Recommendations for the Increased Utilization of Nuclear Power in the United States Energy Infrastructure

Prepared By

Tyler Ellis
Department of Nuclear Engineering
Massachusetts Institute of Technology

Prepared For

The Washington Internship for Students of Engineering [WISE] Program

Sponsored By

The American Nuclear Society

“Men make history, and not the other way around.

Progress occurs when courageous, skillful leaders

seize the opportunity to change things for the better.”

Harry S. Truman

EXECUTIVE SUMMARY

Our nation's overdependence on fossil fuel energy sources is a real problem that poses a threat to our national security. Reliance upon other countries for our energy generation has significant implications on the economy and foreign policy of the United States. Therefore, in order for our great nation to be independent enough to pursue advantageous economic initiatives and formulate appropriate foreign policy decisions, our energy infrastructure needs to be as autonomous as possible. However, given the current legislative environment, the maintenance and development of our energy infrastructure has become a very problematic issue.

Sobering electricity supply and demand projections, coupled with the current volatility of energy prices, have underscored the seriousness of the challenges ahead. According to the Energy Information Administration, the statistical arm of the U.S. Department of Energy, the nation will need 355,000 megawatts of new and replacement electrical generation within the next two decades, assuming electricity demand grows at a modest rate of 1.4% per year, (EIA 2004).

Furthermore, the newly deregulated retail electricity environment discourages investment in any type of electrical capacity construction except for the cheapest option, which formerly was natural gas fired plants. But due to the rising prices of fossil fuels and increased awareness about environmental issues, nuclear power currently represents the only cost-competitive clean source of electricity generation available to address this need. However, in order to allow the deregulated market to realize the full economic potential of new nuclear power, the federal government and utility companies need to work together to help alleviate the large "showstopping" hurdles associated with entrance into this brand-new business environment that the first few nuclear power plants will inevitably encounter.

This paper sought to overcome these hurdles by identifying and investigating the principal concerns from both the federal government and the utility industry. The hurdles to be analyzed were divided up into three major categories: demonstration, development and defrayment. Also included in this analysis are means to successfully overcome these hurdles.

As shown in this analysis current government support for new electricity infrastructure development is inadequate and in order to rectify this situation, several governmental initiatives will need to be implemented in order to send the appropriate signals to the marketplace that the time is right to construct new nuclear plants. First, the federal government, along with the utilities, needs to address the remaining regulatory issues for the licensing of new reactors. Second, legislation by the federal government is required to alleviate the initial financial burden put on the utility corporations during the construction process. This legislation can take several forms including accelerated depreciation,

loans/loan guarantees, investment tax credits, production tax credits and renewal of the Price-Anderson Act. Finally, establishment of power purchase agreements will help to ease the investor/utilities concern of what the energy market look like in the future.

It will take a considerable amount of time and effort, but if utility companies and the federal government continue to work with each other our great nation will be able to realize its dream of a brighter and more secure future through the development of our energy infrastructure.

TABLE OF CONTENTS

LIST OF FIGURES

ACRONYMS

10CFR52 – Title 10 of the Code of Federal Regulations Part 52 "Early Site Permits, Standard Design Certificates and Combined Licenses for Nuclear Power Plants"

ABWR – Advanced Boiling Water Reactor

ACR 700 – Advanced CANDU Reactor 700

ADS – Automatic Depressurization System

AECL – Atomic Energy of Canada Limited

ALARA – As Low As Reasonably Achievable

ALWR – Advanced Light Water Reactor

AP600 – Advanced Passive 600 reactor

AP1000 – Advanced Passive 1000 reactor

BWR – Boiling Water Reactor

CAD – Computer Aided Design

CADD – Computer Aided Design and Drafting

CANDU – CANadian Deuterium Uranium reactor (see PHWR)

CANFLEX – AECL's advanced nuclear fuel for higher burnup

CDF – Core Damage Frequency

CEO - Chief Executive Officer

COL – Construction and Operating License

DC - Design Certification

DOE – Department of Energy

EOL – End Of Life

EPA – Environmental Protection Agency

EPR – European Pressurized water Reactor

EPRI – Electric Power Research Institute

ESBWR – Enhanced Simplified Boiling Water Reactor

ESP – Early Site Permit

F-ANP – Framatome Advanced Nuclear Power

FCCG – Fuel Cycle Crosscut Group

FOAKE – First Of A Kind Engineering

GA – General Atomics

GDCS – Gravity Driven Cooling System

GE – General Electric

GT-MHR – Gas Turbine – Modular Helium Reactor

INIE – Innovations in Nuclear Infrastructure and Education

IRIS – International Reactor Innovative and Secure

ISEP - International Student Exchange Program

ITAAC – Inspection, Tests, Analyses and Acceptance Criteria

ITC – Investment Tax Credit

kWe – KiloWatt Electric

kWh – KiloWatt Hour

LRF – Large Release Frequency

LWR – Light Water Reactor

MACRS - Modified Accelerated Cost Recovery System

MWd/MT – MegaWatt Days per Metric Ton

MWe- MegaWatt Electric

MWt – MegaWatt Thermal

NAS – National Academy of Sciences

NEER - Nuclear Engineering Education Research

NEI – Nuclear Energy Institute

NRC – Nuclear Regulatory Commission

OPEC - Organization of Petroleum Exporting Countries

PBMR – Pebble Bed Modular Reactor

PHWR – Pressurized Heavy Water Reactor

PPA - Power Purchase Agreement

PRA – Probabilistic Risk Analysis

PTC – Production Tax Credit

PWR – Pressurized Water Reactor

RCCS – Reactor Cavity Cooling System

SCRAM – means a rapid reactor shutdown

SWR 1000 – SiedeWasserReaktor 1000 which is BWR in German

TEPCO – Tokyo Electric Power Company

UNI - University Nuclear Infrastructure

ABOUT THE AUTHOR

Tyler Ellis is an upcoming senior at the Massachusetts Institute of Technology in Cambridge, Massachusetts. He will graduate in June 0f 2006 with a Bachelors of Science and Masters of Science in Nuclear Engineering. Last summer he developed nuclear electric propulsion systems for the NASA Jupiter Icy Moons Orbiter mission at Los Alamos National Laboratory. He has also studied reactor physics in Karlsruhe, Germany as a Frederic Joliot/Otto Hahn fellow. Tyler currently serves as president of the MIT chapter of National Society for Collegiate Scholars, co-founder and President of the Hibernian Society, Treasurer for his collegiate chapter of the American Nuclear Society, a member of the Thirsty Ear Executive Board, as well as a committee member of MIT's Committee on Radiation Protection. Besides his schoolwork, Tyler is also a certified nuclear reactor operator at MIT's Nuclear Reactor Laboratory and in his free time, enjoys playing ice hockey as well as hunting and fishing back at home in South Dakota.

ABOUT WISE

The Washington Internships for Students of Engineering [WISE] program is a 10 week long summer that brings together 12-15 exceptional engineering students from across the country to gain a first-hand understanding of the intersection between engineering and public policy. One of the main purposes of this program is to study the decision making on complex technological issues as well as how engineers can contribute to legislative and regulatory public policy decisions. The group this year was able to meet with members of congress, congressional committees, executive office departments, corporate government affairs offices and other prominent non-governmental organizations.

Each student is sponsored by a professional engineering society and encouraged to complete a policy analysis research paper that investigates an engineering related public policy issue within the sponsoring society's respective area of expertise. More information, along with the other work from this year's group can be viewed on the WISE website at: http://www.wise-intern.org.

INTRODUCTION

The US government was actively supportive of nuclear power from the 1940s to the early 1970s. Nuclear power's popularity peaked in 1973 when the dangers of oil dependence were demonstrated by the Arab oil embargo. Debates about the relative cost effectiveness of fossil fuels versus nuclear power seemed to be settled by the doubling of coal prices and the tripling of petroleum prices during that period. As far as both industry and the government were concerned, nuclear power was the answer to all of the nation's energy concerns (Komanoff 1996). Consequently, several aggressive energy policies were proposed. For instance, the 1974 Project Independence report, prepared by a committee appointed by President Nixon, called for nuclear power to constitute the bulk of our nation's energy model. This initial attempt at an all encapsulating energy stratagem stipulated that 1000 reactors were to be built by the turn of the century. Overall the field was blossoming, revolutionizing innovations were discovered daily, and there seemed to be no limit to the benefits and applications of nuclear power.

However, despite the promising aspects that nuclear power offered, no new nuclear plants have been ordered for over 25 years. This past lull in the ordering of new nuclear power plants has been primarily attributed to economic issues (Komanoff 1996) and public apprehension brought about by the Three Mile Island incident. Furthermore, the construction process for nuclear plants is intrinsically capital intensive and several of the nuclear plants in the US in the late 1970s and 80s were hampered by expensive delays caused by engineering and management problems, a cumbersome regulatory process and in some specific cases by opposition from the public. This produced an economic environment that was not conducive to the construction of new nuclear capacity.

In 1992 the California Public Utilities Commission, prompted by a Rhode Island initiative, lobbied for and passed legislation [Assembly Bill 1890 and Senate Bill 90] to 'restructure' or deregulate energy production in California. About half of the states are currently operating under this deregulated environment which further discourages the major capital investment and long-term commitment required for new nuclear plant construction (DOE 2001). The Three Mile Island incident also played a significant role in the decline of nuclear power's popularity. It is widely held that this incident was partially responsible for both the NRC's formulation of a cumbersome regulatory process as well as the heightening of the public's fear of nuclear technology.

Due to this relative aversion to new electrical capacity construction that the deregulated electricity markets have created, the rising demand by the American public for electricity has only been minimally addressed through the limited construction of natural gas fired plants. Thus far, sobering electricity supply and demand projections have underscored the seriousness of the challenges ahead. According to the Energy Information Administration [EIA] the statistical arm of the U.S. Department of Energy – the nation will need 355,000 megawatts of new and replacement electrical generation within the next two decades, assuming electricity demand grows at a modest rate of 1.4% per year, (EIA 2004). Furthermore, there is an impending need for new electrical infrastructure to replace the existing electrical infrastructure, which for the purposes of this analysis, is defined as both the plant and the transmission equipment. The lack of investment in new baseload plants and electricity transmission systems is starting to be a significant problem. According to the Nuclear Energy Institute [NEI], approximately 183,000 MW of electrical generating capacity is 30-40 years old and approximately 104,000 MW is 40-50 years old. This represents nearly one third of the total electrical capacity of the U.S. and clearly illustrates that we have been relying on old, less efficient electrical generating capacity and not bothering to invest in recent cleaner and more efficient technologies. Despite the major increases of electricity being brought to the market, the electricity transmission system funding has fallen $115 million per year for the last 25 years (Fertel 2004).

These deregulated markets only favor one type of new electrical capacity to be installed, the cheapest option available. Since natural gas prices have been at an all time low for the last several years, these are exactly the types of facilities constructed. In fact, these are basically the only types of facilities constructed. As shown below in Figure 1, over 95% of the new electrical capacity installed since the transition to a deregulated environment is natural gas fired.

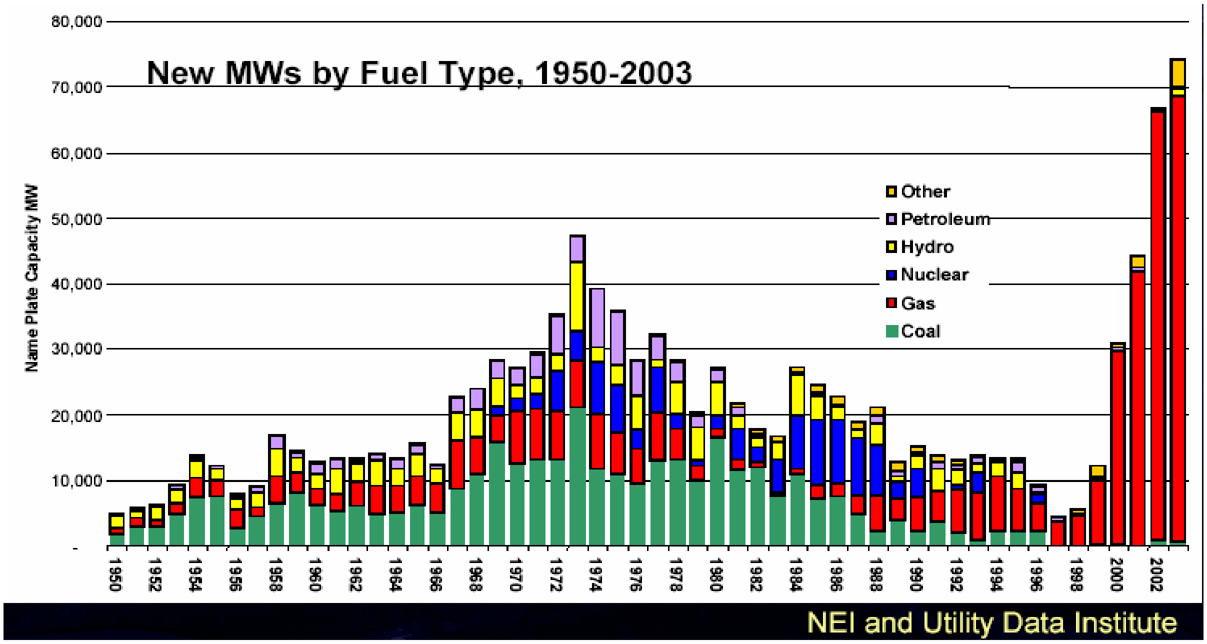

Figure 1: New Electrical Capacity Added in the United States (NEI 2004)

However, unfortunately for American citizens, natural gas companies are suffering from a production decline. Regardless of OPEC's pledge to try and increase production in order to address the rise in crude-oil prices, the natural-gas producers, however, cannot just drill their way out of their problem. North America natural-gas reserves have been declining since the 1980s and importing natural gas presents several logistical difficulties, including the limited number of terminals that can accept the super-cooled gas to be transported, (Gold 2004). Another large logistical concern with importing natural-gas is security. For example, if one of the tankers crashed into a port or otherwise ignited, the explosion would be of the same order of magnitude as the atomic bombs that were dropped on Japan in 1945.

Finally, the scientific community's growing acceptance of the global warming concept has served as yet another blow to the fossil fuel industry. In response to this increasing concern among Americans about the environment, discussions about carbon taxes have entered into the political and social discourse. The combination of all of these setbacks have led to a driving up of the cost of energy and has encouraged the US to diversify its energy generation portfolio in hopes to achieve clean, economical and safe electricity generation.

In America's quest to diversify its sources for electricity generation, numerous options have been investigated. Renewable sources of electricity generation are promising technologies and they help to deal with the pollution problem, but significant technological challenges must be resolved before wide-spread deployment can be discussed. Therefore, given the current state of technology, the only economically feasible and environmentally friendly means to address this electricity need is nuclear generated power. Figure 2 below shows that the relative production cost [not to be confused with levelized cost] of electricity is in fact the lowest for nuclear produced electricity.

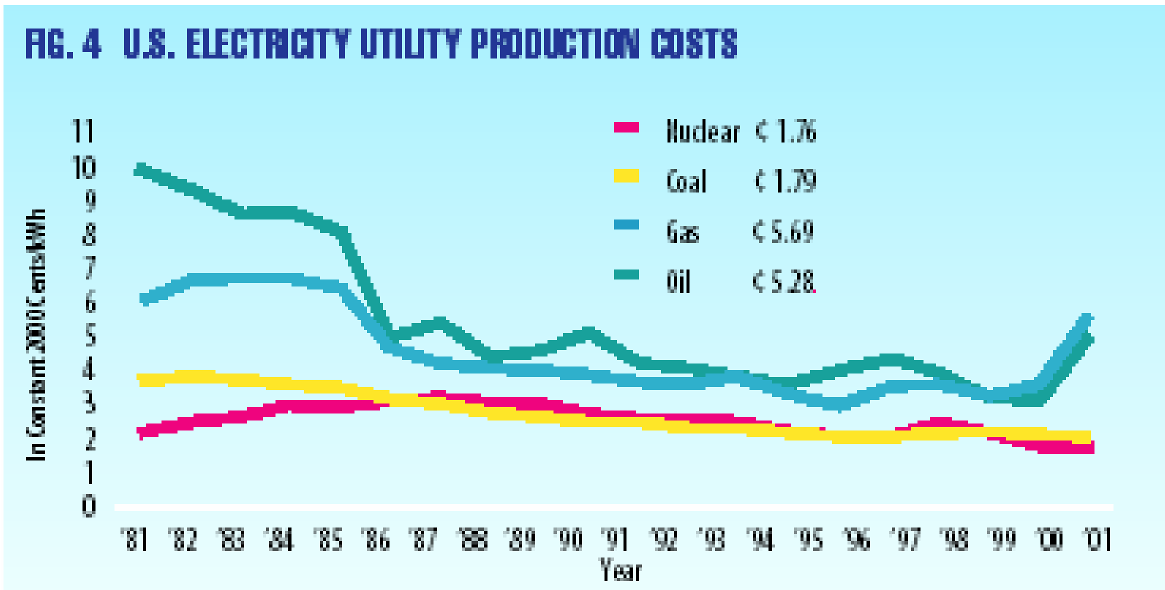

Figure 2: U.S. Electricity Production Costs (NEI 2004)

From this renewed interest in the nuclear industry, the United States government has started to formulate legislation to educate the American people about nuclear science and engineering as well as further technological innovation in the field. In May of 2001, Vice President Cheney submitted the National Energy Policy report on behalf of the National Energy Policy Development Group to President Bush. Nuclear power plays a vital role. In response to this report, the nuclear industry partnered with the Nuclear Energy Institute, to produce “Vision 2020” which proposed the addition of 50,000 megawatts of nuclear energy to the United States energy infrastructure by 2020. A graphical representation is shown below in Figure 3.

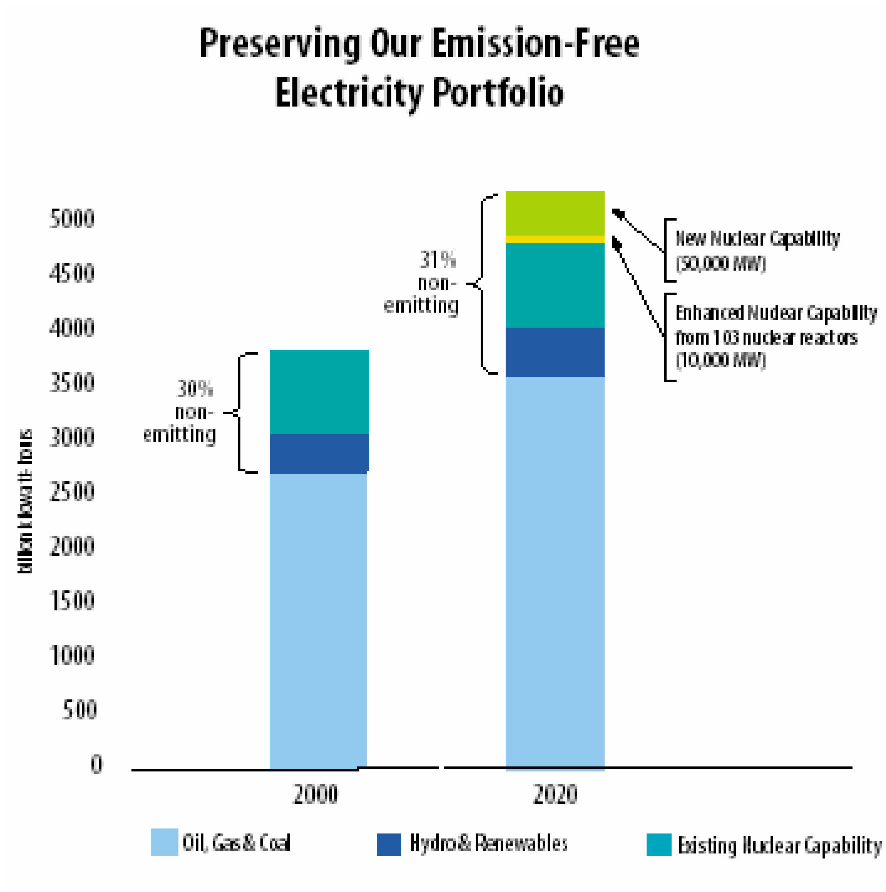

Figure 3: Vision 2020 Electricity Portfolio Projection (DOE 2001)

Other Congressional support includes a proposal in June 2004 from Mr. Knollenberg from the House of Representatives who has proposed a concurrent resolution that Congress recognize the essential role of nuclear power in the national energy policy and support the increased use of nuclear power and the construction and development of new and improved nuclear power generating plants as a means of contributing to national energy independence and maintaining a clean environment (Knollenberg 2004).

This current electricity crisis is not too dissimilar from economic environment created by the 1973 oil embargo due to consumer anxiety about the future electricity supply. The difference today, is that the nuclear industry has spent the last thirty years looking into all the concerns that were raised and has dealt with many of them such as operational safety, reliability, creation of long-lived assets and management of the regulatory environment. This analysis seeks to investigate the remaining concerns by dividing them up into three major categories of barriers facing the employment of new nuclear capacity: demonstration, development and defrayment, as well as provide means to address them.

1. DEMONSTRATION

The first of the three categories of barriers, demonstration, is a significant one. Each of the three required demonstrations described in this section are crucial to secure the investor confidence needed for sustained investment in new nuclear plants. By successfully demonstrating that this revamped regulatory structure can work in today's society with either none or only minor litigation proceedings, investors will become much more confident in nuclear power as well as more amenable to front the required capital for new nuclear power plant construction.

Formerly, the siting and licensing process by the Nuclear Regulatory Commission [NRC] to commission and build a nuclear power plant was relatively cumbersome. In 1989, the NRC attempted to streamline the licensing process by releasing a consolidated set of requirements known as "Early Site Permits, Standard Design Certifications, and Combined Licenses for Nuclear Plants" or 10CFR52. This revamped licensing procedure contains one demonstrated and two undemonstrated licensing procedures; the Design Certification [DC], Early Site Permit [ESP] and the Combined Construction Permit and Operating License [COL] respectively.

A. Demonstration of 10CFR52 Process

1. Design Certification

The Design Certification process was developed to allow the certification of a nuclear reactor design independently of a construction permit or combined license for the facility. One element of the DC are ITAACs or Inspections, Tests, Analyses and Acceptance Criteria which are regulatory requirements mandated by the NRC to ensure that a plant being constructed under a COL is consistent with the certified design. For the previous three certified reactor designs (the ABWR, System 80+ and AP600), ITAACs focused primarily on material and design issues but recently a debate has ensued over whether or not to add procedures to that list. In early May, much to the dismay of the private industry, a few members of the NRC staff proposed that ITAAC should encapsulate a much broader range of programs than previously required as well as go into greater detail. After deliberation on May 14, 2004, the NRC commissioners decided that this initiative would have been a misapplication of resources and an unnecessary extension of the licensing process since these concerns are more appropriately addressed in the COL application stage.

Though the DC process has already been successfully demonstrated with three reactor designs, industry executives have still rated this commissioning risk as a showstopper due to the ITAAC risk. One executive stated, “ITAAC is not resolved. Interveners have too many openings, which drove up costs last time. This is a big issue, a potential showstopper. For example, the emergency evacuation plan was used to halt Shoreham… after it was built! That’s a nightmare!” Another executive added that, “All utilities fear a ‘Shoreham II’. In a market environment [versus a regulated one], nobody wants to bear the risk of not being able to turn on the unit after you build it,” (Scully 2002).

Currently the principle area for concern with regard to ITAACs are what depth of information the NRC will require in the following areas: fire protection, training, quality assurance during operation, fitness for duty, access authorization, radiation protection, physical security, licensed operator and reportability programs. This report is due out on December 31, 2005 and will be presented to the NRC commission by the staff.

2. Early Site Permit

ESPs were established in 1989 by the NRC so that the energy corporations could complete a preliminary environmental analysis of a proposed site before the decision is finalized to actually construct such a facility. The preliminary environmental analysis includes such areas as the local meteorology, hydrology, geology, and seismology; in addition to probable environmental impacts of construction, operation and worst-case accident scenarios. One of the large advantages to the ESP is that after its issue by the NRC, the permit is typically valid for a 10 to 20 year timeframe and the site can be “banked” for the future until the utility is ready to build.

Three ESP applications are currently being reviewed by the NRC. One of these applications, proposed by Dominion Nuclear for the North Anna ESP Site, should be decided upon by the NRC in June 2006. However, further optimization and standardization of the process is still required and after completion of the initial ESP, an approved format for permit submission (i.e. a template) can be assembled for future site certification use.

3. Combined Construction Permit and Operating License

A COL granted by the NRC allows the license holder to both construct and operate a nuclear reactor. Before 10CFR52 in part 50, the NRC required the attainment of two licenses, a construction permit to build and an operating license to operate. This placed several utilities in a highly compromising situation where a significant amount of capital was already invested in the construction of a plant, but because of litigation dealing with the operating license, the plant was not allowed to operate. If the plant was not allowed to operate then the financier's hope for a decent rate of return, along with the initial multi-billion dollar investment, vanish. However, due to the advent of 10CFR52, this concern of constructing a plant and not being able to operate it in theory is eliminated. By combining the construction and operating license, the utilities now know from day one whether or not they have approval from the NRC to construct and operate their plant. According to the Business Case for New Nuclear Power Plants study, industry executives are nearly unanimous in requiring a clearly defined Combined Construction Permit and Operating License process before any effort is extended by industry to construct a single reactor (Scully 2002). Currently there are no COL applications before the NRC, although some consortia have started studying the possibility of submitting a COL. Therefore, in order to test this licensing process one of the utility consortia need to submit an application and, just as the ESP, further optimization and standardization of the certification process is still required. After the first COL is issued, an approved format or template for the license can be developed for future use.

B. Demonstration of Market Need in a Deregulated Environment

One of the principal questions that inevitably arises during a discussion about new nuclear is 'why does a well established or "mature" industry that already supplies one fifth of the electricity of the United States need any financial incentive to aid in the construction of new facilities?' The answer is that though the industry is indeed well established, the economic environment that the industry is now operating in is not.

Ever since Rhode Island, California and Pennsylvania deregulated their electricity market in the mid-1990s, the business environment has evolved into an uncertain market that is not conducive to immense and risky, capital intensive efforts. Several other states were planning to follow suit and change over from a regulated environment but that trend abruptly halted when they saw firsthand what the negatives of a deregulated electricity business environment can be with the problems that California encountered through their poorly planned deregulation scheme.

Formerly, in the "cost of service" or regulated environment, corporations agreed to contracts which guaranteed a reasonable opportunity to recover their capital investment, as well as enjoy a fixed rate of return, through defined electricity rates.

In the current deregulated electricity market no such guarantee exists, the business environment is uncertain, cash flows are volatile and there is no assurance of a reasonable rate of return.

Another large problem with the deregulated electricity business environment is the absence of a means to value other important marketplace attributes like security of supply, price stability, and diversity of fuels and technology (NEI 2004).

So where does this leave the power corporations? In an investment environment which only has one answer for future ventures, that it has to be the option that presents the lowest investment risk available. Therefore, because of this general aversion to risky, capital intensive ventures, the corporations have been essentially forced by their stockholders to construct natural gas-fired power exclusively because of the decreased investment risk when compared other generating options. However, due to rising natural gas prices, these facilities are no longer the cheapest option available. In some cases these facilities have started to become so expensive that the utility companies have been forced to shut them down in order to minimize the financial loss to the corporation. Therefore, given the current state of technology, the only economically feasible and environmentally friendly solution to this electricity need is nuclear generated power and in order to allow the deregulated market to realize the full economic potential of new nuclear power, a two pronged solution will need to be implemented. One, the federal government needs to target temporary financial assistance for the first couple of nuclear power plants to help alleviate the large financial barriers associated with entrance into this brand-new business environment. Two, legislation needs to be employed to address the structure of the electricity market. Rather than allowing the market to continue valuing short-term thinking, changes should be implemented so as to encourage the market to value long-term thinking.

2. DEVELOPMENT

The second of the three main categories of barriers to new nuclear plant construction, development, will require a cooperative effort on part of both the federal government and private industry. Currently, the responsibility for the development of economically competitive reactor designs as well as the expansion of innovations to shorten "Time To Market" has fallen principally on the shoulders of industry. The federal government, on the other hand, has spent a significant amount of time and effort addressing the increasing need for an accelerated development of our critical nuclear infrastructure along with the demonstrated need for a centralized nuclear waste repository.

A. Development of Economically Competitive Reactor Designs

1. Near Term (Generation III and III+)

Fortunately, due to extensive and expensive efforts from numerous corporations, there are several excellent new nuclear power plant candidates which could be deployed within the next ten years. These reactors were designed with the help of experience from existing reactors throughout the world and are often referred to as either Generation III or Generation III+.

Generation III reactors, also known as advanced-design nuclear power plants, include such designs as the Advanced Boiling Water Reactor [ABWR], and the passive-design AP600 reactor. ABWRs have already been built and are operating in other parts of the world. All of these designs are certified by the NRC and are currently available for deployment.

a. ABWR

The Advanced Boiling Water Reactor or ABWR is a 3926 MWt/1350 MWe BWR that was developed by General Electric, in accordination with Hitachi, Tokyo Electric Power Company and Toshiba. When initially designing the ABWR, the development team sought to design a BWR plant that included a careful blend of the best features of operating BWRs worldwide, newly available technologies and newly developed modular construction techniques while still maintaining safety improvements as paramount priority. Efforts were also made to not only reduce the capital cost of construction, but incorporate features that would alleviate maintenance concerns as well. The enhanced safety measures integrated into this design allowed for a reduction in the overall calculated core damage frequency by more than a factor of ten when compared to currently operating BWRs (DOE 2001).

The ABWR is currently the only advanced LWR that is in commercial operation. The first two plants went critical in 1996 and 1997 at Units 6 and 7 of TEPCO's Kashiwazaki-Kariwa site in Japan. Also in 1996, the ABWR became the first reactor design to be reviewed and certified by the NRC under the new provisions of 10CFR52. In Taiwan, two more ABWRs received regulatory approval in 1999 and are currently under construction at the Lungmen site.

Overall, GE's ABWR is the furthest along as far as certification, development and infrastructure are concerned. The ABWR is currently the only NRC certified new reactor design that has been constructed anywhere in the world. Industrial manufacturing infrastructure and fuel cycle infrastructure are also already in place from the deployment of the ABWR units in Japan where operational experience is currently being built up. The FOAKE costs have been addressed and based on previous experience, the uncertainty associated with construction costs is minimal. The remaining concern is the economic viability of the facility, which has been proven in Japan but not, as of yet, in the unregulated U.S. market.

b. AP600

The Advanced Passive 600 [AP600] is a two-loop 1933MWt/610 MWe PWR developed by Westinghouse Electric Company along with the sponsorship of the DOE and the EPRI. This reactor contains advanced passive safety features and various plant simplifications to augment construction, maintenance and operation of the facility. This design shares several similarities with existing Westinghouse PWRs such as the core, fuel, internals and reactor vessel. But an increased importance on safety led to the incorporation of natural forces dependant safety systems, simplification/consolidation of systems, and an improved plant layout that is more conducive to maintenance and ALARA principles.

The question of regulatory acceptance is a relatively minor one since the AP600 has already been certified by the NRC. The international industrial manufacturing infrastructure and fuel cycle infrastructure are strong and in place. However, though the design itself is mature, a significant amount of financial investment will be required in order to finalize a detailed design. The FOAKE costs also have yet to be addressed. According to Westinghouse, the AP600 would be economically competitive in a limited number of U.S. markets.

Generation III+ reactors are designs that were developed in the 1990s and are currently under various stages of design and development. These designs, along with the Generation III reactors, are the principal candidates for deployment by 2010. Generation III+ designs include the Pebble-Bed Modular Reactor [PBMR] and the AP1000, which is currently in the NRC certification process and should be completed by the end of 2004. Both reactors enjoy the benefit of having passive safety designs which makes them attractive from a risk mitigation standpoint.

c. AP1000

Though the AP600 is very cost effective, it still was not competitive on the overnight construction costs; so to address this issue Westinghouse developed a higher power design (based upon the AP600 design) named the AP1000. This power up-rate to 1090 MWe was achieved by increasing the length and number of fuel assemblies to the core, enlarging the reactor vessel in addition to the other primary components and by increasing the volume of the containment. The generating cost for the AP1000 is estimated by Westinghouse to be 30% less than the AP600. This savings was achieved because the increase in power output was achieved with only a minor increase in capital cost.

The question of regulatory acceptance is again relatively minor since the AP1000 has completed the Final Design Approval (technical part) of the Design Certification and now only needs to complete the rulemaking process which should be finalized by December 2005. The international industrial manufacturing infrastructure and fuel cycle infrastructure are strong and in place. Though the AP1000 design itself is mature, a significant amount of financial investment will be required in order to finalize a detailed design. The FOAKE costs also have not yet been addressed and according to a study completed at the University of Chicago, today’s overnight cost estimates for the first AP1000 plant are in the neighborhood of $1500 per kWe, but should settle down to $1000 per kWe for the nth plant (DOE 2001). According to

Westinghouse, the AP1000 would be economically competitive in today's U.S. marketplace.

d. ACR 700

The Advanced CANDU Reactor 700 or ACR 700 is a 703 MWe PHWR designed by Atomic Energy of Canada Limited. It was developed to address the current need for reactors with a reduced capital cost, shorter construction schedule, higher capacity factors, lower operating costs, increased operating life, simple component replacement and enhanced safety features. This design draws heavily from current CANDU reactor technology [CANDU 6 and CANDU 9] but differs in its use of slightly enriched uranium as the fuel and light water as the coolant. This incorporation of light water in the fuel channels allows for both a reduction in the inventory of heavy water required and a decrease in the overall reactor size, which accounts for a marked decrease in capital cost when compared to the currently operating CANDU reactors.

Though the ACR 700 has not yet been built in any country, AECL asserts that the ACR 700 design was formulated from the existing in-depth knowledge of current CANDU systems and that the necessary fabrication infrastructure exists to support future development. Some of the more significant construction advances include; 3-D CADD Planning and Scheduling Open-top Construction and Modularization and Prefabrication. These demonstrated advances should shorten the construction schedule to four years for the n^{th} reactor unit, from the initial signing of the contract to commercial operation. From the combination of these new technological innovations and existing CANDU features, AECL estimates the ACR 700s overnight capital cost at $1000 per kWe.

Due to the existing industrial manufacturing infrastructure and fuel cycle infrastructure from the deployment of CANDU 6s in Canada, Korea, Argentina, Romania and China, the associated concerns and uncertainties are minimal. Although operational experience is not being built up, FOAKE costs have been addressed and based on experience with current CANDUs, the construction costs are highly certain. However, since this technology has never been licensed in the US, much less implemented in a US market, the economic viability still remains unknown. In March 2004, AECL Technology joined under the Dominion led nuclear consortium.

This nuclear consortium was formulated in hopes of implementing the new ACR 700 technology in the US by leading the charge in the testing of the new COL process. Other members of the consortia include Hitachi America and Bechtel Corporation (AECL 2004). However, the ACR 700 has not applied for NRC design certification, nor has it been licensed anywhere else. And due to the fact that the ACR 700 technology is significantly different than any operating power reactor in the United States, the certification process might be subject to delays because of the increased challenge for the NRC in the reviewing process.

e. ESBWR

The Enhanced Simplified Boiling Water Reactor [ESBWR] is a 4000 MWt/1380 MWe BWR that was developed in 1992 by General Electric along with DOE, and various other international designers, research organizations and utilities. The design was inspired by the 670 MWe SBWR, its predecessor, as well as advances utilized in the ABWR. These advances were achieved via GE's three pronged ESBWR development approach: 1) enhance the plants overall performance; 2) capitalize on the passive safety system's modular design; and 3) reduce the amount of construction material needed.

The utilization of innovative design features coupled with simplification of several reactors systems and containment structure dramatically reduces the cost when compared to both the SBWR and the ABWR. On April 18, 2002 GE filed for a pre-application with the NRC for the Design Certification of the ESBWR and in early 2005 has the opportunity to submit a design certification application. Therefore, assuming the previous submission schedule, the earliest that the ESBWRs design could be certified is estimated to be 2009. The industrial manufacturing infrastructure and fuel cycle infrastructure should not present much of an obstacle since the currently operating Asian ABWR facilities are able to support the ESBWR. Although GE has not completed a detailed economic analysis, preliminary studies point that the ESBWR would likely be economically competitive (DOE 2001).

f. SWR 1000

The SiedeWasserReaktor 1000 [SWR 1000], which means boiling water reactor in German, is a 3370MWt/1290MWe BWR that was developed in 1999 at Siemens, before it was bought by F-ANP. The SWR 1000 technology was based upon previous German BWR operating experience but also incorporates several new passive safety features. Like the ESWBR, the SWR 1000 also includes passive safety features to provide enhanced security.

The overall plant design calls for three separate and distinct buildings that have the potential to be constructed at the same time, hence, shorting the construction schedule to 48 months. In the US, Framatome-ANP is engaged in only unofficial discussion with the NRC about the submission of a SWR 1000 pre-application review since the corporate focus is primarily geared towards the construction of an EPR facility at the Olkiluoto site in Finland. Moreover, the fuel cycle infrastructure will require some additional development since the SWR 1000 uses a brand new fuel design (DOE 2001). Preliminary economic evaluations project the Finland site to cost around $1800 per kWe (DOE 2001); however in the US market, the relative economic competitiveness is uncertain. Although the international industrial infrastructure is strong, there are several weak areas that need to be addressed by Framatome-ANP before the SWR 1000 will be ready for cost-effective deployment in the US market.

g. PBMR

The Pebble Bed Modular Reactor or PBMR is a 165MWe graphite-moderated, helium-cooled reactor that was originally developed in Germany but now PBMR (Pty.) Ltd. is championing its deployment in Koeberg near Cape Town, South Africa. The PBMR, which utilizes spherically coated fuel, is based on German high temperature gas cooled technology. The goal of the original design was formulate a plant that has no physical processes which could cause radiation hazards beyond the site boundary. The attainment of this goal is demonstrated by two main design features. First, the integrated heat loss from the reactor vessel is greater than the total decay heat production in a post accident condition. And second, the highest temperature reached in the core during a transient is below the degradation point of the fuel and far below the point where physical structure is affected.

Exelon closed-out the pre-application review prior to completion on May 16, 2002 and in a letter dated February 18, 2004, PBMR (Pty.) Ltd. notified the NRC of its intentions to apply for a design certification after the detailed design for the PBMR demonstration plant is built in South Africa. Therefore after fabrication of this facility, the industrial infrastructure should be reasonably in place. The projected economics are uncertain in South Africa but should be better understood after the successful development and deployment of multiple modules. The safety and reliability of the PBMR is largely dependent upon the high quality manufacture of the fuel spheres. One significant area for concern is the assumption that early on in the PBMR fuel development, the initial U.S. fuel load will have to be procured from a foreign supplier. Overall, the PBMR looks like a promising design but several technological issues as well as concerns about the industrial infrastructure will need to be addressed before deployment in the U.S. can begin.

2. Long Term (Generation IV)

Generation IV reactors, as defined by DOE, are to be developed to address important issues facing the nuclear power industry today such as enhanced safety, fuel cycle sustainability, improved economics and proliferation resistance. Besides energy, these advanced reactors are also designed to facilitate other energy service needs like desalinization, process heat and hydrogen production. These designs are targeted for deployment around 2030 (FCCG 2002).

a. GT-MHR

The 600MWt/286MWe Gas Turbine Modular Helium Reactor or GT-MHR was developed in a joint United States/Russian Federation program that sought to utilize surplus nuclear weapons plutonium. The corporate counterpart completing design work in the US is General Atomics. This advanced concept was also designed to create a more economically competitive reactor that incorporates advanced safety features, higher thermal efficiencies and increased environmental benefits. The graphite moderated reactor is cooled via helium gas in a high efficiency Brayton cycle.

The increased safety margins of the GT-MHR is accomplished from a combination of design selection and inherent safety attributes that take maximum advantage of the reactors design features. These features include:

1. Helium coolant, which is single phase, inert, and has no reactivity effects;

2. Graphite core, which provides high heat capacity, slow thermal response, and structural stability at very high temperatures;
3. Refractory coated particle fuel, which retains fission products at temperatures much higher than normal operation and postulated accident conditions;
4. Negative temperature coefficient of reactivity, which inherently shuts down the reactor above normal operating temperatures; and
5. An annular, low power density core in an uninsulated steel reactor vessel surrounded by a natural circulation reactor cavity cooling system or RCCS (LaBar 2002).

On February 18, 2002, GA submitted a pre-application licensing plan to the NRC for the GT-MHR. The objective of this plan was to help GA identify, plan and execute the pre-application licensing activities. Since no design certification application has been filed with the NRC, it is impossible to estimate as to when the GT-MHR could be certified by. Unless GA wants to develop its own manufacturing capabilities, the industrial infrastructure is dependent upon the qualification of Russian suppliers to be a certified commercial supplier to the U.S. This obviously will require a significant amount of international debate and collaboration. The safety and reliability of the GT-MHR is also highly dependent upon successful fuel development and high quality fuel manufacture. Therefore, due to the level of international dependency, need for development of industrial infrastructure and uncertainty of economic competitiveness, deployment in the U.S. for the near term is an unlikely possibility, unless serious effort is expended to address these areas (DOE 2001).

b. IRIS

The International Reactor Innovative and Secure or IRIS is a 335 MWe light water cooled, integral, modular reactor that was developed by a large international team led by Westinghouse. The IRIS relies on existing proven technological experience of current light water reactors along with unique features such as; five-year long straight burn fuel cycle without shuffling or partial refueling; integral primary coolant circuit; modular helical tube steam generators; internal radiation shields; immersed spool pumps; safety by design approach where several accident initiators are eliminated by design; and maintenance shutdown interval no shorter than 4 years.

Westinghouse met with the NRC on April 15, 2004 to discuss logistics for the pre-application review of the IRIS. They plan to submit a design certification application in 2006 and complete the certification between 2008 and 2010. The international industrial infrastructure has already been pulled together and the initial fuel loads should not present too much of a problem but the economic competitiveness is highly speculative. Westinghouse's analysis, if accurate, would make the design economically competitive, but before a relative economic competitiveness can be ascertained, a more in-depth analysis is needed. The IRIS design has potential for the future, however, it is more than likely not a realistic possibility for near-term deployment.

B. Development of Construction Innovations to Shorten "Time To Market"

Although the risk of construction is not designated as a "showstopper" by industry, it is nonetheless an area that will require significant attention. The construction risk has been primarily attributed to cost or schedule overruns related to construction, labor [including the effects of strikes] and materials. According to a study completed by Scully Capital in July 2002, industry executives to some extent and investors to a large extent attributed a high risk rating to construction concerns due to the fact that new nuclear power plants have not been recently built in the U.S. However, the industry executives and investment firms that I have spoken with today attributed a lessened importance of construction risk since reactor designs deployed in other countries will have already established plant and fuel fabrication infrastructure that can be employed for future application in the U.S. (Scully 2002).

One of the most significant advances in construction technology is the utilization of Computer Aided Design or CAD. CAD systems allow the engineers to build the plant in a virtual three dimensional environment to ensure that all the respective plant systems integrate as they should before a single slab of concrete is poured. These CAD systems also allow for greater access to information to facilitate communication between the engineer, manufacturer and constructor. Modularization, or the pre-assembly of various parts at an offsite facility that is later shipped off to the construction site, allows for significant cost and schedule savings.

Engineering firms that have deployed reactor units in Asia are confident that LWRs can be built at lower prices in the United States. Furthermore, these firms assert, in order to achieve this financial benefit from modular construction a pipeline of orders is necessary, which is now being pioneered in Japan and Taiwan. One equipment vendor was quoted that, “we firmly believe that reactor suppliers [and engineering companies] have the capability to build the next wave of nuclear plants on time and on schedule. Two ABWRs were built in Japan on budget and on schedule, and the same commitments were made for the construction of two more advanced plants in Taiwan” (Scully 2002).

C. Development of Nuclear Workforce

According to the 2004 NEI Work Force Survey, nuclear power generators may experience up to a 46% attrition rate over the next five years, representing an estimated 26,000 workers leaving the industry. Over half of this expected attrition is attributed to retirement. Currently half of the nuclear industries workers are 48 and older with merely 7% aged 32 and younger. NEI defines the current work force situation as critical, but not a crisis (NEI 2004). These concerns can be addressed by both the federal government and private industry with a significant outreach and recruitment effort. Some programs that have already been implemented include the establishment of the UNI program; creation of numerous fellowships, scholarships and grants for nuclear related fields; and apprenticeship/internship opportunities.

1. University Nuclear Infrastructure [UNI] Program

The UNI program was developed in 2003, by the Office of Nuclear Energy, Science and Technology at the U.S. DOE, with the express purpose of helping American colleges and universities stay at the forefront of science education and research by assisting in the operation of research reactors as well as in the performance of other educational activities. This newly developed program pulls together existing programs as well as starts some additional initiatives, which include:

Innovations in Nuclear Infrastructure and Education [INIE] – This program started in 2002 and sought to strengthen the nation’s university nuclear engineering education programs through innovative use of the university research and training reactors and encouraging strategic partnerships between the universities, the DOE national laboratories, and the U.S. industry.

Reactor Fuel Assistance – The Department provides fresh fuel to, and takes back spent fuel from, university research reactors. Several of the research reactors have permanent fuel cores and require no fuel shipments, but for the dozen or so who do not, the DOE supplies them with fresh fuel and removes the spent fuel as needed. These reactors are unique and irreplaceable assets for technical education, and are used for a variety of research, educational and training purposes.

Reactor Sharing – Through this assistance effort, the DOE enables universities with reactors to “share” access to facilities with students and faculty at other institutions who lack such a facility. These reactors are made available for use in research, experiments, material irradiations, neutron activation analysis and training, and facility tours and other educational activities (Office 2003).

2. Fellowships, Grants and Scholarships

Nuclear Engineering Education Research [NEER] Grants – This program, re-established in 1998, is a competitive peer-reviewed program to provide grants allowing nuclear engineering faculty and students to conduct innovative research in nuclear engineering and related fields. These awards run from one to three years and are granted in eight separate technical areas related to nuclear engineering: reactor physics, reactor engineering, reactor materials, radiological engineering, radioactive waste management, applied radiation science, nuclear safety and risk analysis, and innovative technologies for next generation reactors, space power and propulsion, or radiation sources. This type of research is vital to the academic community to help promote excellence in nuclear engineering and provide resolution to issues confronting nuclear engineering in general.

DOE/Industry Matching Grants – The DOE, along with participating companies, provide matching funds, up to $60,000 from each side, to universities for use in funding scholarships, improving nuclear engineering and science curricula, and modernizing experimental and instructional facilities.

Nuclear Engineering/Health Physics Fellowships and Scholarships to Nuclear Science and Engineering Programs at Universities – The DOE provides tuition, stipends, and practicums to outstanding graduate students studying nuclear engineering and health physics and undergraduate scholarships and practicums to students pursuing a nuclear engineering course of study to ensure that our country will have an adequate supply of trained nuclear scientists and engineers.

Radiochemistry – The DOE awards grants to support education activities in the field of radiochemistry in the United States. Radiochemistry is linked to several national priorities including medicine, energy and national defense.

Nuclear Engineering and Science Education Recruitment Program – This program was designed to increase the number of university students entering a nuclear engineering course of study by developing a core curriculum to instruct science teachers in nuclear science and engineering topics (Office 2003).

3. Internship Programs

Summer Internships at National Laboratories – The Office of Nuclear Energy, Science and Technology offers summer internships in technical area related to nuclear engineering through the University Reactor Fuel Assistance and Support program at the Idaho National Engineering and Environmental Laboratory, the Argonne National Laboratory-East and West and the Oak Ridge National Laboratory to undergraduate and graduate students. Each student works with a mentor and receives living expenses and a salary for a 10-12 week program.

International Student Exchange Program [ISEP] – The ISEP sponsors U.S. students studying nuclear engineering to spend 3-4 months abroad doing research at nuclear facilities in German, France and Japan. The program plans to expand to include Argentina, Brazil, and Russia. These six countries will send their students to the U.S. for reciprocal internships at DOE national laboratories (Office 2003).

In addition to recruiting new workers to the field, further measures must be taken in the meantime to retain current workers. According to NEI, the industry has numerous tools that it can use in order retain its current staff including improving retention of new employees, which has added benefit of reducing recruiting and training costs; delaying retirement for older staff, which will temporarily reduce the replacement pressure; increasing the number of “pipeline” employees, which will increase headcount and payroll in the short run, but is the only long term solution; and continue to improve work processes and management practices to increase productivity and function with reduced headcount (NEI 2004). Again as was mentioned in the beginning of the section, the current situation is critical, but not a crisis. If significant effort is expended to address these concerns by both the federal government and private industry, these concerns can be decreased to a minimal level.

D. Development of Yucca Mountain Nuclear Waste Repository

Yucca Mountain, the Nation's proposed nuclear waste repository, has been and continues to be a large political issue. On July 9, 2004, the United States Court of Appeals for the DC Circuit issued a decision in NEI versus EPA. The court rejected all but one of the 12 legal challenges brought up against the Yucca Mountain program by Nevada. The 11 rulings vacated by the court were heralded as a victory to the nuclear power industry since the decision to select Yucca Mountain for a repository site, which came about from the Secretary of Energy's recommendation, the President's recommendation to Congress, and subsequent action by Congress to override Nevada's notice-of-disapproval, remains undisturbed.

However, the lone exception to the court's rejection of Nevada's challenges pertains to the EPA's 10,000 year compliance period, during which the repository must be able to limit the presence of radionuclides in the accessible environment surrounding the repository. In one part of the ruling the Court stated, "It would have been one thing had the EPA taken the Academy's recommendations into account and then tailored a standard that accommodated the agency's policy concerns." Then later the Court asserted that, "Had EPA begun with the Academy's recommendation to base the compliance period on peak dosage and then made adjustments to accommodate policy considerations not considered by NAS, this might be a very different case."

In all actuality though the EPA did exactly what the Court asserted that it should have done. The recommendation from NAS stated that "resolution of policy issues be done through a rulemaking process that allows the opportunity for wide-ranging input from all interested parties." Thus, as the Court required, the EPA used the NAS recommendations "as a starting point for… [its] rulemaking." Furthermore, the EPA did in fact follow the specific NAS observations on the application of policy considerations, following rulemaking: "We note that although a selection of a time period of applicability has scientific elements it also has policy aspects that we have not addressed. For example, EPA might choose to establish consistent policies for managing risks from disposal of both long-lived hazardous nonradioactive materials and radioactive materials." Thereby from the EPA adoption of the 10,000 year period, they elucidated their decision on numerous grounds, including that "it is… consistent with regulations covering long-lived chemically hazardous wastes, which present potential health risks similar to those from radioactive waste…"

The waste disposal risk has been declared a "showstopper" by utility corporate executives. They believe that the securing of a waste facility is crucial for the ordering of new nuclear power plants and would demonstrate that an effective solution to one of the nuclear industry's largest problems has been formulated. It is also apparent to industry executives that the waste transportation issues are completely political, and not technical, since radioactive waste and spent fuel elements have been, and still are being, transported safely across the country (Scully 2002).

The widespread public perception that safe disposal of high level radioactive waste is not achievable has been a driving factor for social reluctance to accept the nuclear option. Therefore, the licensing and commissioning of the Yucca Mountain repository would undoubtedly remove a significant hindrance to the development of nuclear energy in the United States for the near and medium terms (Energy Central 2004).

3. DEFRAYMENT

The third and last of the three main categories of barriers is the defrayment of fiscal challenges. In order for the utilities to be able to finance these exceptionally capital intensive endeavors, the federal government has to aid in defraying both the higher "First Mover" associated costs and the insurance costs that the utilities are required to pay.

A. Defrayment of "First Mover" Construction Costs

In today's deregulated electricity marketplace, new plant designs must be economically competitive in order to attract the significant amount of financial capital required for them. This economic competitiveness of a proposal is judged by potential investors via several factors including cost and cost uncertainty in completing the remaining engineering, construction cost, ability to complete construction on schedule, licensing risks, plant lifetime and projected operating, maintenance and fuel costs, projections of market conditions and alternative system costs. Thus far, the economic viability of nuclear power has been difficult to demonstrate to potential investors since nuclear plants are capital intensive and require a significant investment sustained over a prolonged period of time before the investor can realize any return. In addition, the two decade hiatus in ordering new nuclear plants coupled with the vulnerability of cost overrun due to engineering and management problems, regulatory delays and public opposition, certainly does not help either. Economically competitive reactor designs are key, and do exist to address this concern, but before the investors give the go ahead, additional measures by the federal government to alleviate the potentially high "First Mover" costs need to be in place.

1. Initial Plant Financing

Due to the large amount of capital required to finance a new nuclear plant, external borrowing will continue to be a favorable option, from both a corporate and a project basis. It is difficult for a utility corporation to have sufficient liquidity from internally generated cash flow to support the monetary needs of such a project. Representatives from the DOE declared that the 50/50 Debt-Equity financing option is the way to go and have already committed to supporting it, provided the federal funds are available. Also, according to a business case completed by Scully Capital, "An actual financing is likely to be structured as corporate financing in which the power generating company is the borrower with the backing of the parent company of the integrated entity [a corporate structure that combines a power generation company and an electric distribution company]… It is likely that the capital structure of the borrower will be comprised of (sic) 50% debt capital and 50% equity capital," (Scully 2002).

2. Earnings per Share Dilution

Earnings per share dilution plays a large role in the consideration of investment in new ventures. This phenomenon more or less serves as a corporate accountability mechanism for the executives to the investor. For example, if the executives decide to introduce more shares to the market in order to produce the extra capital needed to finance a new plant, the total number of shares increases while the earnings stays essentially constant until the new power plant comes on-line and starts generating revenue. This temporary drop in the earnings per share can lead to a depression in the price of the stock. Since investors typically look at the price-to-earnings ratio to evaluate the financial health of the company, the current shareholders may become dissatisfied from a temporary depression in the price of the stock and decide to sell, which would cause the market price of the stock to further fall. This situation is obviously undesirable for the corporate executives, so it's understandable why they are reluctant to participate in anything that will dilute their earnings per share. In order to combat this phenomenon, several governmental interventions could be employed such as loan guarantees, ITCs, PTCs and accelerating depreciation.

a. Loan Guarantee

In loan guarantees no financial resources from the U.S. federal government are initially transferred upon agreement. The U.S. simply cosigns loans with another institution which gives bankers confidence to lend that institution money at more favorable terms which can include lower interest rates and longer repayment periods [as much as thirty years instead of only five to seven]. In addition, loan guarantees have no significant impact on U.S. taxpayers unless the institution that cosigned was to default on its loans. In other words, these loan guarantees ride on the credibility of the U.S. government to financially back a project. These have been widely used several times to aid numerous institutions as well as reduce earnings per share dilution in corporations. This type of financial backing has a very small impact on the federal budget due to the low probability of the utility corporations defaulting on the loan.

b. Investment Tax Credit

An investment tax credit reduces earnings per share dilution by providing a providing a tax credit of a certain percentage on an investment. For example, a 10% ITC on a $2 billion project would equate to a $200 million tax credit. Utilities prefer ITCs over PTCs because they are able to recover costs continually over the period of construction, which consequently reduces earnings per share dilution. The federal government tends to shy away from this type of an arrangement because there is less of an incentive for the corporation to finish the construction project when compared to other options (such as a PTC). The impact on the federal budget from the loss of tax revenue is another government concern; however $50 million a year for 4 years out of a $1.5 trillion dollar budget does not make it a significant one. The other main point to keep in mind about ITCs is that they are only temporarily needed for the first 2-3 nuclear plants so that the economics could be proven to investors.

c. Production Tax Credit

A production tax credit offers a predetermined amount of money, typically on the order 1.7 cents per kWh electric produced from the plant. In addition PTCs, just as ITCs, need only to be temporarily put in place for the first 2-3 nuclear plants so that the economics can be realized. PTCs are also currently being used for renewable sources of energy such as wind and biomass. This helps to address market risk, but does nothing to help out earnings per share dilution during the construction process. The problem that utility companies have with PTCs is that the financial benefit is only realized after construction of the facility is completed. So hypothetically if a problem arose in the commissioning process and the facility was not allowed to operate, the utility company would be out the entire cost of the plant, typically 1-2 billion dollars.

The government prefers PTCs for precisely the same reason, since the financial benefit is only paid to the utility upon completion of a nuclear power plant, there is greater incentive to finish the facility on time and at cost. Senate Bill 2095, which is currently being pushed by Senator Domenici, included the nuclear provisions of the H.R. 6 conference report with the expectations of the Production Tax Credit for new generation.

d. Accelerating Depreciation

In normal depreciation, the depreciation in the first year is equal to the depreciation in the second year, third year, etc. But in accelerated depreciation, the pattern assumes a higher dollar depreciation in the early years of an asset's life as compared to the later years. For example, in an accelerated depreciation, the depreciation in the first year is greater than that of the second year, and so on. This allows for a much faster recovery of the initial capital investment. In current tax law, a 15 year depreciation period is specified for electric utilities in the U.S. corporate tax code's Modified Accelerated Cost Recovery System [MACRS]. This depreciation period was perhaps appropriate in a regulated, cost-of-service business environment. However it is not suitable for a competitive, commodity business environment. More appropriate depreciation schedules, for example seven years instead of 15, would allow faster recovery of investment through a reduced liability for income tax. This modernized tax treatment would simply recognize that depreciation conventions established for a regulated, cost-of-service business environment are no longer appropriate for a competitive, high-risk business environment (Fertel 2004).

B. Defrayment of Insurance Cost Via Price-Anderson Indemnification

The Price-Anderson Act authorizes means to insure the public against damages from nuclear related accidents. In current law, commercial reactors need to carry the maximum amount of private insurance for off-site damages available [currently $300 million]. For damages assessed in excess of $300 million, all reactor operators would be assessed up to $10 million per year for as many years as necessary to pay off the total assessment. The Price-Anderson Act also authorizes the DOE and the NRC to indemnify the nuclear-related activities of government contractors and research reactor operators with federal funds (Office 2003).

According to the NRCs 1998 report to Congress, the Price-Anderson Act has proven to be a remarkably successful piece of legislation that has provided in depth coverage and that proved its viability in the aftermath of the Three Mile Island accident. Since the inception of the Price-Anderson Act, the law has been extended three times for successive 10-year periods, and in 1988 it was extended for 15 years. The Price-Anderson Act is a proven law that works in for following important ways:

Assures the availability of billions of dollars to compensate affected individuals who suffer a loss as a result of a nuclear incident.

Establishes a simplified claim process for the public to expedite recovery of losses.

Provides for immediate emergency reimbursement for costs associated with any evacuation of residents near a nuclear power plant.

Establishes two tiers of liability for each nuclear incident involving commercial nuclear energy and provides a guarantee that the federal government will provide additional compensation beyond that explicitly required by law. The Price-Anderson framework provides $9.5 billion of coverage in the two levels of protection (NEI 2001).

Industry executives have commented that the public does not understand that the coverage is limited; utilities are required to match a premium and are responsible for accident consequences up to a pre-determined level. One executive was quoted saying, “The average voter thinks Price-Anderson is a free ride. It is not. It costs us millions of dollars to provide our matching portion of the coverage,” (Scully 2002). These utility executives have gone on to rate this risk as a “showstopper” and are confidant that without renewal of the Price-Anderson Act, no new nuclear plants will be constructed in the U.S. Therefore, new legislation is needed to extend the current law to ensure further indemnification for new commercial power reactors that are constructed after December 31, 2003.

PARADIGM DIFFERENTIAL BETWEEN GOVERNMENT AND INDUSTRY

In order for the parties to work together more effectively, both the federal government and the private industry first need to understand the different paradigms that each is operating under with regard to solving a problem. The federal government does a careful evaluation of all of the contingencies and ramifications in order to make the decision that benefits the largest number of its constituents, while private industry has to make timely decisions that benefit its shareholders to the greatest extent possible. Both institutions seek to benefit their supporters, but the difference is that corporations are constrained by time to a much larger extent than the government is. Thus, in order to work together and move forward with developing our future energy infrastructure, each institution has to understand the constraints that the other is operating under.

After this point is established, developing compromises that both institutions can agree upon should become much easier. First the federal government should understand that due to the capital intensive nature of constructing power plants, the private industry as well as the shareholders are put in a very compromising situation if extensive delays ensue or permits are held up in litigation proceedings. However, these financial incentives need only be in position temporarily [i.e. for 2-3 plants] in order to alleviate the first of a kind engineering costs. After the construction is completed for the first few plants, investor confidence in the construction and licensing process will be well established and the cost per kilowatt hour of capacity will be on par with that of other generating options. In other words, the industry merely needs the government's help to catalyze the process and after it has been proven that the construction of new nuclear plants is a profitable enterprise, the private industry will be able to independently develop electrical infrastructure to satisfy the needs of the Nation.

An area of contention that I've observed after interacting with representatives from some of the utilities is the slow manner in which the government executes initiatives. The utilities, however, need to understand that the government does not operate on the same wavelength as the corporate world does. Government employees are not driven by making a profit; they are driven by making the best decision possible. One of the side effects to this operational philosophy is the drawing out of the decision making process. This is done so that all of the potential ramifications are evaluated in-depth by a large number of people to ensure that the decision that they are arriving at is the best one. Both businesses and governments can come and go with bad decisions, and our current political system was set up to minimize that possibility. Therefore corporations should not be discouraged when the government does not pass initiatives as quickly as they would like, but rather focus their efforts on finding a way to develop a consensus within both the Executive Branch and the Congress that nuclear power is and should continue to be an essential part of our energy portfolio while at the same time coming up with ways to use that consensus to develop support that are both acceptable from a budgetary point of view and best suited to give the industry the jump start it needs.

DISCUSSION

Our nation's overdependence on fossil fuel energy sources is a real problem that poses a threat to our national security. Reliance upon other countries for our energy generation has significant implications on the economy and foreign policy of the United States. Therefore, in order for our great nation to be independent enough to pursue advantageous economic initiatives and formulate appropriate foreign policy decisions, our energy infrastructure needs to be as autonomous as possible. However, given the current legislative environment, the maintenance and development of our energy infrastructure has become a very problematic issue. Renewable energy sources such as wind and solar power are promising technologies and funds should be continually appropriated toward development but given the current economic environment, nuclear power is the only cost effective nonpolluting option available today. However, before new nuclear plants can be constructed in the United States, certain hurdles need to be overcome.

The current lack of investment in new baseload plants and electricity transmission systems is a significant area for concern. According to NEI, approximately 183,000 MW of the nation's electrical generating capacity is 30-40 years old and approximately 104,000 MW is 40-50 years old. This represents nearly one third of the total electrical capacity of the U.S. and clearly illustrates that we have been relying on old, less efficient electrical generating capacity and not bothering to invest in recent cleaner and more efficient technologies. Despite the major increases of electricity being brought to the market, the electricity transmission system funding has fallen $115 million per year for the last 25 years (Fertel 2004). Therefore, it is crucial that further energy policy legislation is passed to develop new energy infrastructure and aid the utility corporations overcome the looming financial and regulatory barriers created with the advent of a deregulated electricity marketplace.

Proposal and passage of this energy policy legislation can send the appropriate signals to the marketplace that the time is right for the construction of new nuclear plants. The near term delivery of this message is crucial if we hope to start an increased diversification of our energy generation technologies and strengthen our energy supply and delivery system. The legislation can take several forms including accelerated depreciation, loans/loan guarantees, investment tax credits, production tax credits and renewal of the Price-Anderson Act.

For additional help in facilitating an increased integration of nuclear power into American society, there are numerous international examples that we can learn from. The French, for example, receive more than 75% of their nation's electricity from nuclear power. They have instituted several initiatives to help nuclear energy gain a greater public acceptance. One such initiative involves bringing in the local community during every stage of the construction process to educate the citizens who live in the area about the types of safety mechanisms that the utilities are installing to safeguard the citizens from an accident. People inherently fear what they do not understand and that is very much the case in the United States where nuclear technologies are not widely understood by the average American. But the citizens in France who are educated about the benefits and risks of nuclear power actually consider living next to a nuclear power plant to be a status symbol, rather than a danger. Nuclear technology has been around since the late 1940s and is not really much of a secret, but due to the current focus on Homeland Security, nuclear reactors are heavily guarded and information about the facility is almost maintained on a classified level. This basically cuts off American citizens from their principal source of information about nuclear technology which creates a large difficulty in being able to educate the public. Further educational programs need to be put in place in order to educate the American public about how nuclear technologies work as well as what it can do for them.

Yucca Mountain represents one of the largest points that nuclear critics have voiced about the industry, the lack of a long-term waste solution. While a long-term waste solution would definitely help out the industry as a whole, it remains a relatively minor concern to utility companies with regard to new nuclear plant construction. This is because currently operating nuclear reactors have been storing their waste onsite for several decades and newer designs, in addition to incorporating these storage facilities, also include additional design innovations that further reduce the amount of nuclear waste produced by the facility. Several utility executives feel that, "Yucca will likely get open eventually. If it does not, then DOE is still on the hook legally to provide an answer," (Scully 2002). Another sentiment universally voiced from utility representatives was that as long as the project retains its forward momentum, this will remain a relatively minor concern. Though the long-term waste solution is not directly correlated with the initial construction of new nuclear plants, it is however, important to the long term viability of the industry and subsequently needs to be addressed through appropriate federal funding and continued effort from the DOE.

Two political initiatives on the horizon that have the potential to significantly increase the attractiveness for the future use of nuclear power are emission taxes and the transition to a hydrogen fuel economy. The EPA has already implemented an emissions cap-and-trade system that has been incredibly successful in the reduction of SO_2. Similar cap-and-trade systems have been proposed recently in Congress to address CO_2, Hg, NO_x and SO_2. If any legislation to limit the emission of CO_2 is passed by Congress, then the cost of energy production for fossil fueled plants will increase, as will the attractiveness of nuclear generated electricity because of its increased cost-effectiveness. Also, if the United States decides to switch to a hydrogen fuel economy, then the attractiveness of nuclear power will further grow. According to NEI's Vision 2020, "Producing clean fuel with an emission-free energy source multiplies the benefits for the environment. Nuclear power can play a significant role in large-scale hydrogen production by providing the electricity needed in this production process. [Currently,] most hydrogen is extracted from fossil fuel raw material. Replacing fossil-based raw materials with nuclear electricity allows those fossil resources to be used for higher end-value processes, such as chemical feedstock, and reduced emissions to the environment," (NEI 2004).

In today's society, questions of how to best secure our future energy generation while having a minimal impact on the environment are being actively discussed in our social discourse. Renewable sources of energy are important and funding should continually be appropriated towards developing them. However, given the current state of their technology and the present economic climate, renewable sources are simply not economically or technologically feasible for large scale deployment. Energy conservation has also been discussed and while it will help, it is very unlikely to alleviate the growing electricity need over the next several decades. Nuclear power is the only environmentally friendly and cost-effective means of making up this energy generation need.

Finally, additional nuclear generating capacity in the United States would give an added economic benefit of displacing other energy resources that the US could export to nations without a nuclear generating capability. Therefore this increased nuclear capacity would serve as a "tide to lift all boats" by aiding and strengthening not only the United States, but other nations as well. The U.S. would benefit from both the attainment of a secure energy supply and a stronger economy through the distribution of United States energy resources to other nations. And the developing nations would benefit from an increased economic development that comes about from a more developed energy supply. Therefore, the cost-effective deployment of additional nuclear energy infrastructure within the United States would not only help solve our energy problems but also aid in the economic development of less developed parts of the world through the utilization of United States energy resources.

RECOMMENDATIONS

This section contains my personal recommendations for near term nuclear plant deployment. This recommendation was formulated from an extensive amount of background reading along with numerous interviews of individuals with a wide spectrum of perspectives. I believe that it is critical for the national security of the United States that our energy infrastructure be further developed by encouraging the construction of new nuclear generating capacity. However, as shown in this analysis, current government support for new electricity infrastructure development is inadequate and in order to rectify this situation, several governmental initiatives will need to be implemented. The concerns of paramount importance that were raised by most of the individuals I met with from the industry/financial sector can be summarized into three principal types: regulatory, financial and future market outlook.

The regulatory concerns are probably the least significant of the three, since considerable effort from both the utilities and NEI have lessened several of the problems previously plaguing the regulatory process. After the current ESP and COL submittals from the utility consortia are completed by the NRC, templates will be created to serve as a model for future license applications, thereby greatly reducing the uncertainty in the process. Several representatives from industry have indicated that while the work with the government in this area must continue, the chances of managing the risk in this category are pretty good.

The second concern, financial issues, is more of a formidable area to deal with and requires immediate help from the federal government. Legislation is badly needed in this area to send the appropriate message to the marketplace that the time is now to construct new nuclear plants. Because as the market currently stands, a corporation wanting to construct a new nuclear plant would require a CEO to put his career, and his corporation, on the line for over a decade before profit can be realized. Given the age demographics and the relative turnover rates of utility Chief Executive Officers, the CEO who gives the go ahead to build and the one who actually implements the construction, may not be the same person. For example, if a CEO announces to his respective corporation today the intention to construct a new nuclear power plant, the company's stock [along with the CEOs financial portfolio] would drop due to earnings dilution and other factors. After several years the profit will start to be realized, but more than likely for a different CEO. The initial CEO who made the announcement may have retired, moved on or been forced out by angered shareholders before the financial rewards from the decision is realized. Now it is not too difficult to understand why utility corporations have not constructed a new nuclear plant for the last several decades. So in order to change the current environment and make the market more conducive to investment in large, capital intensive projects, the federal government needs to implement legislation now. This legislation can take several forms including; accelerated depreciation, loans/loan guarantees, investment tax credits, production tax credits and renewal of the Price-

Anderson Act. But the utility executives have made explicitly clear that unless this area is addressed by the federal government, no new nuclear power plant construction will commence.

The third and perhaps most challenging concern is what will the future energy market look like for the utility corporations. As with any model, the uncertainty associated with the forecasted correlation gets greater the further out in time the model is extrapolated. Numerous questions permeate this area and torment utility CEOs. Will there be a market in the future to sell the electricity that I am producing? Will the electrical transmission infrastructure be able to support this facility? Are smaller, modular units more appropriate to address the energy needs of specific areas? All of the representatives from utility corporations that I have spoken with believe that the consumer need for electricity will be in place. Oliver Kingsley the CEO of Exelon, agreed by saying, "I believe the market will be there for the next generation of nuclear [power]" (Kingsley 2004). The questions of transmission capability and appropriateness of size for new plants are still in the process of being addressed. However, the best way currently to alleviate concern in this area is to set up long term Power Purchase Agreements (PPAs) with the government to ensure a consistently competitive electricity market for the utility companies.

It is critical to the United States national security that our energy infrastructure be further developed; one of the ways that this can be accomplished is from the construction of new nuclear plants. However, as shown in this analysis, current government support for new electricity infrastructure development is inadequate and in order to rectify this situation, several governmental initiatives will need to be implemented. First, the federal government, along with the utilities, needs to address the remaining regulatory issues for the licensing of new reactors. Second, legislation by the federal government is required to alleviate the initial financial burden put on the utility corporations during the construction process. This legislation can take several forms including; accelerated depreciation, loans/loan guarantees, investment tax credits, production tax credits and renewal of the Price-Anderson Act. Finally, establishment of PPAs with the government will help to ease the investor/utilities concern of what the energy market look like in the future.

It will take a considerable amount of time and effort, but if utility companies and the federal government continue to work with each other our great nation will be able to realize its dream of a brighter and more secure future through the development of our energy infrastructure.

ACKNOWLEDGEMENTS

First of all I would like to thank my mentor Alan Levin for his unwavering support in addition to the significant amount of time spent reviewing my paper. Thanks to the American Nuclear Society for this sponsoring this incredibly valuable summer experience and to all of the folks at the Nuclear Energy Institute for being kind enough to provide an office for me. Thanks to Carol Berrigan for your unending assistance in helping me to meet with individuals to advance both my paper and career plans. Also thanks to Richard Meyer and Adrian Heymer for their tremendous amount of guidance. Special thank you to Bob Twilley for taking an entire afternoon to not only explain the politics of the nuclear power industry but other important philosophies as well. Last, but certainly not least, thanks to Sharon and all of the other WISE interns who made this summer exciting and enjoyable.

REFERENCES

Atomic Energy of Canada Limited. "ACR 700 Technical Description." Revision 1. 10810-01371-TED-001. United States Nuclear Regulatory Commission. March 2004.

Berenson, A. "An Oil Enigma: Production Falls Even as Reserves Rise." The New York Times. June 12, 2004.

Chan, P. "ACR Workshop: Core Design and Reactor Physics." Presentation to United States Nuclear Regulatory Commission. Internet. http://canteach.candu.org/library/20031205.pdf. September 25, 2002.

Cheney, D., *et al*. "Nation Energy Policy: Reliable, Affordable, and Environmentally Sound Energy for America's Future." National Energy Policy Development Group Report. 2004.

Colvin, J. Personal Interview. July 20, 2004. 1:00pm.

Department of Energy. "A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010." Volume 2. October 31, 2001.

Deutch, J.M. Lester, R.K. "Making Technology Work: Applications in Energy and the Environment." Cambridge University Press. Cambridge, U.K. 2004

Domenici, P. "Halt of Iraqi Oil Exports Following Attacks Underscores Need to Promptly Pass Energy Bill." Press Release. Senate Committee on Energy and Natural Resources. June 16, 2004.

Energy Central. "Nuclear Power's Future in OECD Countries." Internet. http://www.energycentral.com/centers/news/daily/printer_friendly.cfm?aid=4984985. July 13, 2004.

Energy Information Administration. "Annual Energy Outlook 2004 With Projections to 2025." DOE/EIA-0383(2004). Department of Energy. January 2004.

EnergyPath Corporation. "Study to Evaluate Nuclear Power as Alternative to Natural Gas Receives Department of Energy Financial Assistance." Press Release. March 10, 2004.

Fertel, M. "Testimony before the Subcommittee on Energy of the Energy and Natural Resources Committee." Washington, DC. March 4, 2004.

Fuel Cycle Crosscut Group. “Generation-IV Roadmap.” Department of Energy. March 18, 2002.

General Electric. “ESBWR Design Description.” NEDC-33084. US NRC. http://www.nrc.gov/reactors/new-licensing/new-licensing-files/ml030090345.pdf. December 20, 2002.

Gold, R. “Natural Gas Is Likely to Stay Pricey.” The Wall Street Journal. June 14, 2004.

Heymer, A. Personal Interview. June 4, 2004. 10:00am.

Kingsley, O. “Remarks of Oliver Kingsley at the American Nuclear Society Conference.” June 14, 2004.

Knollenberg, R. Concurrent Resolution in The House of Representatives. http://www.nei.org/documents/Nuclear_Congressional_Resolution_6-3-04.pdf. June 2004.

Komanoff, C. “Reflections on the US Nuclear Industry’s 25 Lean Years.” Synthesis/Regeneration. Issue 11. http://www.greens.org/s-r/11/11-07.html. 1996.

Kriel, W. “PBMR Operational Modes and States.” PBMR PTY LTD. November 30, 2001.

LaBar, M. P. “The Gas Turbine – Modular Helium Reactor: A Promising Option for Near Term Deployment.” Internet. http://www.ga.com/gtmhr/images/ANS.pdf. April 2002.

Meserve, R. Personal Interview. June 24, 2004. 3:30pm.

Meyer, R. Personal Interview. June 9, 2004. 11:00am.

Miller, T. Personal Interview. June 30, 2004. 3:00pm.

National Research Council. “Electricity in Economic Growth.” Committee on Electricity in Economic Growth. 1986.

Nuclear Energy Institute. “Investment Stimulus Frequently Asked Questions.” Washington, DC. June 2004.

Nuclear Energy Institute. "Testimony Marvin S. Fertel Before the Subcommittee on Energy and Air Quality United States House of Representatives." Internet. http://www.nei.org/index.asp?catnum=3&catid=678. Washington, DC. June 27, 2001.

Nuclear Energy Institute. "U.S. Court of Appeals Rejects Constitutional Challenge of Yucca Mountain Repository." Washington, DC. July 9, 2004.

Nuclear Energy Institute. "Vision 2020: Nuclear Energy and the Nation's Future Prosperity." Washington, DC. April 2002.

Nuclear Energy Institute. "Work Force Survey." Washington, DC. May 2004.

Nucleonics Week. "U.K. Study: Nuclear, Gas Turbines Cheapest New Electricity Sources." March 18, 2004.

Office of Nuclear Energy, Science and Technology. "Price-Anderson Indemnification." Department of Energy. Internet. http://www.ne.doe.gov/home/PriceAnderson.html. August 19, 2003

Office of Nuclear Energy, Science and Technology. "University Reactor Fuel Assistance Support." Department of Energy. March 2003.

Robles, M. Personal Interview. June 25, 2004. 1:30pm.

Royal Academy of Engineering. "The Costs of Generating Electricity." March 2004

Schick, A. "The Federal Budget: Politics, Policy, Process." The Brookings Institution. Washington, D.C. 1995.

Scully Capital. "Business Case for Early Orders of New Nuclear Reactors." Washington, DC. July 2002.

Twilley, R. Personal Interview. July 14, 2004. 1:00pm.

van Zyl, N. "Nuclear Power: Government Policy and public opinion in the United States and Japan." MIT Senior Thesis (10.391j). May 1, 2001.

Vietti, A. "Memorandum to William D. Travers. Subject: Staff Requirements – SECY-04-0032-Programmatic Information Needed For Approval of a Combined License Without ITAAC." Nuclear Regulatory Commission. May 14, 2004.

Wallace, M. Personal Interview. July 16, 2004. 5:00pm.

Wasitis, D. Personal Interview. June 25, 2004. 10:00am.

World Nuclear Association. "The Economics of Nuclear Power." Internet. http://www.world-nuclear.org/info/printable_information_papers/inf02print.htm. March 2004.

World Nuclear Association. "US Nuclear Power Industry." Internet. http://www.world-nuclear.org/info/printable_information_papers/inf41print.htm. March 2004.

World Nuclear Association. "Energy Subsidies and External Costs." Internet. http://www.world-nuclear.org/info/printable_information_papers/inf68print.htm. March 2004.