_8, conversion, enrichment, and fabrication) will affect the ultimate price that customers pay for their nuclear fuel requirements. Some of the recent issues and trends affecting each of these interdependent fuel cycle segments have been examined and discussed above. In estimating fuel costs, it is important to keep in mind that changing market conditions, trade restrictions and government policies in one or more fuel cycle segments may significantly influence final pricing parameters.

(3)Procurement Parameters

To better understand the parameters by which the price estimates were derived, two GNF-A fuel management plans (Options 1 and 2) were evaluated. Detailed information on each option can be found in Appendix F.6.2 and F.6.3.

(a) Option 1

The "high energy/high discharge" plan from GNF-A for a 24-month initial cycle length envisions an initial core fuel loading of XX metric tons of EUP in the form of fabricated fuel bundles. This translates to a required initial core fuel load of fabricated fuel containing approximately XX SWU and XX KgU of natural UF_6. Furthermore, with reloads every 24 months (approximately), a refueling of the TVA Bellefonte ABWR reactor would require approximately XX SWU and XX KgU of natural UF_6. The actual quantity of EUP, SWU, and natural uranium (represented by XX) for this option is located in Appendix F.6.2.2, due to its proprietary nature.

(b) Option 2

GNF-A has also determined an alternate fuel management plan comprised of an initial core with a 12-month cycle length followed by two transitional 18-month cycles leading to a 24-month cycle comparable to the Option 1 plan described above. In this case, the initial core fuel would contain approximately XX SWU and XX KgU of natural UF_6. The two transitional 18-month cycles in Option 2 would each require fuel containing approximately XX SWU and XX KgU of natural UF_6. The actual quantity of EUP, SWU, and natural uranium (represented by XX) for this option is located in Appendix F.6.2.3, due to its proprietary nature.

Procurement of the required natural uranium and SWU components, as well as the necessary fabrication, involves the issuance of a request for proposal (RFP) by TVA or its authorized fuel procurement agent. Typically, the RFP for fabrication would include a firm request for the initial core plus a combination of a number of firm and optional reloads. The exact scope of the fabrication RFP, including the number of firm and optional reloads, will depend upon a number of factors including, but not limited to:

- TVA's procurement history with fabrication suppliers
- Necessary and/or desired product design features
- TVA's risk management profile
- Environmental management system requirements (such as supplier ISO certifications and the like)

Additionally, TVA should continue to promote the qualification process for fabrication facilities to increase competition while continuing to meet high quality assurance and operational performance parameters.

Procurement of the necessary enriched uranium should be pursued either by purchasing individual components (SWU, natural UF_6, conversion, or U_3O_8) or by purchasing EUP or bundled fuel assemblies. At times, the dynamics of the commercial nuclear fuel market may offer packaged discounts or premiums on the price of individual components. In order to capitalize on potential opportunities for discounts (and to avoid premiums), a fuel supply plan requires continuous monitoring of the market.

The timing of procurement activities should be in conformance with the acceptable risk management limits of TVA's overall nuclear fleet. However, procurement flexibility should be maintained in order to take advantage of potentially attractive opportunities in the marketplace, such as an opportunity to procure some or all of the necessary components earlier than required for normal processing time.

Additional procurement actions should ensure that any "buy and hold" consideration be viewed in tandem with acceptable inventory policies and that strategic alliances with key nuclear fuel industry participants be considered.

Throughout the assessment and implementation of the TVA Bellefonte ABWR Project fuel supply initiatives, TVA should continuously seek to leverage existing arrangements, especially with nuclear fuel suppliers. Regular monitoring of this type can mitigate cost (such as the average procurement price) over the duration of the project and operation of the nuclear plant. In addition to leveraging existing arrangements, contractual flexibilities in areas like quantity, fuel cost optimization, binding notices, delivery dates/locations, and payment terms, should all be vigorously pursued.

(4) Fuel cycle cost calculations

There are three factors to consider when calculating the fuel cycle cost for each of the proposed Bellefonte ABWR units under GNF-A Option 1 and Option 2. They are the front-end cycle cost(s), the corresponding front-end interest expense, and the back-end cycle cost. Front-end cycle costs include expenses associated with acquiring fabricated fuel or its components (natural uranium, SWU, fabrication). The front-end cycle costs also take into account fuel design engineering services. The front-end interest factor is the interest expense incurred by acquiring the aforementioned front-end fuel and design services in advance of the fuel loading process. TVA has historically assumed this interest expense to be 1.11 percent. Lastly, the back-end cycle cost consists of a congressionally mandated Yucca Mountain waste repository fund expense of $0.93/MWh (not subject to escalation), to eventually store and dispose of spent fuel. Detailed fuel cycle cost estimates for option 1 and 2 are located in Appendix F.6.3.1 and F.6.3.2 due to its proprietary nature.

(5) Fuel cost calculations

In calculating fuel costs, two options are proposed that consider different initial core requirements and reload patterns. Option 1 provides for a 24-month initial core followed by 24-month cycles. Option 2 provides for a 12-month initial core with two subsequent 18-month cycles, followed by 24-month cycles. It should be noted that Option 2 will require one additional cycle during the first four years of operation when compared to Option 1. This must be taken into account when attempting to compare the relative costs of the two options. For detailed cost breakouts and methodology with supporting assumptions, please refer to Appendix F.6.2 due to its proprietary nature.

(6) Potential fuel financing options

Commercial financing alternatives for nuclear fuel fall into three basic categories:

(a) Capitalization

Capitalization of nuclear fuel increases an owner's overall debt and equity holdings and thus decreases performance metrics like return on equity (ROE). A majority of nuclear power plant owners in the United States capitalize their nuclear fuel costs. The typical asset life of this fuel is three to five years, amortized over the same period of time.

(b) Leasing

Leasing increases fuel costs due to the inclusion of leasing expenses. The main benefit of leasing is that it reduces a company's capital expenditures and in doing so, improves performance metrics like ROE. A number of utilities will lease their nuclear fuel depending on interest rates, tax laws, deregulation status, competitive position, and the overall financial condition of their company. Most of these utilities use subsidiaries to perform leasing functions; however, leasing can also be performed through specialized financial institutions.

In general, one potential deal structure would involve leasing nuclear fuel to a plant owner who would in turn pay the cost of fuel with matching revenue income. Under this structure, a plant operator can avoid the traditional "short investment-recovery" cycle. In fact, this leasing structure has already been implemented at several investor owned utilities.

However, if TVA is the owner of the Bellefonte plant, this leasing structure is not economically sensible because there is no tax benefit to TVA (being that it is a non-taxable entity), making the implicit interest rate in the lease higher than TVA's borrowing rate. Alternatively, if the business structure allows the Bellefonte ABWR to be owned by a third party while being operated by TVA, the fuel costs could be reduced.

The primary objective of the BOL structure in Figure 4.3-12 is to take full advantage of the available tax benefits, which a Fuel Holding SPC can achieve by leasing fuel to BOL. Such a business structure contains the following properties:

- TVA (as the licensee) will provide operational service to BOL. In turn, BOL will provide the necessary funds for TVA to operate the Bellefonte ABWR.
- BOL would secure Power Purchase Agreements (PPA) with TVA and other interested parties in exchange for plant output.
- BOL would secure a fuel lease utilizing guaranteed revenue from the PPAs.

- Fuel Holding Special Purpose Company (SPC) will realize depreciation and other potential tax benefits (e.g. production tax credit). TVA's fuel cost under this lease option should be equal to or less than TVA's traditional procurement cost.

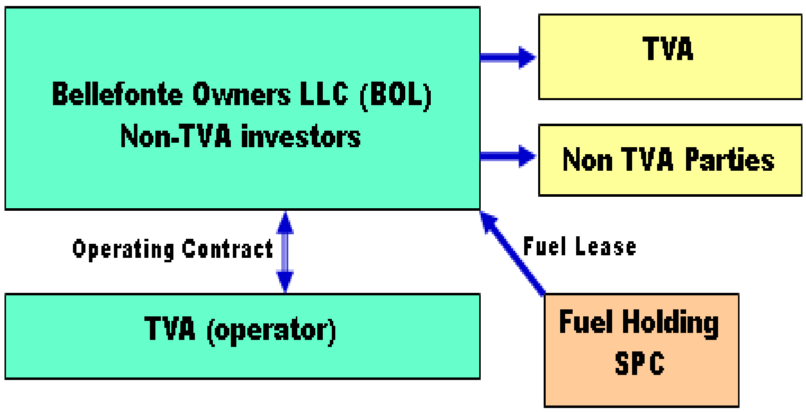


Figure 4.3-12 Potential Leasing Structure

In order to develop an alternative fuel purchase option, coordination between the project owners and the ultimate financing deal structure will be essential in determining overall power generation costs. Lastly, it is recommended that the TVA Bellefonte ABWR team develop and maintain an optimal business structure during the construction and operation of the plant in order to allocate risks and benefits.

(c) Power for SWU (P4S)

The P4S concept gives a nuclear plant the opportunity to pay for its enrichment with power. Under a P4S agreement with USEC, TVA could trade scheduled electricity under a power purchase supply agreement (PPSA) in return for SWU. Such an arrangement could be implemented either directly between USEC and TVA or via an independent energy marketer/partner (see Figure 4.3-13).

Under a P4S arrangement, the TVA Bellefonte ABWR could realize a number of economic and financial benefits including:

- Optimized power capacity
- Improved cash position and earnings stability
- Reduced operating risk through multi-year power commitments
- Reduced market risk through locked in, agreed upon prices
- Diversification of delivery options

- An example of the terms and conditions of P4S financing is as follows:

- *Transaction Structure*: USEC will deliver enriched uranium to the ABWR plant. To pay for the SWU in the enriched uranium, the plant would deliver a schedule of fixed MWH under a PPSA either directly to USEC (assuming available transmission capacity) or via an Energy Partner. If the latter arrangement is adopted, the Energy Partner would pay USEC for the SWU or the electricity.

- *SWU Quantity & Price and MW Quantity & Location*: Per PPSA as agreed.

- *Quantity/ Timing Changes in Reactor Requirements*: Settled through a "True-Up" mechanism between the ABWR plant and USEC.

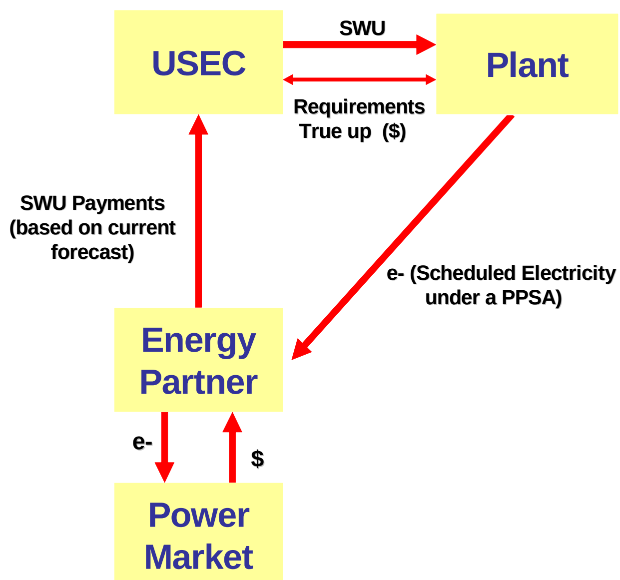


Figure 4.3-13 Potential P4S Structure

5.0 PROJECT DEPLOYMENT MODEL

5.1 OBJECTIVE

The objective of the Project Deployment Model activity was to propose a project structure for deployment of the Bellefonte ABWR Project, including high-level agreement on the roles, responsibilities, and interfaces for the project ABWR Delivery Team. Toshiba and GE have worked closely together to reach basic agreements for the Bellefonte ABWR Project Deployment Model.

5.2 BACKGROUND

The project implementation practice typically used in the construction of past U.S. nuclear power plants was to clearly separate the areas of NSSS, BOP, and AE scope. An NSSS vendor was responsible for the design and supply of major NSSS equipment. An AE or other contractor(s) was responsible for the design and supply of BOP systems and equipment. The AE was also responsible for civil design and construction as well as installation of equipment, piping, electrical, etc., including supply of materials associated with the construction and installation work. These numerous interfaces and the potential coordination difficulties between the NSSS vendor, the AE, and other contractors often contributed to construction delays and cost overruns. The Project Deployment Model proposed below for the Bellefonte ABWR Project considered these past problems and incorporates a more consolidated project structure to improve the project implementation.

Many of the improvements in the proposed deployment model for the Bellefonte ABWR Project grow out of the cooperative experience between Toshiba and GE on the first ABWR project in Japan. Key points of this Japan ABWR project experience include:

- Joint work to develop the complete plant design
- Joint Venture (JV) type contract
- Separate Civil JV
- NSSS/BOP vendor scope including installation work
- Fixed price, lump sum basis contracts

This Japan ABWR project was successfully implemented based on:

- Established detailed design completed before the start of construction,
- Low licensing risk under the fixed Japanese license process, and

- Long-term continuous experience of nuclear plant construction.

This successful project model has been considered in establishing the Bellefonte ABWR Project Deployment Model activity.

5.3 APPLICATION OF ABWR CERTIFIED DESIGN

A key advantage for the Bellefonte ABWR Project will be the application of the Certified ABWR Design. Using this pre-certified standard plant design under 10CFR Part 52 will remove many risks and uncertainties from the process of licensing and constructing the Bellefonte plant. To take full advantage of the Part 52 process, the design basis for the Bellefonte plant must closely follow the Certified ABWR Design as reflected in the ABWR Design Control Document. Therefore, Toshiba and GE have agreed to use the Certified ABWR Design, as implemented in the DOE-sponsored First-of-a-Kind-Engineering (FOAKE) Program and the Lungmen Nuclear Power Station, as the design basis for the Bellefonte ABWR Project.

As described in Chapters 3 and 6, the Bellefonte ABWR design will be augmented with selected design enhancements developed by Toshiba and GE in order to achieve a more cost effective plant with improved performance and operability. These enhancements include design improvements derived from Toshiba and GE's recent ABWR project experience. The successful design, licensing, construction, and operation of the proven ABWR design provide a high degree of confidence that this design can be successfully deployed at the Bellefonte site in a turnkey basis project.

5.4 PROPOSED PROJECT DEPLOYMENT MODEL

5.4.1 Staged Project Model

Figure 5.1 illustrates the overall project schedule and milestones of the Bellefonte ABWR project. The project can be separated into three phases: (1) COL preparation and COL work phase; (2) Detail engineering phase; and (3) Construction phase.

(1) COL preparation and COL work phase

The COL preparation phase consists of basic and limited detailed design and engineering for COL development and preparation of COL application materials. Interface and negotiation activities with the NRC after COL application can be treated as a part of this phase. This activity will be initiated in parallel with TVA's Notice of Intent to prepare an environmental impact statement. All or a portion of this activity may be performed under a DOE-funded effort as a part of the "New nuclear power plant licensing demonstration project."

(2) Detailed engineering phase

The detailed engineering phase will complete all activities, which consists of the detailed design engineering and the detailed construction plan, in sufficient detail to start construction work. Since detailed interface information for equipment and facilities is required to finalize the design work, the procurement engineering and selection of suppliers will also be performed in this phase. This activity will be initiated following TVA's Record of Decision.

(3) Construction phase

The Construction phase consists of all construction, testing activities, and plant commissioning. Fabrication activities for equipment and materials are also part of this phase. This activity will start with the COL issued by the NRC. Before moving to this phase, construction companies must be selected for the civil work and mechanical and electrical installation.

Figure 5.1 reflects the three project phases and milestones described above for the Bellefonte ABWR Project. TVA and the ABWR Delivery Team can proceed with the project step by step and make decisions to move the project forward. This approach will optimize the total plant costs and minimize the risks for both the owner and vendor team. Competitive tenders are expected not only for equipment supply but also for construction activities, which will further result in minimizing the project costs.

5.4.2 Project Organization and Structure

Toshiba and GE addressed several options for the organization and structure of the ABWR Delivery Team. Of course, the organization of the ABWR Delivery Team will depend in part on the way in which TVA intends to organize the project and structure the Delivery Team subcontracts. Subject to further discussion with TVA on the project organization and contracting arrangement, Toshiba and GE propose to organize the ABWR Delivery Team under a Consortium or Joint Venture (JV) agreement. Toshiba and GE have a long history of working closely together on successful BWR construction projects, including some projects which were performed under a JV arrangement. Therefore, the two parties are confident that the Bellefonte ABWR Project can be successfully implemented using a Consortium or JV type of structure for the ABWR Delivery Team.

Figure 5.2 illustrates a possible Consortium or JV project structure for delivery of the Bellefonte ABWR Project in each project stage on a turnkey basis. This figure shows three major JV partners, with one partner nominally responsible for the design and delivery of the Nuclear Island, another JV partner nominally responsible for the design and delivery of the Turbine Island and Balance of Plant, and a third JV partner responsible for the civil construction. The two JV partners responsible for the NI and TI/BOP would use common subcontractors for the installation of mechanical and electrical equipment in order to enhance the construction interface.

<Phases1 and 2>

In Phase 1, COL Preparation and COL Work, GE and Toshiba will establish a Consortium or Joint Venture (JV) to perform basic and some detailed design engineering for COL, preparation of COL application materials, and interface with the NRC after COL application. The Consortium or JV may include a Civil AE and other vendor/AE as its sub-contractor at this stage.

In Phase 2, Detailed Engineering, the project JV will continue in the same organization and structure as Phase1 to accomplish the detailed design engineering, the detail construction plan, and procurement engineering.

<Phase-3>

In Phase 3, Construction, the project Consortium or JV will invite a constructor responsible for civil construction to join the project team to perform civil construction work. GE and Toshiba will use common subcontractors for mechanical/electrical installation work.

5.4.3 Project Leadership

Since the Bellefonte ABWR Project will be a United States-based construction project, constructed for a U.S. Customer, and implemented under the regulation of the U.S. NRC, Toshiba and GE have agreed that GE should take a leadership role for the ABWR Delivery Team and act as the primary interface with TVA. Toshiba and GE will arrange a rational sharing of the project scope, but GE will act as leader of the combined ABWR Delivery Team.

5.4.4 Division of Responsibilities

Table 5.1 lists a high-level division of responsibilities between the major parties involved in delivery of the Bellefonte ABWR Project. This table reflects the basic agreements reached between Toshiba and GE during the Project Deployment Model discussions. GE will have responsibility for overall Project Management, and Toshiba will have primary responsibility for Construction Management.

GE will take the lead role on the licensing interface with TVA and will have overall responsibility for the design and delivery of the Nuclear Island. Although the scope of design work for the Nuclear Island will be minimized by using the completed, construction-level Lungmen design as the starting point for the Bellefonte ABWR Project, GE has agreed in principle that Toshiba will have responsibility for some NI design scope.

Toshiba will have overall responsibility for the design and delivery of the Turbine Island, Radwaste, and Balance of Plant.

Toshiba and GE will split the responsibility for supply of equipment packages. International sourcing will be used to ensure that the most cost effective, qualified equipment suppliers are selected for the Bellefonte ABWR Project.

The agreements listed in Table 5.1 establish the preliminary roles and responsibilities for the Bellefonte ABWR Project. Once TVA makes a decision in principle to proceed with the project, Toshiba and GE have committed to work towards establishing a detailed division of responsibilities which achieves a rational sharing of the project scope between the two parties.

5.5 SUPPORT FOR THE PROJECT

Figure 5.3 illustrates possible sources of support for the Bellefonte ABWR Project.

Such support from NEI, DOE and the U.S. government will help to ensure the successful deployment of the Bellefonte ABWR Project.

(1) COL preparation and COL work stage

In the COL preparation and COL work stage, preparation of the COL guideline by NEI and sufficient assignment of NRC staffing should help the timely application and issue of the COL. Financial support by the DOE as part of the "New nuclear power plant licensing demonstration project" should be effective for TVA to make a decision on proceeding with the project implementation to the COL stage.

(2) Construction stage

Governmental support such as loan guarantees, risk insurance and tax credits should support TVA in proceeding to the plant construction stage.

Table 5.1 Possible Division of Responsibilities for Bellefonte ABWR Project

Work Activity	GE	Toshiba	Civil Constr	M/E Installer	TVA
1. Project Management					
a. Overall Project Management (Overall coordination/integration of activities of Delivery Team and other TVA contractors)	√	I			I
b. Scheduling					
b.1 Project Schedule and tracking for Delivery Team engineering, procurement, and delivery	√	I			I
b.2 Construction Schedule and tracking	I	√	I	I	I
c. Project Procedures	√	I			I
d. Configuration Management and Information Management Systems (IMS)	√	I			I
2. Construction Management					
a. Overall coordination/integration of site construction activities	I	√		I	I
b. Construction planning and sequencing	I	√		I	I
c. Civil construction	I	I	√		
c. Equipment installation and construction testing	I	I		√	
3. Licensing					
a. NRC interface	I	I			√
b. Project Licensing coordination; Preparation of Licensing submittals	√	I			I
4. Design * (Design of systems, equipment, structures analyses, and arrangement)					
a. Nuclear Island	√	I	I		
b. Turbine Island	I	√	I		
c. Radwaste	I	√	I		
d. Yard and Plot Plan	I	√	I		
c. Modularization design and implementation	I	√	I	I	
d. Constructability of Delivery Team engineering	I	√	I	I	
e. Integrated plant analyses and procedures (e.g., PRA, reliability, operating procedures, startup test procedures)	√	I			I
5. Equipment Supply	√	√			

Key: √ = lead task responsibility, I = interface inputs and support responsibility
Remarks *: GE and Toshiba will establish a Bellefonte ABWR design jointly.

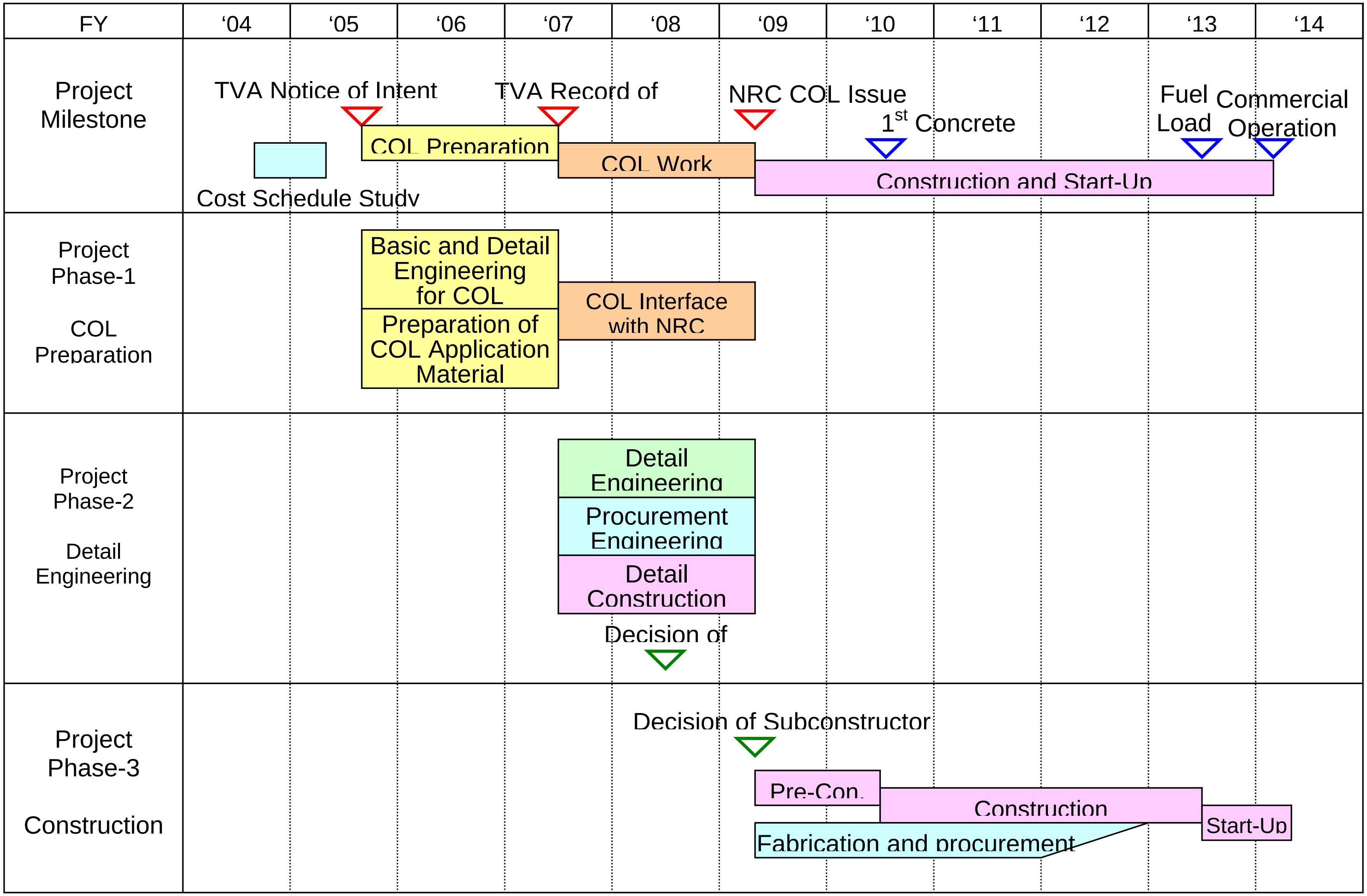


Figure 5.1 Project Milestone and Possible Project Model

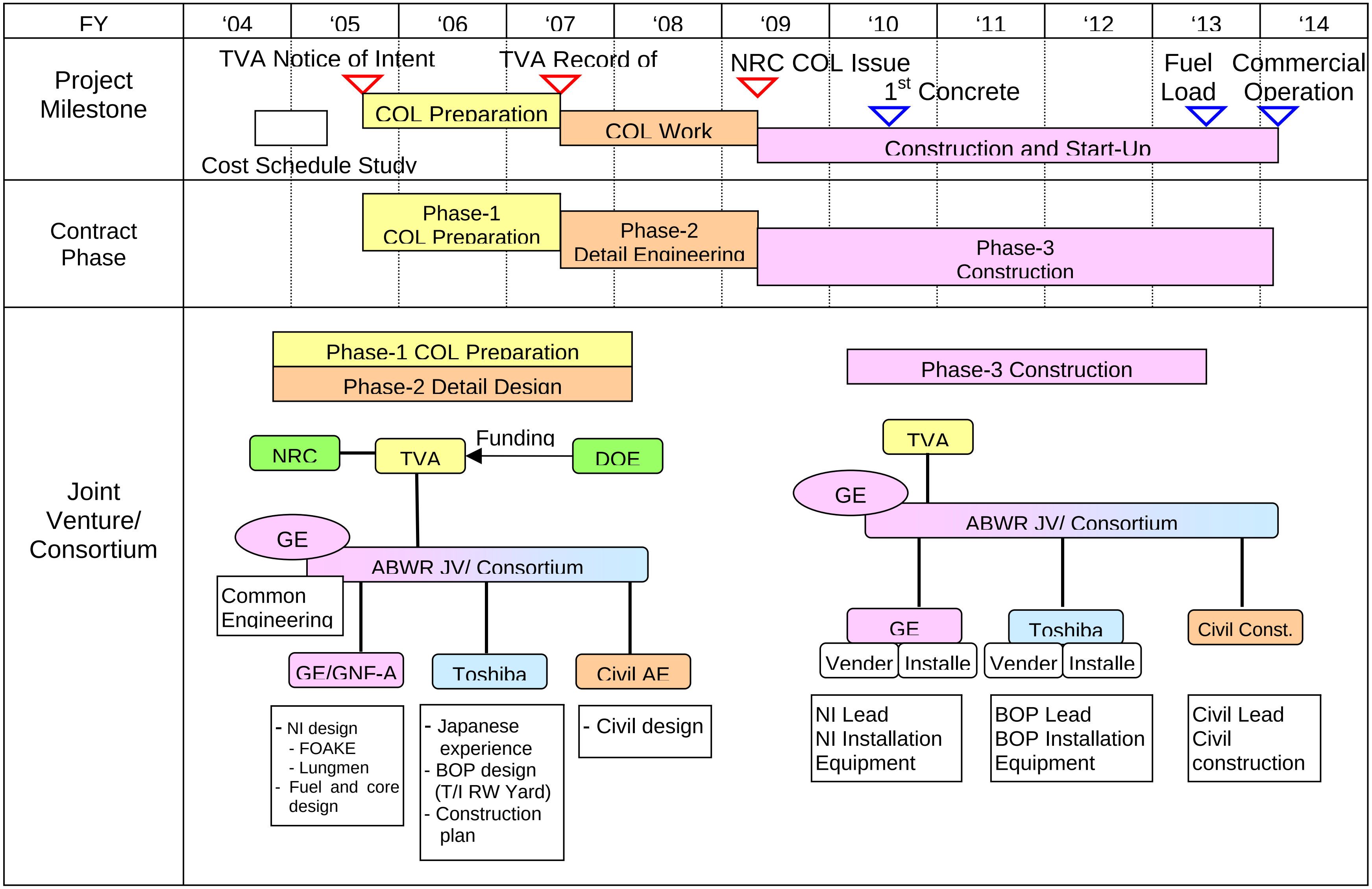


Figure 5.2 Possible Joint Venture/Consortium Model

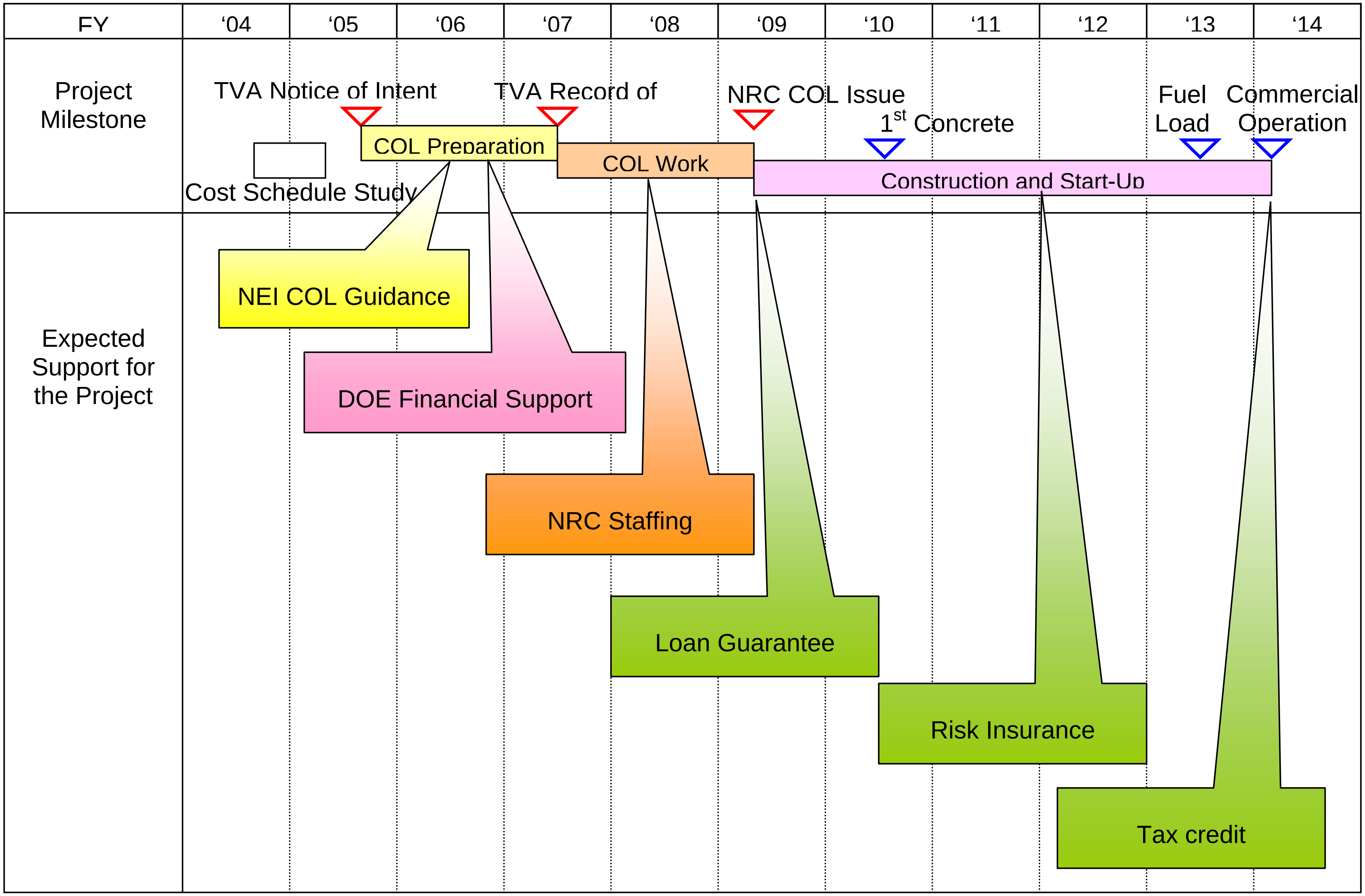


Figure 5.3 Project Milestone and Expected Supports

6.0 ADDITIONAL PLANT ENHANCEMENT OPTIONS

6.1 INTRODUCTION

Additional plant enhancement options for improving the cost, schedule and performance of the base concept Bellefonte ABWR were evaluated in Task 3. As was done in Task 1, Toshiba and GE proposed items for evaluation, based on their respective experiences, and jointly determined the items to be evaluated in Task 3. The enhancements evaluated in Task 3 were identified after Task 1 was completed or were deferred from Task 1. Of the twenty-one items that were evaluated in Task 3, eighteen were recommended for adoption.

6.2 IDENTIFICATION AND EVALUATION PROCESS

Figure 6.2-1 illustrates the process used by Toshiba and GE starting with the base plant concept from Task 1 to identify and evaluate additional plant enhancements for Task 3. The enhancements identified in Task 3, result from Toshiba's and GE's latest technologies. Toshiba and GE reviewed the identified enhancements, considered alternatives, and determined the impact on the DCD. Once the enhancements and their resultant deviations to the DCD were identified, GE reviewed these deviations with regard to their licensability for Bellefonte. Finally, GE and Toshiba discussed and agreed upon the items to be incorporated in Task 3. Based on the agreed items, Toshiba identified the changes from the basic plant concept under Task 1 and qualitatively evaluated the respective impacts on cost and schedule.

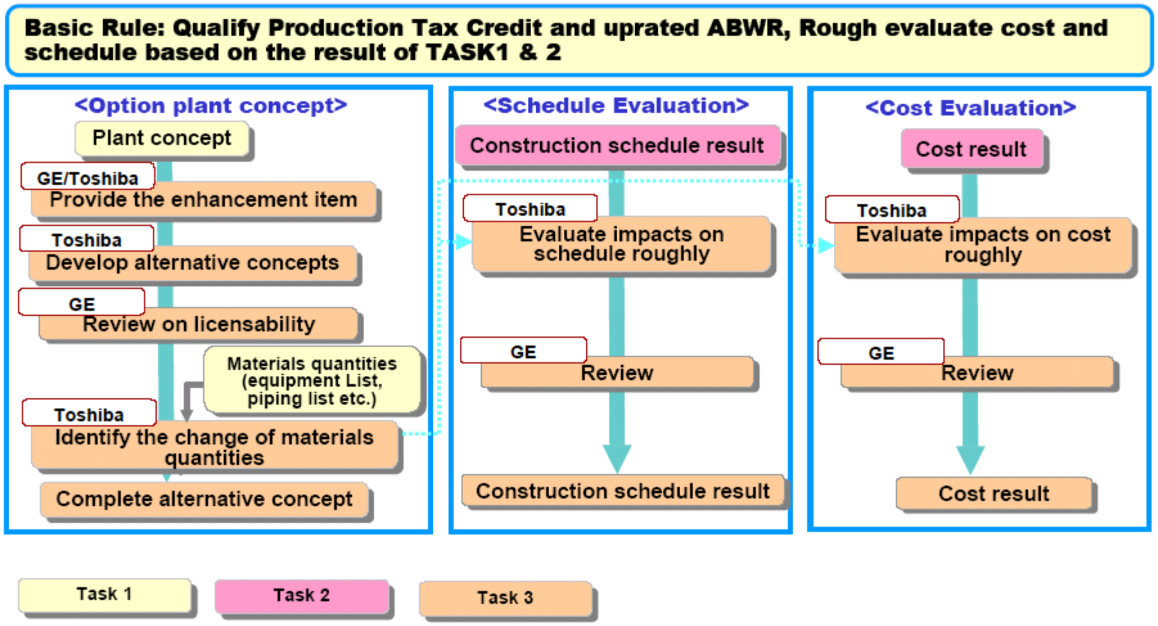


Figure 6.2-1 Key Flow Chart in Task 3

6.3 SCOPE OF ENHANCEMENT FOR TASK 3

6.3.1 Basic Criteria for Task 3 Enhancements

Whereas, the selection of enhancements in Task 1 was focused on those that would reduce the cost and schedule for constructing the Bellefonte Project, the scope of Task 3 also considered enhancements which would reduce the plant's O&M cost. In addition, a 10% power increase to reduce the plant's $/kW was evaluated in Task 3 after being deferred from Task 1. The same criteria as used in Task 1, to judge if proposed deviations from the DCD should be adopted, was employed in Task 3.

6.3.2 Identified items to deviate from DCD

The enhancements and deviations are classified as Tier 1 exemptions, Tier 2* departures, and Tier 2 departures. Table 6.3-1 shows the selected enhancements and deviations from Task 3-1 activities. In Table 6.3-1, the items are arranged according to the related DCD section. The licensability and advantage of each item is summarized.

A more detailed explanation of each item is attached as Appendix-G. The description of each design enhancement includes:

- Description in DCD
- Description of Proposed Change
- Basis of Proposed Change
- Advantage of Change
- Licensability of Change
- Licensability Evaluation

"Advantage of Change" is classified into two categories, that is, cost reduction and other advantage. Furthermore, cost reduction is classified into three categories, that is, >$1M, <$0.1M, and between $0.1M and $1M. "Licensability of Change" is classified into three categories, inconsistent with current U.S. regulations, consistent with regulatory change after Design Certification, and consistent with current U.S. regulations. Some enhancements are combined, and there are not independent listings for the sub items.

Tables 6.3-2 through 6.3-19 show the deviations from the Task 1 documents in Chapter 3 which resulted from application of each enhancement option.

Table 6.2-20 shows the discussed but withdrawn enhancement options in Task 3-1 activities. The reason to be withdrawn is summarized in Remarks.

Table 6.3-1 Selected Enhancements and Deviations from Task 3-1 Activities

Categor	No.	Title	Licensability	Advantage	Remarks
Tier 1	*1.2 General Provisions*				
	1	Power Uprate to 4300MWt	Acceptable Licensing Risk, worth the $/kW reduction.	Increased electrical power output, decreased $/kW	
	2	Thermal Power Optimization Equipment	No Licensing Risk	From $0.1M to $1M initial cost reduction Improved power calculation accuracy, elimination of ultrasonic flow equipment	Triplicated high accuracy flow rate instrumentation serves as less costly alternative to ultrasonic flow equipment.
	2.2 Control and Instrument Systems				
	3	Non-Class 1E design applies for the SIP of S-FMCRD	Changing the design of the SIP from Safety-Related in the Certified ABWR to non-Safety-Related in Bellefonte will be viewed by the NRC as removing safety margin built into the Certified design. This is viewed as a significant Licensing risk for TVA in gaining approval for this change and obtaining an Operating License.	More than $1M initial cost reduction	
	4	Electrical System	Acceptable Licensing Risk due to plant safety improvement.	Improved plant safety	
	2.10 Power Cycle Systems				
	5	Gland Steam Evaporator Capacity	No Licensing Risk	Improved plant economics	
	2.12 Station Electric Systems				
	6	RCIC Power Supply	Minor Licensing Risk due to improved RCIC reliability.	Less than $0.1M initial cost reduction	
Tier 2	*7.0 Instrumentation and Control Systems*				
	1	Remote Shutdown Panel	Minor Licensing Risk due to increase in RSP capability.	Improved operator interface	
	8.0 Electric Power				
	2	Security System Diesel	No Licensing Risk	Improved plant investment protection	
	9.0 Auxiliary Systems				
	3	Increase in FPC Heat Exchanger Capacity to Shorten Outage	No Licensing Risk	Reduction in outage length	
	4	Reduction in number of main turbine oil coolers	No Licensing Risk.	From $0.1M to $1M initial cost reduction	
	5	DCIS Room HVAC	Minor Licensing Risk due to increased DCIS reliability.	Improved operator interface and plant safety	
	6	ASDs for HVAC	No Licensing Risk	Less than $0.1M initial cost reduction Improved plant reliability	
	7	Diesel Generator	No Licensing Risk	Improved plant reliability and safety	
	10.0 Steam and Power Conversion System				
	8	Turbine Generator	No Licensing Risk	More than $1M initial cost reduction Increased electrical power output, decreased $/kW	
	9	Reduction of turbine bypass capacity	Minor Licensing Risk	From $0.1M to $1M initial cost reduction	
	10	Change of Number of Condensate Pumps	No Licensing Risk	Mitigation of transient behavior of a plant	
	11	Addition of measurement of feedpump startup valve flows	No Licensing Risk	Improvement of operability	
	12	Monitoring of heater drain flows	No Licensing Risk	Improvement of monitoring	

Table 6.3-2a Changes Resulted from 10% Power Uprate (Reactor System)

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1 (3992 MWt)	For TASK 3 (4300 MWt)	
B21	NBS	Differential Pressure of MSIV	54KPa[dif] (@1.91X10^6kg/h)	65KPa[dif] (@2.1X10^6kg/h)	The diameter of the seat may be modified to lower the velocity of steam through the seat. In such case, DP can be decreased.
B31	RRS	RIP Flow rate and TDH	6912m^3/h, 32.6m, 7700m^3/h, 40m (at 1450rpm)	7320m^3/h, 37.5m, 8200m^3/h, 46m (at 1550rpm)	The same size of RIP can be used.
		RIP Motor capacity	830kW	1020kW	The same size of RIP motor can be used.
		RIP Motor H/X capacity	134KW(4.57X10^7BTU/hr)	170KW(5.80X10^7BTU/hr)	The same size of RMHX can be used.
C41	SLC	Sodium Pentaborate	3720kg	3940kg	Minimum Boron Concentration is changed from 850ppm to 900ppm
E11	RHR	RHR H/X capacity	6.94 MW (K=195 BTU/sec deg F)	8.53 MW (K=240 BTU/sec deg F)	K:Heat Removal Capacity Value, Service Water Temp.=35degC, Suppression Pool Temp.=52degC
E51	RCIC	RCIC Pump Flow Rate and System Head (at Reactor Pressure)	182m^3/h (801gpm) and 900m (2950 ft) (at 8.12MPaG and 1.04MPaG)	230m^3/h (1013gpm) and 930m(3050) (at 8.12MPaG and	
		RCIC main piping	200A (8B) (at RCIC Pump Suction Line)	250A (10B) (at RCIC Pump Suction Line)	
G31	CUW	CUW Pump Flow	77m^3/h	85m^3/h	Assumed in proportion to the change of the feedwater flow, i.e. change of the reactor thermal output
		CUW RHX capacity	31.9MW	35.1MW	Assumed in proportion to the change of the reactor thermal output
		CUW NRHX capacity	5.58MW	6.14MW	Assumed in proportion to the change of the reactor thermal output
		CUW F/D Flow Rate	77m^3/h	85m^3/h	
K00	RW	Radwaste (liquid, solid) Volume Generated	Base	Slightly increase	Radwaste volume generated will be increased, for example CUW F/D sludge, Condensate Filter sludge, Condensate Demineralizer resin
P20	RNCW	RNCW H/X capacity	13.7MW	14.5MW	Depends on RMHX and NRHX capacity change
P21	RCW	RCW H/X capacity	15.0MW	17.8MW	Depends on RHR capacity change

Table 6.3-2b Changes Resulted from 10% Power Uprate (Turbine System)

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1 (3992 MWt)	For TASK 3 (4300 MWt)	
N21	CFCAE	Duty of No.6 feedwater heaters	$67X10^3$kW	$72X10^3$kW	per shell
		Duty of No.5 feedwater heaters	$35X10^3$kW	$38X10^3$kW	per shell
		Duty of No.4 feedwater heaters	$43X10^3$kW	$47X10^3$kW	per shell
		Duty of No.3 feedwater heaters	$45X10^3$kW	$49X10^3$kW	per shell
		Duty of No.2 feedwater heaters	$140X10^3$kW	$151X10^3$kW	per shell
		Duty of No.1 feedwater heaters	$144X10^3$kW	$156X10^3$kW	per shell
		Capacity of SJAE	Base (100%)	Approx. 102.5%	Depends on the increase of the hydrogen and oxygen produced by radiolysis of water in the reactor
N22	FWHD	Capacity of feedwater heater drain pumps	$1800m^3$/h	$1950m^3$/h	
N31	MT	Generator Output	Base (at 101.7% thermal power)	Approx. 110%	
N35	MSR	Volume of whole component	Base (at 101.7% thermal power)	110%	
N37	TBV	Capacity of Turbine Bypass	33%	Approx. 30%	Diameter of Turbine Bypass Valve will not be changed
N61	COND	Duty	$253X10^4$kW	Approx. $274X10^4$kW	Approx. 110%
		Volume of whole component	Base (at 101.7% thermal power)	110%	This value will be stretched mostly in height
		Volume of hotwell	Base (at 101.7% thermal power)	110%	This value will be stretched mostly in height to retain 2 minutes to attenuate radioactivity
N71	CWS	Diameter of main circulating water lines	3400/2200/3200ID	3600/2300/3400ID	Supply line/condenser water box lines/return line
		Capacity of circulating water pumps	$36010m^3$/h	$38950m^3$/h	
		Number of Additional Cooling Tower	10 cells per unit	15 cells per unit	2% duty per 1 cell
P22	TCW	Capacity of TCW pumps	$2940m^3$/h	$2980m^3$/h	This value will be a little concerned by the design of power generation/transmission equipments depending on Generator Output
		Capacity of TCW heat exchangers	$66.8X10^9$J/h	$67.4X10^9$J/h	This value will be a little concerned by the design of power generation/transmission equipments depending on Generator Output

Table 6.3-2c Changes Resulted From 10% Power Uprate (Electrical System)

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1 (3992 MWt)	For TASK 3 (4300 MWt)	
C81	RFCS	ASD Capacity (rated output frequency)	1250KVA(47Hz)	1550KVA(52.8Hz)	
		Driven Motor Capacity for RIP MG set	3800KW	4700KW	
		Generator Capacity of RIP MG set	5000KVA	6100KVA	
		RIP MG set outline	Base	The size is increased by increase of GD2.	
N21	CFCAE	ASD Capacity for MD-RFP	10000KVA	12000KVA (pending)	
N41	GEN	Output Voltage, Capacity	27KV, 1580MVA(@pf=0.9)	27KV or 28KV, 1740MVA(@pf=0.9)	Generator Capacity is reviewed how the generator is operated in the power transmission system.
		Axial Length of Generator	17.1m	19.5m	The pedestal might be changed for this item.
		FCB Rated	Base	Possibility of specification change	

Table 6.3-3 Changes Resulted From Thermal Power Optimization Equipment

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
C31	FDWC	Ultrasonic feedflow measuring equipment	applied	eliminated	This change does not appear on Task 1 documents.

Table 6.3-4 Changes Resulted from Non-class 1E Design Applies for the SIP of S-FMCRD

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
C11	RCIS	RCIS Interface with SIPs	Rod separation signals from SIPs are inputted into the rods action control cabinets (RACCs).	Rod separation signals from SIPs are inputted into the remote communication cabinets (RCCs).	In case of the system interface of Task 1, the signals from SIPs are inputted RACCs in the main control room area through the essential multiplexing system (SIPs are classified Class 1E).

Table 6.3-5 Changes Resulted From Electrical System

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
R24	MCC	Non 1E class associated buses for FMCRDs, 250VDC standby charger and starting air compressors for EDG	Non safety transfer board(Number:3) Non Safety transformer 6900/210V(Number:3)	Non safety 480VAC MCC(Number:3) Non safety Transformer 6900/480V (Number:1) Non safety transformer	

Table 6.3-6 Changes Resulted From Gland Steam Evaporator Capacity

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
N33	TGS	Gland steam evaporator	not equipped as heat exchangers	equipped as the heat exchanger(s) with capacity for Turbine gland steam, building heating steam, radwaste steam and other utilities	Approx. 36ton/h capacity in current study
		related valves, orifices, pipings and instruments	not equipped	equipped	depends on the evaporator control specification

Table 6.3-7 Changes Resulted From RCIC Power Supply

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
R42	DC	MCC for RCIC System	Safety 125VDC MCC(Number:1)	Safety 480VAC MCC(Number:1)	
R46	VAC	CVCF for RCIC System	–	Safety 480VAC output CVCF(Number:1)	

Table 6.3-8 Changes Resulted From Remote Shutdown Panel

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
C61	RSS	System Configuration	The RSS has two divisional panels. RSS controls and indicators are hard-wired direct to the interfacing components and sensors.	The RSS has two divisional panels. RSS controls and indicators are hard-wired direct to the interfacing components and sensors. In addition to these RSS controls and indicators, the RSS panel (div A) has a div 1 video display unit (VDU) and the RSS panel (div B) has a div 2 VDU. These VDUs are connected to ESF control panels in the main control room area by multiplexing network.	In case of the system configuration of Task 3, if the safety related control panels in the main control area are functioning then the operator can operate by VDU. If the safety related control panels are not functioning the operator operates by switches that are already installed RSS panels.

Table 6.3-9 Changes Resulted From Security System Diesel

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
Y86	PP	Power Supply of the main turbine auxiliary pumps (oil, turning gear, bearing etc)	–	Cable from Bus of Security System Diesel to PIP MCC for the main turbine auxiliary pumps	

Table 6.3-10 Changes Resulted From Increase in FPC Heat Exchanger Capacity to Shorten Outage

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
G41	FPC	FPC heat exchanger capacity	6 MW (20.5x10^6 Btu/hr)	approx. 12 MW (41x10^6 Btu/hr)	
		FPC pump capacity	450 m^3/hr (2000 gpm)	approx. 900 m^3/hr (4000 gpm)	
		FPC main piping diameter	pump suction: 300A (12B) pump discharge: 250A (10B)	pump suction: 450A (18B) pump discharge: 350A (14B)	
P20	RNCW	RNCW heat exchanger capacity	13.7 MW (46.8x10^6 Btu/hr)	approx. 18 MW (61.5x10^6 Btu/hr)	
		RNCW pump capacity	1023 m^3/hr (4500 gpm)	approx. 1500 m^3/hr (6700 gpm)	
		RNCW main piping diameter	550A (22B)	650A (26B)	

Table 6.3-11 Changes Resulted From Reduction in Number of Main Turbine Oil Coolers

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
N34	LO	Number of main turbine oil coolers	100%×2	100%×1	
		related valves, orifices and pipings	2 sets	1 set	from inlet valve for oil cooler transfer to outlet valve
P22	TCW	related valves, orifices, pipings and instruments	2 sets	1 set	from inlet valve for each oil cooler to outlet valve
		Total required system flow	Base	reduced by 100～200m^3/h (approx.)	will be slightly reduced for the elimination of standby oil cooler

Table 6.3-12 Changes Resulted From DCIS Room HVAC

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
U41	HVAC	DCIS Room HVAC	–	Add 2 air handling units and HECW pipings	

Table 6.3-13 Changes Resulted From ASDs For HVAC

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
U41	HVAC	ASDs for HVAC (R/B exhaust fan and T/B exhaust fan)	–	Non safety 220kVA ASDs(Number:3) Non safety 520kVA	If the ASDs O&M cost is higher than saving, normal motor is used for exhaust fans for R/B and T/B.

Table 6.3-14 Changes Resulted From Diesel Generator

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
R24	MCC	MCC for CTG starting system	–	Non safety 480VAC MCC(Number:1) Non safety Transformer	

Table 6.3-15 Changes Resulted From Turbine Generator

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
N21	CFCAE	Number of LP heater strings	3 strings	2 strings	Capacity of one string should be reconsidered.
N22	FWHD	ditto	ditto	ditto	ditto
N31	MT	Turbine generator	TC6F−52" turbine (1 HP turbine and 3 LP turbines)	TC−4F turbine (2 LP turbines with larger last stage buckets)	
N61	COND	Number of condenser shells	3 shells	2 shells	Specification of individual condensers will be changed. (Approx. ×1.5 for duty, conceptually)

Table 6.3-16 Changes Resulted From Reduction in Turbine Bypass Capacity

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
N11	MS	Diameter of turbine bypass lines			
		from Main Steam Header to branching of turbine bypass line	800A(32B)	700A(28B)	
		from branching of turbine bypass line to the near of turbine bypass valve chest	550A(22B)	500A(20B)	
		Number of turbine bypass lines from turbine bypass valve to	3	2	Total capacity of turbine bypass will be reduced.
N37	TBV	Number of turbine bypass valves	3	2	

Table 6.3-17 Changes Resulted From Number of Condensate Pumps

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1 (3992 MWt)	For TASK 3 (4300 MWt)	
N21	CFCAE	Diameter of main condensate/feedwater lines			
		from LPCP suction header to LPCP	900A(36B)	800A(32B)	Number of LPCP will be changed from 3 to 4
		from LPCP to LPCP discharge header	450A(18B)	400A(16B)	Number of LPCP will be changed from 3 to 4
		from HPCP suction header to HPCP	600A(24B)	550A(22B)	Number of HPCP will be changed from 3 to 4
		from HPCP to HPCP discharge header	500A(20B)	450A(18B)	Number of HPCP will be changed from 3 to 4
		Number of condensate pumps	3/3	4/4	LPCP/HPCP
		Capacity of condensate pumps	3400/3400m^3/h	2270/2270m^3/h	Number of LPCP/HPCP will be changed from 3 to 4

Table 6.3-18 Changes Resulted From Addition of Measurement of Feedpump Startup Valve Flows

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
N21	CFCAE	Measurement of RFP startup valve flows	not equipped	equipped into the RFP C/D startup valve line	depends on the plant monitoring/control specification

Table 6.3-19 Changes Resulted From Monitoring of Heater Drain Flows

SYSTEM		SPECIFICATION			REMARKS
No.	ABBREVIATION	ITEM	For TASK 1	For TASK 3	
N22	FWHD	Monitoring of heater drain flows	not equipped	equipped into each drain flow (specifically, performed in the level control valves for each drain line)	Most of each monitoring will be performed by the flow rate signal transmitted from LCV itself. With some difficulties, monitoring will be alternatively performed by the measurement of position and differential pressure of LCV or not performed.

Table 6.3-20 Discussed but Withdrawn Enhancement Options in Task 3-1 Activities

Categor	No.	Title	Licensability	Advantage	Remarks
Tier 1	*2.14 Containment and Environmental Control Systems*				
	1	Drywell Cooling System	Licensing Risk of increased exemptions for Tier 1 changes is not prudent for cost reductions <$100K.	Less than $0.1M initial cost reduction Improved plant maintenance/drywell access	It is required to supply the low relative humidity air to lower drywell to prevent the SCC.
Tier 2	*3.0 Design of Structures, Components, Equipment and Systems*				
	1	The soil profile considering for seismic design	Applying the site specific soil profile to safety-related structures, RW/B and T/B of MSL and FWL would create an unacceptable licensing risk. As for non-safety-related structure, for example T/B, Alabama state building code can be used. With regard to the building out of scope of ABWR DCD (including Spray Pond, RSW pump house), site specific soil profile as a result of seismic study may be used in seismic design.	More than $1M initial cost reduction	The site specific soil profile should not be applied to safety-related structures, RW/B and T/B of MSL and FWL design due to licensing risk. As for non-safety-related structure, for example T/B, Alabama state building code can be used. With regard to the building out of scope of ABWR DCD (including Spray Pond, RSW pump house), site specific soil profile as a result of seismic study may be used in seismic design.
	9.0 Auxiliary Systems				
	2	Fire Protection System Power	Branch Technical Position requires for Multi-unit plants	Simplified electrical system design, improved fire system reliability	According to SRP 9.5.1 (CMEB 9.5.1) and Regulatory Guide 1.189, there is no problem to apply the following configuration for the Fire Protection System for two units: - one 100% motor-driven fire pump powered by one unit - one 100% diesel-driven fire pump

6.4 LICENSABILITY EVALUATION

As explained in the prior sections, the opportunity was taken during the Bellefonte Cost and Schedule Study in Task 3 to consider additional design enhancements that would further reduce the construction cost for the plant, reduce O&M cost or improve plant operability. Each of these potential design enhancements was compared to the ABWR Design Control Document (DCD) to determine its impact on the Part 52 licensing process.

The following describes the Licensability Evaluation that was performed as part of the study for the design enhancements proposed in Task 3. The Licensability Evaluation consisted of 1) a comparison of the proposed design enhancements to the DCD, 2) the identification of impacts on the DCD, 3) comparison against regulations, and 4) the evaluation of licensing risk.

6.4.1 Comparison of the Proposed Design Enhancements to the DCD

Each proposed design enhancement was compared against the DCD by writing a design description of the enhancement and searching the DCD for the sections that described equipment performing similar functions. Table 6.3-2a through Table 6.3-2r document the design enhancements and the DCD descriptions for the original equipment performing similar functions.

6.4.2 Identification of Impacts on the DCD

Also provided in Table 6.3-2a through Table 6.3-2r is a listing of the DCD subsections which contain text that would need to be modified to describe the proposed design enhancement. The design enhancements are also subdivided into three groups: those that impact Tier 1 of the DCD, those that impact Tier 2, and those that impact Tier 2*.

6.4.3 Comparison against Regulations

Each proposed design enhancement was compared to U.S. NRC Regulations (i.e. 10CFR) and assigned to one of three categories: 1) Consistent with current U.S. Regulations, 2) Consistent with regulatory changes after design certification or 3) Inconsistent with current U.S. Regulations. No design enhancements were recommended for adoption for the Bellefonte Project that were in the third category, inconsistent with current U.S. Regulations.

6.4.4 Evaluation of Licensing Risk

Each proposed Design Enhancement was evaluated for the risk it would present towards obtaining Bellefonte's Combined License under 10CFR Part 52. Of course, the lowest licensing risk would result from proposing no changes from the DCD. However, with the experience of constructing both the Hamaoka Unit-5 project (the third ABWR in the world) and the Lungmen Project (the first ABWR based on U.S. certified design), it has become apparent that there are some design details in the DCD that will need to be changed in order to have a feasible design. Thus, knowing that there will be changes to the DCD for constructing an ABWR in the U.S. it becomes reasonable to ask what other changes should be considered to make the design more cost effective without substantially increasing the licensing risk.

The first step in evaluating the licensing risk of each proposed design enhancement was to categorize if the design change impacted Tier 1, Tier 2 or Tier 2* of the DCD.

6.4.4.1 Tier 1 information

Tier 1 means the portion of the design-related information contained in the generic DCD that is approved and certified by Part 52 Appendix A (hereinafter Tier 1 information). The design descriptions, interface requirements, and site parameters are derived from Tier 2 information. Tier 1 information includes:

1. Definitions and general provisions;

2. Design descriptions;

3. Inspections, tests, analyses, and acceptance criteria (ITAAC);

4. Significant site parameters; and

5. Significant interface requirements.

6.4.4.2 Tier 2 information

Tier 2 means the portion of the design-related information contained in the generic DCD that is approved but not certified by Part 52 Appendix A (hereinafter Tier 2 information). Compliance with Tier 2 is required, but generic changes to and plant-specific departures from Tier 2 are governed by Section VIII of Appendix A. Compliance with Tier 2 provides one acceptable method for complying with Tier 1. Compliance methods differing from Tier 2 must satisfy the change process in Section VIII of Appendix A. Regardless of these differences, an applicant or licensee must meet the requirement in Section III.B to reference Tier 2 when referencing Tier 1. Tier 2 information includes:

1. Information required by 10 CFR 52.47, with the exception of generic technical specifications and conceptual design information;

2. Information required for a final safety analysis report under 10 CFR 50.34;

3. Supporting information on the inspections, tests, and analyses that will be performed to demonstrate that the acceptance criteria in the ITAAC have been met; and

4. Combined license (COL) action items (COL license information), which identify certain matters that shall be addressed in the site-specific portion of the final safety analysis report

(FSAR) by an applicant who references Part 52 Appendix A. These items constitute information requirements but are not the only acceptable set of information in the FSAR. An applicant may depart from or omit these items, provided that the departure or omission is identified and justified in the FSAR. After issuance of a construction permit or COL, these items are not requirements for the licensee unless such items are restated in the FSAR.

6.4.4.3 Tier 2* information

Tier 2* means the portion of the Tier 2 information, designated as such in the generic DCD, which is subject to the change process in VIII.B.6 of Appendix A. This designation expires for some Tier 2* information under VIII.B.6.

6.4.4.4 Changes to Tier 1, Tier 2 and Tier 2* information

Changes to Tier 1 information are the most sensitive and require the Commission's Exemption to the Certification. An applicant or licensee who references a standard design certification may request an exemption from one or more elements of the design certification Tier 1 information. The Commission may grant such a request only if it determines that the exemption will comply with the requirements of 10 CFR 50.12(a). In addition to the factors listed in § 50.12(a), the Commission shall consider whether the special circumstances which § 50.12(a)(2) requires to be present outweigh any decrease in safety that may result from the reduction in standardization caused by the exemption. The granting of an exemption on request of an applicant must be subject to litigation in the same manner as other issues in the operating license or combined license hearing.

An applicant or licensee who references this appendix may depart from Tier 2 information, without prior NRC approval, unless the proposed departure involves a change to or departure from Tier 1 information, Tier 2* information, or the technical specifications, or involves an unreviewed safety question as defined in paragraphs B.5.b and B.5.c of Part 52 Appendix A. When evaluating the proposed departure, an applicant or licensee shall consider all matters described in the plant-specific DCD.

A licensee who references this appendix may not depart from the following Tier 2* matters without prior NRC approval. A request for a departure will be treated as a request for a license amendment under 10 CFR 50.90.

(1) Fuel burnup limit (4.2).

(2) Fuel design evaluation (4.2.3).

(3) Fuel licensing acceptance criteria (Appendix 4B).

6.4.4.5 Licensing risk for Tier 1 changes

Since the Bellefonte Project may be the first plant to be licensed under Part 52, no precedent or yardstick exists to quantitatively measure the licensing risk for changes to Tier 1 information. Since Tier 1 changes are exemptions to the certification and have to be approved by the Commission, it is difficult to judge if the Commission will approve alternative design detailing as long as there is no decrease in safety, or if they will want to adhere strictly to the certified design in order to achieve design standardization. In order to provide a relative ranking of the licensing risks for the Tier 1 changes, they have been evaluated assuming the former.

However, since every Tier 1 change will require an exemption, they should not be pursued lightly. The licensing risk evaluation for each design enhancement proposal that has a cost reduction in the neighborhood of $100K indicates that the change should only be considered in light of its addition to the licensing risk and its relatively minor cost reduction. A relatively liberal screening process has been applied for the Tier 1 changes in order to provide the customer with the maximum possible cost reduction opportunities from which the final selections will be made. The results of the licensing risk evaluations for the Tier 1 changes are provided in Table 6.3-2a through Table 6.3-2f.

6.4.4.6 Licensing risk for Tier 2 changes

Changes to Tier 2 information are much less sensitive than Tier 1 changes. They do not require prior NRC approval unless the change impacts the technical specifications, or involves an unreviewed safety question. Thus, the licensing risk evaluations for Tier 2 items provided in Table 6.3-2g through Table 6.3-2r primarily conclude that there is no licensing risk or minor licensing risk.

6.4.4.7 Licensing risk for Tier 2* changes

There are no Design Enhancement proposals in Task 3 that fall in the Tier 2* category.

6.4.4.8 Results of Licensing Risk Review

As a result of applying the above Licensing Risk Review process and other considerations the total list of 21 potential design enhancements was screened down to 18 design enhancements that are being considered for the Bellefonte Project. The considered design enhancements have been drawn from past plant experience and are proven technologies. They are evolutionary improvements and do not change system functionality. In order to reduce any adverse impact on the licensing schedule, including consideration of their cumulative effect, all of the considered design enhancements will be pre-reviewed with the NRC prior to extensive work on the COL Application. Any items which appear to present an unwarranted risk to the Bellefonte licensing schedule will be deleted.

6.5 EFFECTS OF ENHANCEMENT ON PLANT CONSTRUCTION SCHEDULE

Prior to the evaluation of schedule impact, the different enhancements selected under Section 6.3 were summarized (see Table 6.3-1).

Following the screening for licensability as discussed in Sec. 6.2, the impact of each enhancement item on the plant construction schedule was evaluated. The conclusion of the schedule evaluation was that no items selected in Task 3 for enhanced plant construction have a major impact on schedule (see Table 6.5-1).

Table 6.5-1 Schedule Evaluation in Task 3

Categor	No.	Title	Schedule evaluation
Tier 1	*1.2 General Provisions*		
	1	Power Uprate to 4300MWt	Minimal impact with precedents
	2	Thermal Power Optimization Equipment	Negligible impact
	2.2 Control and Instrument Systems		
	3	Non-Class 1E design applies for the SIP of S-FMCRD	Negligible impact
	4	Electrical System	Minor impact
	2.10 Power Cycle Systems		
	5	Gland Steam Evaporator Capacity	Negligible impact
	2.12 Station Electric Systems		
	6	RCIC Power Supply	Negligible impact
Tier 2	*7.0 Instrumentation and Control Systems*		
	1	Remote Shutdown Panel	Negligible impact
	8.0 Electric Power		
	2	Security System Diesel	Negligible impact
	9.0 Auxiliary Systems		
	3	Increase in FPC Heat Exchanger Capacity to Shorten Outage	Minor impact
	4	Reduction in number of main turbine oil coolers	Negligible impact
	5	DCIS Room HVAC	Negligible impact
	6	ASDs for HVAC	Negligible impact
	7	Diesel Generator	Negligible impact
	10.0 Steam and Power Conversion System		
	8	Turbine Generator	Major reduction in Turbine Island schedule
	9	Reduction of turbine bypass capacity	Negligible impact
	10	Change of Number of Condensate Pumps	Negligible impact
	11	Addition of measurement of feedpump startup valve flows	Negligible impact
	12	Monitoring of heater drain flows	Negligible impact

6.6 EFFECTS OF ENHANCEMENTS ON PLANT COST

Following the licensibility evaluation under Sec. 6.2, the cost impact of each enhancement item was evaluated. In the cost evaluation, construction cost of the enhancement item was evaluated. The result of the cost evaluation is presented in Table 6.6-1. The 10% uprate and the modernized turbine generator are the major factors to improve initial capital costs.

Table 6.6-1 Cost Evaluation in Task 3

Category	No.	Title	Initial Cost Impact per plant (*)
Tier 1	*1.2 General Provisions*		
	1	Power Uprate to 4300MWt	Increase "S"
	2	Thermal Power Optimization Equipment	Decrease "A"
	2.2 Control and Instrument Systems		
	3	Non-Class 1E design applies for the SIP of S-FMCRD	Decrease "B"
	4	Electrical System	Increase "C"
	2.10 Power Cycle Systems		
	5	Gland Steam Evaporator Capacity	Increase "B"
	2.12 Station Electric Systems		
	6	RCIC Power Supply	Increase "A"
Tier 2	*7.0 Instrumentation and Control Systems*		
	1	Remote Shutdown Panel	Increase "C"
	8.0 Electric Power		
	2	Security System Diesel	Increase "C"
	9.0 Auxiliary Systems		
	3	Increase in FPC Heat Exchanger Capacity to Shorten Outage	Increase "A"
	4	Reduction in number of main turbine oil coolers	Decrease "C"
	5	DCIS Room HVAC	Increase "A"
	6	ASDs for HVAC	Increase "A"
	7	Diesel Generator	Increase "C"
	10.0 Steam and Power Conversion System		
	8	Turbine Generator	Decrease "S"
	9	Reduction of turbine bypass capacity	Increase "B"
	10	Change of Number of Condensate Pumps	Increase "A"
	11	Addition of measurement of feedpump startup valve flows	Increase "B"
	12	Monitoring of heater drain flows	Increase "C"

(*)
"S": more than 5M$/plant
"A": between 1 to 5 M$/plant
"B": between 0.2 to 1 M$/plant
"C": less than 0.2M$/plant

6.7 CONCLUSIONS

Based on the basic plant concept developed in Chapter 3, enhancement option items have been selected and evaluated in Task 3, including increase of generation output, decrease in construction costs, and decrease of O&M costs. It is recommended that power generation companies select whether to adopt the Task 3 options or not, as some of them might result in slightly higher capital cost but significantly lower $/kW or O&M costs. The highlighted features among the selected items in Task 3 are a 10% power uprate and modernization of turbine generator. These two items are described below.

6.7.1 10% Power Uprate

A 10% Power Uprate from the first ABWR (3926MWt) would definitely contribute to a significantly lower $/kW, but further consideration is required regarding transmission capacity and power demand. For more than a decade, the power uprate program on conventional BWRs has been adopted and it is a very common practice now. While some minor physical modification of plant systems is required to uprate, uprates of more than 10% are not rare. It is recommended that the Bellefonte ABWR be initially designed and constructed for 4300MWt (~10% uprate). The planned licensing strategy would be to license Bellefonte initially for 1.7% power uprate using Appendix K and run the first cycle at that power. After the first cycle, the application for a 10% power uprate could be processed as it has been for many plants previously. Consistent with the NRC approved GE Power Uprate Licensing Topical Report, the plant will be tested for flow induced vibration under the increased core flow conditions. Any potential impact on the dryer due to the increased steam flow will be addressed consistent with NRC requirements. In light of past experience for other plants, a 10% uprate after the first cycle is a reasonable licensing risk.

A unique feature of the 10% power uprate concept is that it requires only minimal equipment changes in the nuclear island and balance of plant. While the output of the turbine generator is larger, it is not necessary to alter the feedwater or condensate systems. Although, as discussed in Sec. 3.3, TVA selected not to use 10% power uprate in Task 1, it could provide a very attractive option for potential new power generation companies who are planning to construct an ABWR.

6.7.2 Modernization of Turbine Generator

More modern turbine systems have been developed since the ABWR DCD description was written. These turbine systems have been in use or have been proposed for several years for some European Nuclear Plants and for some U.S. fossil plants. Two different types of modernization designs are described below:

(1) Use of longer last blade low pressure (LP) -turbine blades than the current 52" blades would contribute better thermal efficiency, and the number of LP turbines can be reduced to 2. This configuration yields a shorter and lighter turbine-generator. The shorter and lighter turbine-generator enables a shorter turbine building with less foundation materials to be built.

(2) Replacement of dual flow high pressure turbine with combination high pressure and intermediate pressure turbine in a single casing. Use of the intermediate pressure turbine and its lower exit pressure allows the use of a shorter low pressure turbine. Again, this configuration yields a shorter and lighter turbine-generator. The shorter and lighter turbine-generator enables a shorter turbine building with less foundation materials to be built.

For power generation companies, the use of modernized turbines provides a good option because it would reduce the quantities required for the turbine building as well as yielding a higher efficiency for the turbine system.

7.0 COST AND SCHEDULE REVIEW RESULT

After over two decades of no new nuclear power plant construction in the United States,

This study was initiated to evaluate, using the latest ABWR as a benchmark case, the cost and schedule for building two ABWR units on TVA's Bellefonte site.

The study made the maximum use of existing detailed technical information and the experience of the most recent ABWR construction around the world. Both GE and Toshiba used detailed information of actual ABWRs under construction or constructed in Taiwan and Japan. The study also assumed use of the latest technology and methods to enhance efficiency in the plant itself and its construction. New technologies developed and proven effective in the continuous construction of ABWRs and BWRs in Japan were evaluated under the Bellefonte site's specific conditions.

The results were based on detailed design and quantity data information and the latest research in the U.S. market, by GE, Bechtel and Toshiba, and were assessed by TVA.

As a result, this evaluation indicates that a two unit ABWR can be built today in the U.S. environment in a 40 month construction period, each, for a price of $1611/kWe for the basic 1371Mwe (net) power units and $1535/kWe for the 1465MWe (net) uprated power units. These are improved figures compared with the past nuclear construction experience in the U.S.

Builder's risk, property and liability insurances and import duty are not included in the above costs. The ballpark estimate for the insurances and import duty is approximately equivalent to $20/KW in the case of EPC Overnight Cost of $1,611/KW for Entire Plant, but could vary based upon specific terms and conditions.

The following two factors, which are major contributors to nuclear plant construction cost and duration, should be examined in more detail.

(1) U.S. construction productivity

Construction productivity, evaluated as Unit Rate, is the dominant factor affecting construction period and cost. As mentioned in Chapters 4.1 and 4.2, a detailed study was executed by the team based on the past nuclear plant construction records in the U.S., recent fossil plant construction records in the U.S., proposals from multiple U.S. architect engineering companies including Bechtel, and recent nuclear plant construction records in Japan. Furthermore, reviewing work procedures discussions with other construction companies, and use of Visual Work Process Analysis (VWPA), differences in construction practices between the U.S. and Japan were identified. Also taken into account are Bellefonte regional characteristics and special requirements in large nuclear construction. As the result of this detailed and comprehensive study, it is impossible to find significant differences in work practices, including work organization and QA/QC requirements between the U.S. and Japan. However, more than 20% difference in the average unit rate between the U.S. and Japan was recognized. This difference in the unit rate directly affected the increase of the estimated construction period and overall labor cost, which contributes to more than 1/3 of the entire cost.

Appendix L shows a trend of man-hours for Japanese BWR construction. In the past twenty years, Japan has achieved significant man-hour reductions by utilizing design construction technology improvements. As the result of these continuous improvement efforts, current enhanced productivity has been achieved and construction man-hours have been reduced.

Improvement in construction productivity is considered as a major issue for the U.S. nuclear industry. It is essential to continue discussions with the U.S. construction industry, evaluate the proposed new construction technologies quantitatively, and incorporate some advantages of Japanese construction management to the U.S., up to the actual construction implementation of the Bellefonte ABWR.

In parallel, enhancement of modularization is to be considered to reduce the field installation work. As described in Chapter 4.1, modularization for the Bellefonte ABWR was optimized based on the experience of Japanese ABWR construction. For example, the modularization ratio of the large bore piping is 30% in length including pre-assembly in the current plan. However, extension of the modularization scope with less field work could reduce the total cost.

(2) The U.S. wage rates

As mentioned in Chapter 4.2 and Appendix O, the Union based unit rates for TVA are higher than the average rates in the Bellefonte area. These rates are very close to those of Japanese work forces, which are considered to be high. It is difficult to resolve this issue for the TVA/Bellefonte site at this moment, but it is anticipated that continuous discussion with the construction industry would improve this issue.

In the case of a green field site, consideration of regional wage differences, as well as Union/Non-Union and sub-con/direct hire packages may offer opportunities to lower cost.

APPENDICES

All APPENDICES are proprietary information.

A: System Description
B: System Flow Diagram
C: Control Block Diagram
D: General Arrangement
E: Single Line Diagram
F: Proprietary Fuel Cycle Information
G: TASK1 and TASK3 Enhancement Evaluation
H: ABWR Construction Plan
I: Site Temporary Construction Facilities and Laydown Areas
J: Yard Construction Plan
K: Differences of Construction Practices between U.S. and Japan
L: Construction Manpower Trend in Japan
M: Level 2 Construction Schedule
N: ABWR Preoperational Test Schedule
O: Bellefonte Area Labor Survey
P: Total Facility List
Q: Bechtel Evaluation Report

- Construction Milestone Summary Schedule
- Level 2 Construction Schedule
- Sustained Installation Rate Curves
- Manpower Curves
- Zero Accident Performance Program

Appendices contain information that is proprietary in nature, therefore the appendices are not part of this public report.