

New Nuclear Power Plants – Learning from History to Understand Costs and Mitigate Risks

George B. Bradshaw, PE CCE and Christopher O. Gruber, CCC

Future sources of electric power generation are a critical issue for the US and other countries. Our continued economic growth, the maintenance of our quality of life, and assurance of our security all depend on an abundant, affordable supply of electricity. Nuclear power is an important fuel source, not only because of cost stability factors, but also for protecting the environment and ensuring a lasting supply of clean, safe and reliable delivery of electric service. In order for nuclear power to play a key role in future electric generation, there must be confidence in the cost estimates used to demonstrate the competitive economics of nuclear power when compared to alternatives, such as coal and natural gas plants.

The history of nuclear power in the US does not foster an environment that leads to confidence in plant cost estimates, or even in the economics of this very necessary and potentially beneficial energy generation alternative. In addition to concerns over nuclear plant project costs resulting from the industry's historical record, the availability of a skilled workforce, the length of time since start of the last new nuclear project, potential for public resistance, permitting delays, spent fuel disposal issues and many others risks appear as potential impediments to a nuclear revival in this country. Fortunately, many of the risks facing future construction projects have been exhaustively addressed by an industry that is actively seeking ways to ensure success through advanced technology and licensing initiatives.

Completely new nuclear plant designs were developed by industry in response to problems the industry experienced in the 1970s and the 1980s, including impacts that have evolved because of the Three Mile Island Unit 2 accident. It was realized that incremental improvements could not meet the deregulated electricity generation cost requirements. However, there are still many risks associated with the construction cost of these new designs and these are exacerbated by the 30 year hiatus the industry has experienced since the last plants were completed. This paper presents a brief history of nuclear power; discusses the industry woes in the 1980's, as well historical cost drivers; provides an overview of current regulatory, governmental and industry initiatives; and summarizes a few of the major risk areas for the next generation of nuclear power projects.

COMMERCIAL NUCLEAR POWER A HISTORICAL PERSPECTIVE

In late 1957, the Shippingport Atomic Power Station in Western Pennsylvania became the first nuclear central station to produce electricity commercially in the United States. In 1960, the Dresden Nuclear Power Station in Illinois became the second nuclear central station to begin commercial operation. These very early plants were built with a subsidy from the Atomic Energy Commission, which had responsibility for both promotion and regulation of the nuclear industry. In December 1963, the Jersey Power and Light Company placed the first order without government funding, for Oyster Creek, and had a "turnkey" price of \$132/kW.

There was a false sense of security about nuclear plant costs from 1963 to 1966, a period in which some 13 fixed-price turnkey contracts were placed. This was a period of relative economic and regulatory stability, an environment under which utility companies cost estimates were well founded.

A rapid growth in nuclear plant orders occurred in 1966 and 1967 when 52 orders were placed, coinciding with a discontinuation of the fixed-price, turnkey contracts being offered by the Nuclear Steam Supply System (NSSS) vendors. However, this rapid growth led to regulatory delays simply for the AEC to process the applications and issue construction permits. Growth continued until 1974, with over 200 NSSS orders placed. However, during this period, the industry was experiencing dramatic slow downs because of major and unexpected changes and challenges, including the following.

- A National Environmental Policy Act (NEPA) requirement for an environmental impact statement.
- Unprecedented levels of inflation and high interest rates.
- Formation of the Nuclear Regulatory Commission (NRC), with a subsequent deluge of new requirements.
- TVA's Browns Ferry nuclear plant fire in 1975.
- Three Mile Island (TMI) incident in 1979. And,
- NUREG-0660 and NUREG-0737 responses to TMI.

Prior to these events in the 1970s, construction times of four years and costs of \$200/KW, were being experienced for nuclear plants rated around 400 MWe. The landmark Calvert Cliffs decision in 1971 requiring nuclear power plants to comply with

NEPA led to lengthy public hearings which impacted some 63 licensing applications, and resulted in cancellation of many projects which now faced more stringent regulations because of the delays. Many advanced design high temperature gas-cooled reactor (HTGR) plants were canceled in 1975, eliminating the benefits of this more efficient technology.

After the Browns Ferry fire, concerns for nuclear safety continued to build and the NRC responded with regulatory changes focusing on missile protection, physical separation, seismic protection, cable separation, pipe-break restraints, security, physical separation of electrical and mechanical equipment, and in-service inspection. These evolving regulatory requirements led to increased costs and delays in re-design and retrofiting. Plants that went into operation between 1975 and 1980 averaged between \$400 to \$600/Kw. After 1980, nuclear plant costs increased dramatically to an average cost of \$1500 to \$3000/Kw.

A comprehensive and widely read report on the plight of the nuclear industry was published in *Forbes* magazine in 1985 [1]. The report stated that without an understanding of what caused the nuclear debacle, the US would lack any clear sense of what it must do not only to restore nuclear energy as a viable energy option, but also to assure that history does not repeat itself. Obstructionists were given some of the credit for the incredible price increases:

“The opponents of nuclear power have hampered and harassed it, inflated its costs and stretched out construction times to unconscionable lengths, but they could not, unassisted by events, have prevailed.”

The list of other culprits included the US federal government and the NRC, the equipment manufacturers, the contractors and subcontractors, the utility executives and the state regulatory commissions. Most frequently cited complaint by utilities was the NRC’s poor management and failure to consider the economic cost of the regulations it imposed. Regulatory problems and plant cost increases were by far the greatest following

the TMI accident in March 1979 and the vast number of design changes imposed on plants during construction when the impacts were the most difficult to control. There were significant cost growths before TMI, but not as dramatic as those after. At the time these cost increases were accepted because of the cost recovery nature of the regulated utility; utilities relied on the public service commissions to bail them out.

To provide a projected impact of nuclear plant capital costs on electricity rates, *Forbes* provided a table of 35 different power plants and stations nearing completion. The plant cost data from this table is presented statically in figure 1, which shows projected capital costs (including interest during construction) normalized for net capacity (kilowatts electric). The highest cost was for the Long Island Lighting Co.’s Shoreham plant at \$5,192/kwe of which 35 percent was the cost of capital (allowance for funds used during construction, or AFUDC). The plant with the lowest projected cost was Duke Power’s McGuire two unit at \$912/kwe with 33 percent because of the cost of capital during construction. The average cost of all of the plants was \$2,860/kwe, with a standard deviation of \$1,050/kwe. Although some of the plants listed were canceled, actual costs for most of those shown had subsequent increases.

Utilities reacted to both the increased costs of nuclear plants and reduced load projections by canceling projects. TVA canceled 8 out of 17 nuclear projects and Duke canceled six out of 13 planned projects. Washington Public Power canceled four of the 5 plants under construction, many with substantial completion, and resulted in their defaulting on \$2 billion in nuclear plant bonds.

The current business environment has changed considerably and is much more risk averse. This is one reason that the last construction permit issued to a nuclear plant in the US was in 1978, and no nuclear plant has achieved commercial operation in the US since the TVA Watts Bar plant in 1995.

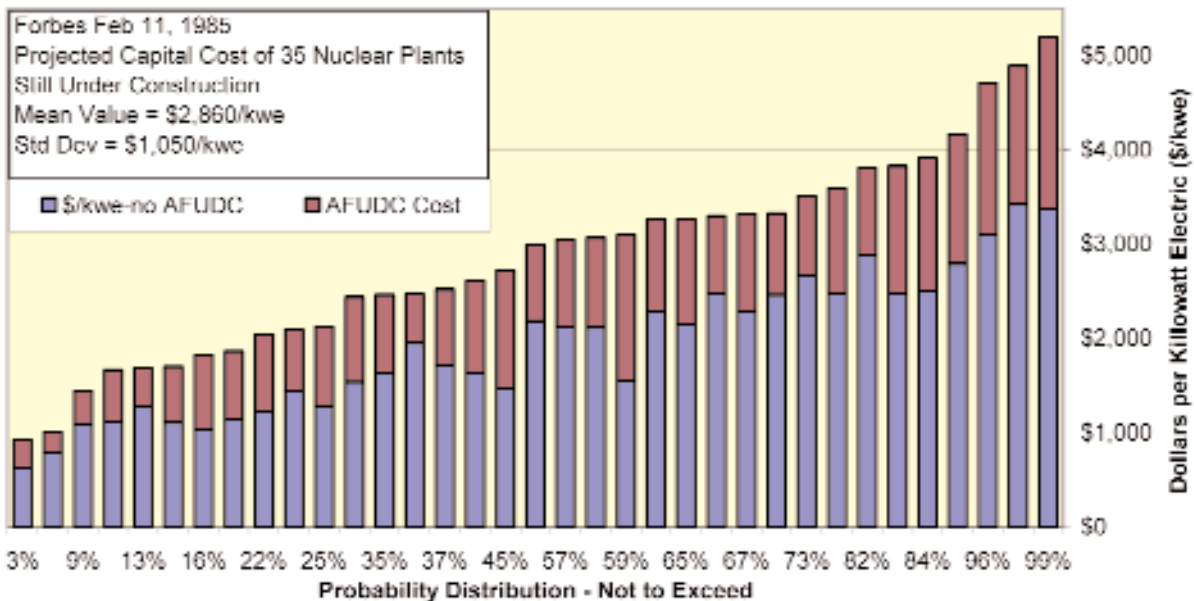


Figure 1—Projected Cost of Nuclear Plants in 1985

Commodity	Units	1960s		1970s		1980s	
		200	400 MWe	500	1000 MWe	800	1200 MWe
Piping	feet	130,000		200,000		480,000	
LB Pipe Supports	each	2,000		4,000		15,000	
Cable	feet	2,000,000		3,000,000		7,000,000	
Conduit	feet	190,000		330,000		600,000	
Cable Tray	feet	21,000		40,000		95,000	

Table 1—Growth of Nuclear Plant Commodities (approx.) and Power Levels

NUCLEAR POWER PLANT COST DRIVERS

During the 1970's and 1980's, United Engineers and Constructors Inc. (UE&C) conducted numerous studies of the factors contributing to the cost of nuclear plants [2]. The studies were performed to identify areas where significant improvements in cost, schedule and manhours appeared feasible and to provide a basis for estimating the magnitude of possible reductions in the DOE sponsored energy economic data base (EEDB-X) cost models, a tool used to derive industry cost estimates. This and other comparable industry studies can offer a perspective on the key cost drivers for nuclear plant capital costs, as well as offer insights into the potential impacts on these drivers as a result of current industry initiatives and current, as well as anticipated, regulatory and commercial environments.

Equipment Cost Drivers

The procurement of nuclear grade equipment involves the imposition of many regulations and codes and standards, as well as an extensive quality assurance program. The results are purchase specifications containing hundreds of more pages than for equipment and materials purchased to commercial standards. Also, the installation of nuclear grade equipment and material must be more rigidly controlled through procedures, training, quality control inspections and QA.

Cost multipliers for nuclear safety class equipment above commercial equipment vary considerably. For example, nuclear grade pumps may vary from 2.5 to 4 times commercial pump prices; valves range from 2 to 17 times more expensive for nuclear installations; and nuclear quality pipe is at least twice the cost of standard pipe. A nuclear grade water chiller unit may be three times a non-nuclear unit. Consequently, reduction of equipment quantities will have a large beneficial effect toward reducing nuclear plant costs. One new reactor design, the Westinghouse AP1000, has passive safety systems which eliminate components and enable the use of non-safety grade active pumps. Eliminating unnecessary standards, codes, quality assurance requirements, and systematizing audit requirements should help reduce nuclear equipment costs.

Another factor which influences the cost of nuclear grade equipment is the reduction of competing bidders which has declined dramatically over the last few decades. There has been a significant consolidation of the nuclear steam supply vendors which can be expected to impact equipment availability, manufacturing capacity and pricing. In addition, due to a lack of business opportunities over recent years, there are now many fewer equipment vendors capable of providing nuclear quality equipment. This limited market has been cited as a contributing factor in the significant cost growth being experienced by the largest nuclear construction project currently under way in the

US, the Department of Energy's Waste Treatment and Immobilization Plant being built at the Hanford site. That project has grown from initial estimates of less than \$5 billion to the latest forecast of over \$12 billion. While there have been many problems and challenges that have confronted that project, the diminished nuclear marketplace has not been an insignificant one. Furthermore, in addition to impacting equipment availability and costs, the lack of a skilled, experienced nuclear workforce has also been a major result of the nuclear turndown and will need to be overcome by the next generation nuclear power projects.

Commodity Cost Drivers

The dramatic increase in regulations during the 1970s led to major increases in nuclear plant quantities, construction duration and plant costs. Table 1 shows how commodities increased from the early plants in the 1960s to 1970s and 1980s.

As could be expected, the increasingly larger plant sizes that became the industry norm resulted in significant quantity increases. Not only did the quantity of commodities increase, but the complexity of content (materials, engineering, and construction) increased dramatically as well. For example, a wall mounted pipe restraint in the 1980s required approximately nine times as much material, 10 times as many engineering hours and over twice the construction time as ones built in the 1960s. In addition to the content increases, the process of performing the engineering and construction work became less flexible because of rigid procedures and more hold points being required. Variations in commodity content were an important factor in explaining cost differences between plants, even more than regional labor cost differences.

Causes for commodity increases have been studied and have shown, for example, that 70 percent of the cable quantity increase were regulatory-induced changes to the original design basis. Compared to the 1960s, 50 percent of the cable increase was attributed to greater building volume (longer runs) with 20 percent because of plant capacity, 15 percent to redundancy and 15 percent because of separation requirements. More than 80 percent of the pipe support increase was due to regulatory-required changes, which increased design documentation in even greater proportions.

It is interesting to note that in the 1980s, material and equipment costs were less than 20 percent of the total plant cost, compared to around 50 percent in the 1960s. This was largely because of the fact that interest, engineering and owner costs became a greater portion of the total; from around 25 percent in the 1960s to 55 percent in the 1980s.

Labor Cost Drivers

Labor cost increases from the 1960s to the 1980s greatly overshadowed any problems in the area of material unit cost increases. Consequently, many early design choices may have significantly underestimated the construction impact. For example, plant designs that minimize building volume may create extremely congested working conditions and increase costs for both construction and maintenance. Between the 1960s and 1980s, construction labor has increased from less than five hours per KWe to over 20 hours per KWe (20 million for a 1000 MWe plant). These increases are reflected in higher unit rates for commodity installation and schedule extensions.

The University of Texas and others have performed extensive studies on labor productivity trends and causes. Some surveys indicated that the most significant increases in lost time occurred in the areas of rework and inspection delay. These problems were particularly acute for pipefitters and electricians, as compared to carpenters. Many of the areas for productivity loss can be controlled and improved by project management actions, such as time lost due to materials, tools and equipment. Other factors, such as single or multiple units, PWRs or BWRs, southern and northern units, union rules, and local supply, all contribute to labor cost variations. Peak craft work force level is also an important factor in overall labor productivity, and should be carefully controlled. Over manning of projects has also been found to contribute to poor worker morale and hence productivity, not to mention the impact to the local community's ability to provide services. UE&C found that the multitude of variables did not allow for consequential statistical analysis of nuclear plant labor and generally resulted in meaningless conclusions.

Engineering and non-manual worker hours also increased considerably from the 1960s to the 1980s, escalating at a steeper rate than craft hours. Much of the increase was because of increasing documentation and analysis to accommodate low probability events. For example, in the 1960s approximately 10,000 hours would be sufficient to qualify nuclear piping, compared to nearly two million hours in the 1980s. Single unit plants suffer a much greater penalty for engineering and non-manual hours than multiple units.

Examples of major areas for savings identified by UE&C included design standardization, modularization of equipment, reducing complexity, reducing regulatory uncertainty, and owner prior experience. Designers were challenged to avoid placing unnecessary requirements on constructors and, if manufacturing type tolerances were required, designers should encourage the use of offsite prefabrication of components and systems. Reducing change orders was a major area for improvement and could be achieved through a high degree of engineering completion prior to construction combined with constructability reviews to evaluate all options prior to start of construction. Interestingly, the advantages of standardization were found to far outweigh any advantages of economy of scale.

Nuclear Power Plant Schedules

Nuclear plant schedule duration (construction permit to fuel load) increased from around 40 months in 1970 to over 100 months in the 1980s, as shown in Figure 2 [3]. The Electric Power Research Institute (EPRI) performed the most notable

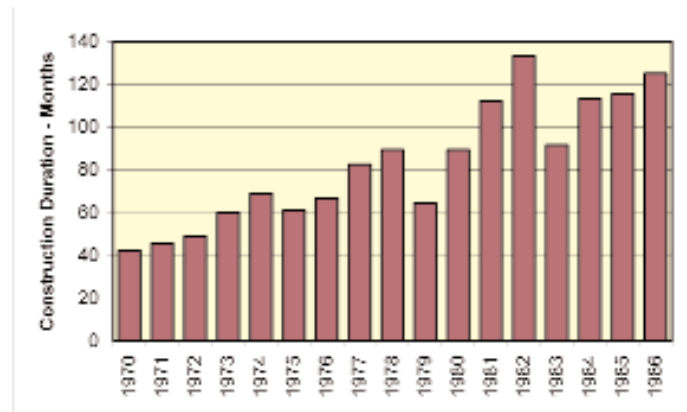


Figure 2—Nuclear Plant Average Construction Durations

industry studies of nuclear plant schedules. These studies identified causes of delays between initial forecasts and actual durations in terms of months.

Construction problems contributed to 43 months of delays of which 78 percent was because of out-of-scope work and 22 percent because of deliberate delays; 68 percent of the out-of-scope work was because of redesign and rework of which 94 percent was attributed to regulatory ratchets.

However, not all of the nuclear projects experienced these delays. One exception was the St. Lucie Unit 2 project completed in August 1983 within 6 weeks of its original forecast (May 1977) for commercial operation [4]. Success factors for this project and others have been extensively documented and included in a NRC report to the US Congress [5]. Although quality in the design and construction of nuclear power plants was the focus of the study, strong project management was found to be a critical factor for success.

Load growth, labor costs, and interest during construction influence schedule decisions the most. In the 1980s, the percentage of interest during construction varied from 18 percent to 44 percent with an average of 31 percent. Various studies have concluded that integrated planning between engineering, construction and startup activities must be accomplished if an optimum overall duration is to be achieved. Changing from a bulk construction mode to systems startup and turnover mode was incorporated by the St. Lucie 2 project and is a crucial decision point. Experience has demonstrated the benefits of a clear but logical transition from physical accomplishment of commodities to the completion of systems in the proper order. Successful projects have had a commitment to good scheduling, project controls reporting and management actions based on accurate information. In addition, foreign plants have benefited greatly from learning curve and standardization related improvements.

A PATH FORWARD FOR NEXT GENERATION NUCLEAR POWER PROJECTS

Given the problems that have confronted the US nuclear industry in the past and a better understanding of the issues and cost drivers that impact these projects, the industry and the US government have introduced several initiatives aimed at paving the way for a nuclear renaissance in this country. These are briefly summarized below.

Changes in the Licensing of a Nuclear Plant

One of the major hurdles for new construction was the regulatory regime of two steps licensing required by 10 CFR Part 50. This 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 operating license are issued at the same time, and the risk of delay during construction should be significantly reduced.

The ESP schedule includes 15 months to prepare the application, 20 months for the NRC reviews and 12 months for hearings. The COL schedule includes 24 months to prepare the application, 20 months for the NRC reviews and 12 months for hearings. The ESP and design certification processes allow for early identification and resolution of issues, and facilitates the COL process.

Nuclear Plant Incentives

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, the US Congress passed an energy bill

including strong incentives to construct new nuclear power plants, such as production tax credit, US federal risk insurance, and a loan guarantee program. Passage of the energy bill demonstrates a strong policy of the US federal government for new nuclear energy in the US.

Industry Response to the Nuclear 2010 Program

Three industry consortia responded in 2004 to the U.S. Department of Energy’s solicitation under the Nuclear Power 2010 initiative and were awarded matching funds [6]. Two will test the construction and operating license process and one will explore construction feasibility.

- The Dominion-led consortium includes GE Energy, Hitachi America, and Bechtel Corp., and has selected General Electric's Economic Simplified Boiling Water Reactor (ESBWR). In 2005, the consortium selected Dominion's North Anna nuclear plant site for the COL application, scheduled to be submitted in 2007.
- The NuStart Energy LLC consortium consists of Constellation Generation Group, Duke Energy, EDF International North America, Entergy Nuclear, Exelon Generation, Florida Power & Light Co., Progress Energy, Southern Co., GE Energy, TVA, and Westinghouse Electric Co., and has chosen the ESBWR and the AP1000 reactors. In 2005, the consortium chose TVA's Bellefonte nuclear plant site and Entergy's Grand Gulf

Cost Type	Cost Item	EEDB-V 1982 \$s Million	EEDB-V 2007 \$s Million	Adjustments based on AP1000 Factors		
				% Reduction	\$ Million	
Equipment Costs 31% of base construction costs	Nuclear Steam Supply System (NSSS)	136	280	-30%*	196	
	Turbine Generator	107	220		220	
	Mechanical	88	177	-80%	35	
	Valves/Supports/Specialties	26	54	-50%	27	
	Structural	35	72	-45%	40	
	Electrical/I&C	49	101	-70%	30	
	Construction Services Major Equipment	24	49	-50%	25	
	Total Equipment...	463	954		573	
Material Costs 10% of base construction costs	Structural Steel	21	43	-45%	24	
	Reinforcing Steel	19	39	-45%	22	
	Concrete and Form work	14	29	-45%	16	
	Cable and Raceway	16	33	-70%	10	
	Piping	43	89	-80%	18	
	Construction Services	41	84	-50%	42	
	Total Material...	154	317		131	
Labor Cost 58% of base construction costs	Structural Craft	188	348	-45%	190	
	Mechanical Craft	132	272	-80%	51	
	Electrical Craft	84	173	-70%	52	
	Construction Services	67	138	-50%	69	
		Craft total...	451	929	Craft total...	366
		Engineering	278	573	75%	315
	Field Non-Manual	136	280	-50%	140	
	Total Labor Cost...	865	1,782		821	
Escalation (35% of estimate and Interest (27% of estimate)	Base Construction Costs...	1,482	3,053		1,525	
	Escalation (8% per year, EEDB-V)	1,387	2,818	Contingency	305	
	Total Cost (no AFUDC)...	2,849	5,869		1,830	
	Interest (9.5% interest charges, EEDB-V)	1,065			-	
	Estimated Plant Cost...	3,914			1,830**	

* Estimated reduction based on improved NSSS manufacturing techniques and passive cooling;

** Assume overnight costs for AP1000

Table 2—EEDB-V Breakdown for a 1139 MWe PWR (1982) With AP1000 Adjustments

site for COL applications, expected to be submitted in 2007.

- The third consortium, led by TVA, includes General Electric, Toshiba, USEC Inc., Global Fuel-Americas, and Bechtel Power Corp., formed to develop a feasibility study for a TVA site based on the General Electric Advanced Boiling Water Reactor (ABWR). The study was completed in 2005.

The overall conclusion of the TVA cost and schedule study was that two ABWR nuclear units could be constructed at the Bellefonte site on a 40 month schedule for each reactor. This time frame is the duration from installation of the first reactor structural concrete to fuel load. The engineering, procurement and construction cost (2004 \$s) for the two units was \$1611/KW for the 1371 MWe certified ABWR plant design that incorporates some technology advancements developed during the Japanese and Lungmen ABWR construction. The NRC has certified the ABWR design in 10 CFR 52, Appendix A.

The Dominion Energy led group evaluated the cost and schedule of four advanced reactor designs: ABWR, ESBWR, AP1000 and the CANDU ACR-700 reactor [3]. Because of lack of detailed backup what was intended to be a quantitative analysis became only a summary-level qualitative assessment. Based on the reviews, the first concrete to fuel load durations for the ABWR (43 months), ESBWR (39 months), and ACR-700 (40 months) should be achievable. However the Toshiba ABWR and AP1000 schedules of 36 months were viewed as very aggressive and may not be achievable until the US nuclear experience base has been reestablished. Studies documented in a second volume concluded that modularization and open top construction offered the greatest potential to help achieve the aggressive construction schedules proposed by vendors [5]. The time from site preparation to fuel load ranged from 54 to 61 months. This is comparable to plants constructed before 1973, but much shorter than the averages after 1973.

NuStart Energy Development is a consortium of nine nuclear utilities, and two reactor vendors formed to develop a combined construction and operating license, select two sites and develop two designs anyone could. After selecting a site the plan is to issue an RFP for construction by 2007, select a final design by 2008, submit COL applications by 2008 and begin construction by 2010. In September 2005 NuStart selected the AP1000 advanced design reactor as its design of choice. In January 2006 the NRC approved the final design certification for the AP1000. The first plant construction start date is expected in 2010 with operation by 2014.

Impact of Design Improvements on Cost

Examples of plant designs, which combine most of the recommendations made by the UE&C and other studies, are the Westinghouse AP600 and AP1000 Reactors. The use of passive safety systems eliminates many of the components of current plant designs and reduces building volume. Specific component reductions cited by Westinghouse include 50 percent fewer valves; 35 percent fewer pumps; 80 percent less piping; 80 percent fewer HVAC units; 70 percent less cable; and 45 percent less seismic building volume. To illustrate how these

reductions in plant complexity and equipment might impact estimated costs; table 3 compares the EEDB-V cost model before and after applying the AP1000 adjustments. The EEDB-V model is based on a 12 year project schedule and a seven year construction schedule. Table 2 presents the 1982 model cost data adjusted to 2007 dollars based on the ENR CCI index and these costs adjusted based on AP1000 reported component reductions. (Note: AP1000 is rated at 1117 MWe, essentially the same as the model.)

Based on AP1000 power rating, the adjusted estimate with 20 percent contingency is \$1638/KW. For comparison, Areva is estimating \$1800-\$2000/KW for US EPR plants, Westinghouse \$1500-\$1800/KW for AP1000, and GE \$1850/KW for ABWR and \$1600/KW for ESBWR [8]. In the Annual Energy Outlook 2005, EIA assumes new nuclear plants would have an overnight capital cost of \$1,928/KW. Considering the differences in plant size, accuracy range of the parametric process, escalation assumption, and other variables, this represents relatively good agreement.

MANAGING RISKS FOR THE NEW NUCLEAR POWER PROJECTS

An effective process for managing risk is necessary for the successful completion of any large complex project. The risk management process involves the following steps: planning, identification, analysis, handling and monitoring. Considering various historical and current industry nuclear project issues, an initial summary level risk analysis for new nuclear projects is presented in table 3.

A review of the literature combined with independent analysis indicates that past conditions leading to huge cost overruns in nuclear power plant costs may no longer exist. The primary improvements toward reducing uncertainty include new licensing approaches, design and engineering completion prior to start of construction, and application of advanced engineering and construction technologies. Considering the importance of meeting cost and schedule projections it is imperative that prudent management practices are used and that past experience guide risk reduction initiatives [9]. The US will have a nuclear future, the only questions are; will there be sufficient skilled resources to meet the capacity needs, will the business environment support large capital investment risk, and will owner's support a standard plant design and implement management strategies that ensure initial cost estimates can be realized.

REFERENCES

1. Forbes, "Nuclear Follies" by James Cook, February 11, 1985.
2. "Nuclear Power Plant Cost Drivers", UE&C Report No. 830729, DOE Contract DE-AC01-81NE32077, September 1983.
3. "Study of Construction Technologies and Schedules, O&M Staffing and Cost, Decommissioning Costs and Funding

2007 AACE International Transactions

Requirements for Advanced Reactor Designs”, Vol.1, 19. Bradshaw, George, et al, “Prudency, Project Management and the Utility Industry”, PMI Proceedings, October 1996.

4. Bradshaw, George and William Derrickson, “Achieving Project Goals in Contrasting Environments: The Value of a Strong Management Philosophy”, PMI Proceedings October 1987.
5. “Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants” NUREG-1055, May 1984.
6. “Industry Progress Toward Building New Nuclear Power Plants” Nuclear Energy Institute, www.nei.org/index.asp?catnum=4&catid=345.
7. “DOE NP2010 Construction Schedule Evaluation”, and “Application of Advanced Construction Technologies to New Nuclear Power Plants”, Volume 2, MPR.
8. “Nuclear Power in USA”, Briefing Paper #58, September 2006, www.uic.com.au/nip58.htm.



George B. Bradshaw, PE CCE
 Project Time & Cost, Inc.
 2727 Paces Ferry Road, Suite 1-1200
 Atlanta, GA 30339, US
 Phone: +1.770.444.9799
 Email: george.bradshaw@ptcinc.com

Critical Element	Potential Risk Factors	Risk Minimization Approaches
Owner Management	Lack of project management and nuclear experience; failure to monitor the contractors closely; poor management of procurement; inability to control design changes; financial commitment uncertainty.	Limit to large experienced utilities or groups with multiple nuclear plants. Need to maximize use of industry expertise and avoid the “not invented here” attitude. Develop position qualification descriptions to guide selection process; use advanced information management system; expand use of benchmarks and performance measures.
Regulators	Permitting delays caused by lack of resources; regulatory changes after construction start; public resistance	Government covers interest cost during regulatory delay; use of streamlined licensing process of 10CFR52; public hearings prior to issuance of COL; commit resources necessary to ensure success of new processes
Consumers and Public Stakeholders	Lack of confidence in nuclear industry; limited experience with nuclear development in recent years; intervenor related delays	Extensive public education programs; independent oversight and reviews by non-proponents; open licensing processes and public hearings
Development costs	First of a kind costs to develop new components, simulators, instrumentation, etc.	Federal R&D support of new designs (FOAKE) and COL; Westinghouse passive plant technology is mature; extensive industry investment (\$440 million for AP1000)
Capital costs	Low confidence in current cost estimates based on past experience; tendency to be overly optimistic; poor control of changes, etc.	Standardized design; use of the design certification process; detailed estimate based on vendor quotes; independent reviews of estimates; use of EVMS controls; use of fixed price contracts; complete engineering design and development prior to construction start; Government support and incentives for initial projects; risk and reward sharing. (The AP800 estimate was based on 1,800 commodity categories and 25,000 specific items; verified by FPRI and several utilities.)
Nuclear Equipment Vendors and Capacity	Limited number of qualified vendors; lack of experienced and skilled nuclear quality workforce; lack of adequate manufacturing capacity	Industry focused development initiatives supported by Federal government financial incentives; education and training programs; slow buildup in number of projects to allow industry to achieve reasonable growth rates and capacity
Engineering	Design changes after project start	Early involvement of all owner groups in plant design; high degree of engineering complete prior to start of construction
Construction	Availability of qualified labor	Shift work to other parts of the country through modularizing portions of the plant; construction inspection procedures, inspection, tests, analyses and acceptance criteria (ITAAC) established; extensive industry wide recruitment and training programs
Operation	Schedules overly optimistic	Use of modularized components; maximize activities done in parallel; use of 4D models to validate schedules and installation rates; supply chain established
	Procurement delays	Both domestic and foreign suppliers need to be qualified; studied extensively by Westinghouse
Operation	Adequate module fabrication facilities	Extensive industry operating experience and improvements over past 20 years; training simulators constructed in sufficient time; early involvement of operating staff in system startup process
Operation	Lack of operating experience on new designs	
Spent fuel	Spent fuel disposition	Option of onsite dry fuel storage; Yucca Mountain may be an option in 2017

Table 3—New Nuclear Power Plant Risk Factors and Minimization Approaches



Mr. Christopher O. Gruber CCC
Independent Consultant
4 Red Cloud Circle
Royersford, PA 19468, US
Phone: +1.610.792.0821
Email: chris.gruber@verizon.net