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# Status of the U.S. Nuclear Option, Conditions Leading to its Resurgence, and Current Licensing Requirements

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## ABSTRACT

The projected increase in electricity demand, increased concern over emissions along with more stringent emission requirements, volatility of the gas and oil supplies and prices, and the convergence of favourable conditions and legislation make nuclear power a practical option for meeting future electricity base-load demands.

## 1 INTRODUCTION

As energy demands grow; increase in global demand for gas and oil; and heightened concern over emissions and global warming, interest in construction of new nuclear power plants in the United States (US) and throughout the world is increasing. Currently in the US, four (4) utilities have submitted applications for an early site permit (ESP) for future construction of a nuclear power plant. Two ESPs have been granted by the NRC, and the other two are in final review. As of February, 2007, fifteen (15) utilities have notified the US NRC of their intent to submit applications to construct 24 new nuclear power plants following the 10CFR Part 52 subpart C combined construction and operation license applications (COLA) process [1], and the number of applicants is growing. This paper describes the conditions and new licensing process that have led to the current resurgence of nuclear power as a viable option for future generation of electricity in the US. Many of the same conditions leading to the resurgence of nuclear in the US also affect other parts of the world.

## 2 CONVERGING CONDITIONS

### 2.1 Need for Power

No other issue is central to the continued well-being of a country as is energy availability and security. Economic growth is a driving force in the global economy as well as driving the growth in the power demand. This is evident in countries experiencing robust economic growth, such as the US, Europe and Asia where the volume and proportion of imported oil and gas is escalating. A compounding effect in the rising need for power is the projected growth of the world’s population. Projections are that the population will grow from the current 6.5 billion to 8.3 billion in 2030. [2]

In one case study, US total electricity sales are projected to increase 41 percent to 5,168 billion KWh by 2030 from 3,660 in 2005. By end-use sector, electricity demand in the residential sector is anticipated to grow by 39 percent, by 63 percent in the commercial sector, and by 17 percent in the industrial sector by 2030 [3]. In a similar case study, world net electricity consumption is forecasted to increase nearly 85 percent from 16,424 billion KWh in 2004 to 22,289 billion KWh in 2015, and 30,364 billion KWh in 2030. Strong growth averaging 3.5 percent per year is projected for the developing world, while in the industrialized world, with more mature markets, a slower average growth rates of 1.3 to 1.6 percent per year are anticipated. [4]

Notwithstanding the numerical differences in various energy demand projections, the results of these investigations consistently indicate the continued world-wide growth of electricity demand, and reductions of the electricity supply margins, if no new generating stations are constructed. While they are an important element of the power generation portfolio and need to be pursued, renewable power sources are intermittent in nature since there is no way to store this energy, and, along with enhancements to existing generating capacity, these measures will not be able to meet the projected base-load demand.

## 2.2 U.S. Clean Air Act

The U.S. Clean Air Act is the comprehensive Federal law that regulates US air emissions from area, stationary, and mobile sources. This law authorizes the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect the public health and the environment. The goal of the Act was to set and achieve NAAQS in every state by 1975. The act was amended in 1977 to primarily set new dates for achieving NAAQS since many areas of the U.S. failed to meet the deadlines. The 1990 amendments to the Clean Air Act were intended to meet unaddressed or insufficiently addressed issues such as acid rain, ground-level ozone, stratospheric depletion, and air toxins [5]. While the Clean Air Act has been amended several times, the 1990 Clean Air Act Amendments, on which current U.S. regulations are based, were the most far-reaching. It authorized the EPA to set NAAQS that established acceptable concentrations of six (6) criteria pollutants: ozone ($O_3$), carbon monoxide (CO), sulphur dioxide ($SO_2$), lead (Pb), nitrogen dioxide ($NO_2$) and particulate matter. In March, 2005, new Clean Air regulations were announced concerning power plant emissions of nitrogen oxides, sulphur dioxide, and mercury. Under the “Clear Skies legislation” introduced in 2002, emissions of nitrogen oxides, and sulphur dioxide would be significantly reduced in 28 states and Washington D.C., and reduce mercury emissions from coal-fired plants by seventy (70) percent below 2000 emission levels.

The U.S. Congress has yet to act on the Clear Skies legislation. Consequently, on March 10, 2005, the EPA issued the Clean Air Interstate Rule (CAIR) that will achieve the largest reduction in air pollution in more than a decade. CAIR will permanently cap emissions of sulfur dioxide ($SO_2$) and nitrogen oxides (NOx) in the eastern United States. CAIR achieves large reductions of $SO_2$ and/or NOx emissions across 28 eastern states and the District of Columbia. When fully implemented, CAIR will reduce $SO_2$ emissions in these states by over 70 percent and NOx emissions by over 60 percent from 2003 levels. A closely related action is the EPA Clean Air Mercury Rule. This rule is the first ever federally-mandated requirements that coal-fired electric utilities reduce their emissions of mercury. Together the Clean Air Mercury Rule and the Clean Air Interstate Rule create more stringent requirements for emissions throughout the United States [6]. Nuclear power, which emits neither carbon nor other regulated pollutants can play a critical role in meeting emissions goals.

## 2.3 Kyoto Protocol

Similarly, the Kyoto protocol contains binding emissions targets for developed countries, and under the convention, both developed and developing countries agree to take measures to limit and reduce emissions. The group target will be achieved through individual cuts by various countries world-wide to achieve a collective reduction of six key greenhouse gases by at least 5 percent. Each countries emissions target must be achieved by the period 2008-2012. It is expected that the reductions will be larger than 5 percent. Compared to the levels in the year 2000, the richest industrialized countries will need to reduce their collective output by about 10 percent since many of these countries did not succeed in meeting their early non-binding aim of returning to the 1990 levels by the year 2000. It has been estimated that for the developed countries as a whole, the 5 percent target, represents an actual cut of approximately 20 percent when compared with the emissions levels projected for 2010, assuming no emissions-control measures are implemented. With an increasing need for power, and more stringent emissions targets, emissions-control measures will need to be implemented to both existing generating facilities and any new facilities.

## 2.4 Security, Demand, and Volatility of Oil and Gas Supply

Energy security is a subject of great concern both in the U.S. and the rest of the world. Energy security implies having a diversity of energy supplies at reasonable prices to keep an economy growing. The US economy is much more efficient in using energy than in the past, due in large part to energy conservation and fuel switching actions. Since 1970, the amount of energy needed to produce each dollar of U.S. Gross Domestic Product has been reduced by 49 percent [7, p9]. Nevertheless, the U.S. is more vulnerable to supply shock and strategic manipulation of energy supplies than at any other time in recent history. Record-high global demand, concentration of oil reserves, and reliance on the major oil producing countries for production and distribution of fuels contribute to America's vulnerability. In addition, natural disasters, particularly hurricanes (for example; Hurricanes Katrina and Rita – 2005; Hurricane Ivan – 2004) significantly affect the U.S. oil and gas infrastructure because of the Gulf of Mexico's central role in production and refining. Almost 40 percent of the U.S. crude oil refining capacity is located on the Gulf Coast.

Global competition for oil and gas is significantly increasing. Demand projections for China alone are astounding. China was the source of 40 percent of the world oil demand growth from 2001 to 2005 [7, p12], and China's electricity consumption has recently been climbing at a more than 15 percent annual rate [7, p13]. In addition, the Chinese government predicts the number of cars and trucks in China to reach 130 million by 2020, an increase from less than 20 million in 2000 [7,p13]. China is now the second oil consumer and importer in the world, and the amount of diesel fuel or gasoline required to supply the projected 2020 numbers of cars and trucks will be enormous. It is expected that India will closely follow China in regard to energy use. With a current population of 1.1 billion, India is projected to increase oil consumption by 24 percent by 2010, and increase the demand of natural gas by 5.1 percent annually. It is further projected that Asian developing countries will lead the world in energy consumption growth as their incomes become more advanced and population continues to rise. Forecasts indicate that the region will account for 45 percent of the total increase in world oil consumption through 2025. [7, p 13]

Further complicating the oil and gas supply picture is the tight global refining capacity. Currently, the world system spare refining capacity is estimated to be 3 to 4 percent, and existing refineries are operating at maximum capacity. Some estimates indicate that a large new refinery built in the US would cost in the range of USD 5 to 7 billion and require more than five years to build, with no return on the investment until the refinery is completed [7, p18]. With current demand and projected profits from this demand, refining companies appear reluctant to change this condition. Hence, sudden increases in demand result in a significant impact on price due to the limited ability of the current refining capacity to meet a surge in demand. Higher prices and volatility of the oil and gas supplies can be expected to become the norm for the US, and large parts of the world. A stable and predicable fuel supply and cost is a critical consideration in the planning of new base-load generation.

## 2.5 Public Opinion

A recent Nuclear Energy Institute (NEI) sponsored public opinion poll shows that two-thirds (65 percent) of Americans favor the use of nuclear energy as one of the means to provide electricity in the U.S, and 35 percent strongly favored the use of nuclear energy compared to 15 percent who strongly opposed it [8]. There is also a trend of former "anti-nuke" public figures that are either now in support of or are open to consideration of the nuclear option. Patrick Moore, a founding member of Greenpeace, today supports nuclear power. In a 2006 article in the Washington Post, Moore argued that any realistic plan to reduce reliance on fossil fuels and the emission of greenhouse gases should include increased use of nuclear energy [9].

Regardless of the debate over what is the actual numerical percentage of Americans favoring nuclear power, there is trend that as the American public's sense of urgency regarding energy independence, clean air, and global warming increases, public support of nuclear power is increasing. A similar trend is also developing in Europe. Countries that once rejected nuclear power, such as Germany and Italy, are beginning to reconsider their policies. Even in Sweden, where the referendum in the 1980s placed a moratorium on nuclear power, public opinion polls indicate that 77 percent favor continued nuclear generation [7, p29], and efforts are underway to implement power uprates at existing nuclear plants.

## 2.6 Economics of Nuclear Power

Nuclear plants have produced power reliably with stable, predictable, operating costs that are relatively insulated from price fluctuations. The availability and cost of uranium have been relatively stable and more predictable, although, as demand increases so will the price. Currently, a fully depreciated nuclear plant (which many of the U.S. nuclear plants are in this category) now generates at about 1.5 cents/kWh. This is considerably less than the US retail price for electricity. It is less than coal, and much less than natural gas.

Despite nuclear power's apparent advantages, the U.S. experience in the 1970s and 1980s new regulations, licensing, litigation and other factors resulted in significant construction delays and escalating project costs. This has led to a reluctance of utilities to go nuclear since financial challenges potentially stand in the way of new plant construction.

Construction costs for nuclear plants completed since the 1970s and 1980s ranged from USD 2 to 6 billion, averaging more than USD 3,000/kW, in 1997 dollars. Estimates for new nuclear plants vary, but the initial plants are expected to cost in the range of $1700/kW to

$2000/kW, when considering the "overnight cost" (cost of the plant at beginning of construction) and interest during construction, generally assumed to be 48 months for a standard plant. Costs are expected to decline for the later plants ($4^{th}/5^{th}$) based on experience gained both in construction and the new 10CFR Part 52 subpart C licensing process. The large capital costs for nuclear power, time to complete construction and generate electricity, and interest during construction are critical factors in determining the economic competitiveness of nuclear energy.

Because of the prior nuclear experience, and in spite of the passage of legislation to make the licensing process more predicable (that is; 10CFR Part 52) and favourable factors discussed above, for new nuclear plants to be constructed in the US, government assistance would be needed to help "jump start" any new construction. This assistance and incentive came in the form of "The Energy Policy Act of 2005".

## 3 THE ENERGY POLICY ACT OF 2005

The Energy Policy Act of 2005 is comprehensive energy legislation offering sweeping measures aimed at expanding and diversifying the US fuel supplies. The act incorporates a wide range of measures that support today's operating nuclear plants and provides important incentives for building new nuclear plants. The key nuclear energy provisions in the Act include the following.

### 3.1 Price-Anderson Act Renewal

It extends the Price-Anderson act, the framework for industry self-funded liability insurance, for 20 years. This extension is the longest ever granted by the U.S. Congress. A nuclear plant operator is required to purchase all of the private insurance available to them, currently USD 300 million, to serve as primary coverage. If this is insufficient to cover claims arising from an accident, companies are obligated to contribute to a fund that provides secondary level of coverage. It increases the amount of total coverage to USD 10 billion. It also excluded a proposed "subrogation" provision that would have increased the potential liabilities of contractors at a nuclear site and would made participation riskier.

### 3.2 Loan Guarantees for New Nuclear Plants

The bill authorizes the Secretary of Energy to provide loan guarantees to support the development of innovative energy technologies "that avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases". The loan guarantee can be up to 80 percent for up to 30 years or 90 percent of the project life.

### 3.3 Production Tax Credits for New Plants

The legislation provides for a production tax credit of 1.8 cents/kWh for the first 6,000 MWe of capacity from new nuclear power plants for the first 8 years of operation, for plants placed in service by 2021. A company operating a qualified facility may claim no more than USD 125 million in tax credits per 1,000 MWe of allocated capacity. If a larger plant is operated, such 1200 MWe, and the company has received an allocation for 1200 MWe of capacity eligible credit, the annual limitation would then equal to 1.2 times USD 125 million. It should be noted that the production tax credit places nuclear on an equal basis with other sources of emission-free power that have been receiving production tax credits since 1992.

### 3.4 Standby Support for New Reactor Delays (Delay Risk Insurance)

The bill offers "Standby Support" to offset the financial impact of delays beyond the industry's control that might occur during construction and initial phases of plant startup for as many as six new nuclear plants. It provides for 100 percent coverage of the cost of delays for the first two new units, up to USD 500 million each, and 50 percent of the cost of delays, up to USD 250 million each, for the next four units. The standby support covers delays caused by the Nuclear Regulatory Commission's failure to comply with scheduled "inspections, tests, analyses, and acceptance criteria" (ITAAC).

### 3.5 Tax Treatment of Decommissioning Funds

The legislation updates the tax treatment of decommissioning funds to reflect the fact that many nuclear plants now operate in a competitive, unregulated market. "Non-qualified" funds were previously taxed at the full corporate rate. It is estimated that industry-wide, USD 5 billion of decommissioning funds were unqualified, that will now be "qualified" for a more favourable tax treatment. The new law allows companies to establish qualified decommissioning trust funds and make tax deductible contributions to those funds.

## 4 10 CFR PART 52, EARLY SITE PERMITS, STANDARD DESIGN CERTIFICATIONS, AND COMBINED LICENSES

The U.S. Nuclear Regulatory Commission published 10 CFR Part 52 in April 1989. The new "one step" licensing process was established in 1992. The rule is designed to improve the efficiency and predictability of the licensing process. Part 52 includes 4 sub-parts:

- Subpart A - Early Site Permits (ESP)
- Subpart B - Standard Design Certifications
- Subpart C - Combined Licenses (COL)
- Subpart D - Violations

Under Part 50, the licensing process was divided into two distinct phases. The first phase led to the NRC granting a construction permit that allowed the plant owner to construct the plant. This phase was followed by an operating license phase which allowed the licensee to load fuel and operate the plant. The sequenced licensing processes resulted in overlapping reviews and an inefficient and unpredictable licensing process with opportunity for intervention, hearings and significant delays.

The Part 52 licensing approach allows for early resolution of environmental and reactor safety issues. Once issues are resolved during the ESP or the reactor design certification process, they are not considered during the COL application review.

### 4.1 Subpart A - Early Site Permits

An Early Site Permit is an NRC approval under 10 CFR Part 52 for a site of one or more nuclear power facilities. An ESP addresses site description suitability issues, environmental protection issues, plans for coping with emergencies, and safety assessment independent of the review of a specific nuclear plant design. Under Part 52, the NRC can also issue an ESP for approval of a site separate from an application for combined construction and operating license (COL). Once approved, an ESP can be "banked" and is good for 20 years, and may be renewed for an additional 10 to 20 years.

An ESP can be submitted without selecting a specific reactor technology. This can be accomplished by utilizing a Plant Parameter Envelope (PPE) approach. This approach includes site information and information from a number of reactor plant designs, either currently commercially available or anticipated to be commercially available within the term of the ESP. The information is used to develop the PPE and the Site Safety Analysis Report (SSAR). The selected reactor designs form the basis of a surrogate plant bounding design that is referred to as the PPE. Under this approach, the facility may be one of the reactor designs included in the PPE or an alternative design that is demonstrated to be bounded by the PPE, is suitable for the site, and thus the terms of the ESP granted remain valid. For example, the Clinton ESP included seven reactor designs (ABWR, AP1000, Pebble Bed Modular Reactor, Gas Turbine Modular Helium Reactor, Advanced CANDU Reactor, International Reactor Innovative and Secure, and ESBWR), and the PPE was comprised of 225 site and reactor parameters [10] enveloping the seven technologies.

An ESP application includes an Administrative Section, Site Safety Analysis Report, Environmental Report, Emergency Plan, and Site Redress Plan. The ESP is independent of NRC reviews of specific nuclear power plant designs. To date, four ESP applications have been submitted (existing Clinton, Grand Gulf, North Anna and Vogtle nuclear plant sites), and two permits were granted earlier this year for the Clinton and Grand Gulf sites.

### 4.2 Subpart B – Standard Design Certifications

Similarly, design certification allows a reactor vendor to obtain NRC approval of a standard plant design. Subpart B sets the requirements and procedures applicable to the NRC issuing the rules granting standard design certification for a nuclear power facility separate and independent of a specific site or application for a combined license for such a facility. An application for a standard design certification must include information describing the design and the proposed inspections, tests, analyses, and inspection criteria (ITAAC). The ITAAC requirements are those that are necessary and sufficient to provide reasonable assurance that if performed and acceptance criteria met, a plant that references the standard design, is built and will operate in accordance with the design certification.

To date, three standard reactor designs have been certified by the NRC (GE ABWR, and Westinghouse AP600 and AP1000), and one is under review (GE ESBWR). In addition, pre-application reviews have been requested for five standard designs (ACR700 by Atomic Energy of Canada Limited; US-APWR by Mitsubishi Heavy Industry, Ltd.; US-EPR by AREVA Nuclear Power; IRIS by Westinghouse; and Pebble Bed Modular Reactor).

### 4.3 Sub Part C – Combined Licenses (COL)

Part 52 provides for a single, combined construction permit and operating license (COL). The COL is granted prior to the beginning of construction. A COL application (COLA) may reference either, neither or both an ESP and a design certification. In instances where either an ESP or a certified standard design is not referenced, the applicant is required to provide an equivalent level of information in the COL application. Regulatory reviews regarding suitability of the site and the design of the plant, once completed under subparts A or B, are not revisited prior to issuance of the COL. The Part 52 licensing approach allows early resolution of reactor safety and environmental issues, such that issues once resolved through the design certification rulemaking process and/or during the ESP hearing process, are not reconsidered during the COL application review, except under very well defined circumstances. The application for a COL must contain essentially the same information required in an application for an operating license submitted under 10CFR Part 50. The applicant must also describe the ITAAC program. ITAACs are quantitative indicators that allow the NRC to verify that the plant is built to specifications and that the plant will operate safely. If ITAAC requirements are met, there are no grounds for hearings and therefore delays after the COL is issued.

Recently the NRC issued Regulatory Guide 1.206, Combined License Applications for Nuclear Power Plants (LWR Edition). This regulatory guide provides guidance for the preparation of applications for COLs for nuclear power plants. In general, the information in RG 1.206 is also reflected in the standard review plan (NUREG-0800) since the NRC uses the guidance in the standard review plan to review applications for COLs. An application for a COL is comprised of a Transmittal Letter, Final Safety Analysis Report, ITAAC, Probalistic Risk Assessment, Environmental Report, Security Plan, General and Financial Information, and Quality Assurance Program Description. As noted above, an ESP or standard design may be referenced; however, if an ESP or a certified standard design is not referenced, the applicant is required to provide the equivalent level of information in the COL application.

As of August, 2007, the USNRC website indicates that in the 2007-2009 time frame 19 COLAs are expected to be submitted encompassing 28 units for the following reactor technologies and number of COL applications (in parentheses): AP1000 (6), ESBWR (3), ABWR (1), EPR (5), US PWR (1), and three COLAs with reactor technology not yet selected. The conditions described above, in conjunction with the Energy Policy Act of 2005 and 10 CFR Part 52 combined construction and operating license process were major contributors to the resurgence of the US nuclear option in the US.

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