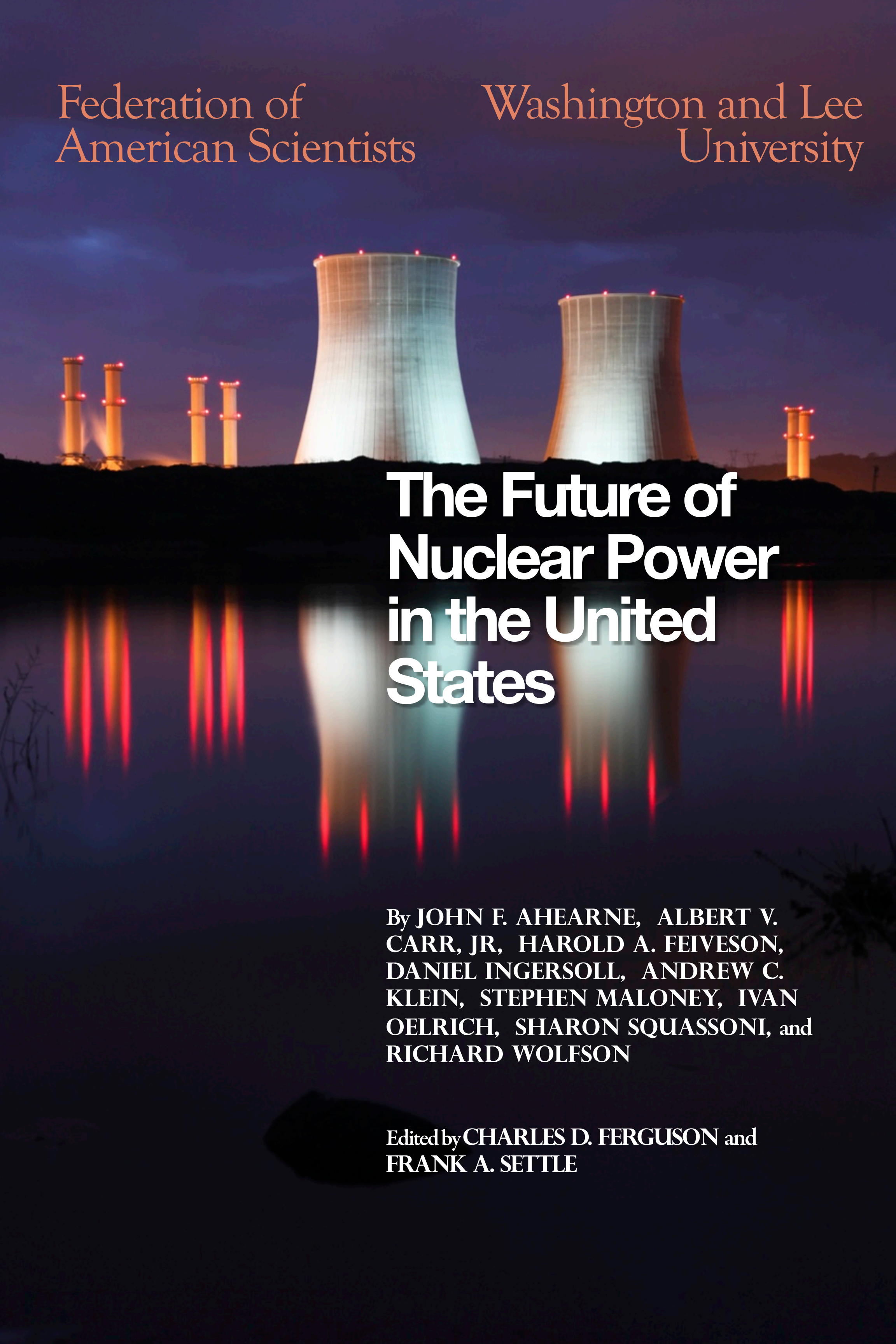

Federation of American Scientists

Washington and Lee University

The Future of Nuclear Power in the United States

By JOHN F. AHEARNE, ALBERT V. CARR, JR, HAROLD A. FEIVESON, DANIEL INGERSOLL, ANDREW C. KLEIN, STEPHEN MALONEY, IVAN OELRICH, SHARON SQUASSONI, and RICHARD WOLFSON

Edited by CHARLES D. FERGUSON and FRANK A. SETTLE

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Chapter 2

A CRITICAL EXAMINATION OF NUCLEAR POWER'S COSTS

by Stephen Maloney

Nuclear power generation is the product of and entirely dependent on central planning. Utilities are insufficiently capitalized to build nuclear power plants, or fully insure third parties against damages from an accident. But for government support in its various forms, nuclear generation would not exist as an enterprise anywhere in the world. Given such subsidies, utilities worldwide happily build and operate nuclear facilities, banking the returns while socializing the risk.

The federal government's role in nuclear generation extends from cradle to grave. Federal loan guarantees fund construction. Once operating, excess liabilities (e.g., third party damages) from nuclear accidents are capped and underwritten by the federal government. In many states, nuclear power plant construction is subsidized by ratepayers for the decade it takes to build a plant. In those states, ratepayers also absorb much of the cost overruns and the effect of schedule delays on replacement power costs. And, the federal government is obligated to take custody of spent nuclear fuel (though it has continually breached contracts in this area since 1998).

The systemic mispricing of risk is among the unintended consequences of centrally planned capital projects and markets. Such mispricing often leads to enterprises assuming more risk than their balance sheet can safely support. This dynamic arises from the implicit "put" option to taxpayers associated with the subsidy or loan guarantee. In many ways, utilities are no different from Fannie Mae, Freddie Mac, and the broad range of government-backed enterprises.

This chapter examines the systemic nature of nuclear construction risk in the context of current markets for wholesale power generation. The federal government's dual role as regulator and subsidizer creates conflicts that are often resolved through the repeating dynamics of "boom and bust" construction cycles.

Regulatory dynamics have driven construction risk over the more than 50 years the nuclear industry has existed. The physics and radiochemistry of nuclear accidents are not well understood nor are the countably infinite number of scenarios that can lead to core damage and radionuclide release. As new information becomes available concerning nuclear hazards, a new safety requirements are triggered that are both more stringent and increasingly detailed. Regulatory dynamics are also activated by specific accidents such as at Browns Ferry (1975), Three Mile Island (1979), Chernobyl (1986), and Fukushima (2011).

After 50 years of government subsidy, the federal government faces a critical fiscal crisis threatening its ability to sustain its wide array of subsidies. Since the bursting of the latest credit bubble in 2008, government spending has grown while tax receipts have declined. Annual deficits are running in excess of $1 trillion per year. Fiscal 2012 net tax receipts are running more than $8 billion per month less than net receipts a year ago.

In an attempt to boost the economy to support this spending, central banking devaluation policies are having a counter effect, fueling substantial inflation faster than energy and commodity supplies can grow. The combined effects of extraordinary debt accumulation and growth in the money supply have been corrosive to markets and capital throughout the economy.

Nuclear operating companies cannot build nuclear power plants without substantial subsidy, be it federal loan guarantees or ratepayer financing of construction. Utility balance sheets are as weak as they were in the late 1970s, having suffered setbacks from the latest credit bubble burst. At the same time, the extraordinary debt loads and high debt-GDP ratios threaten federal solvency, even under the current policies for debasing the currency. As the solvency of the federal government continues its decline, federal and state support for nuclear construction and operation faces increasing risk of disruption.

Nuclear Safety Regulation Drives Nuclear Capital Costs

Accident prevention and mitigation systems distinguish nuclear power plants from other large baseload generation facilities. These safety systems attempt to reduce the likelihood of a reactor accident, and mitigate the consequences of such accidents should they occur. Since there are a wide range of potential scenarios that could lead to a reactor accident, the structures, systems, and components important to safety ("nuclear safety systems") are increasingly complex. Building redundant, independent, and increasingly complex safety systems inevitably leads to the high costs of a nuclear power plant.

Confounding the design challenge is the minimal understanding of reactor accidents. Since the inception of the nuclear industry, there have been about 20 core damage events in civilian and military reactors throughout the world. The most recent accident at Fukushima is especially notable and may well become among the most studied. Yet, to this day, the physics and radiochemistry of reactor accidents, and the environmental hazards are poorly understood. While attempts have been made for decades to estimate the frequency of reactor accidents, those models have never been properly validated nor have they been shown to be responsive to proper treatment of volatilities and uncertainties. Thus, nuclear safety regulation is constantly playing "catch-up" to the latest insight.

Fukushima is particularly notable because it engulfed multiple units at a reactor site, and by the overall severity. Previously, the cross-correlation or "dependent failure" likelihood of a reactor accident at one unit on adjacent units or their spent fuel pools has not been closely studies. And, few studies ever considered how widespread those effects might be. One of the higher estimates of radioactivity released is an extraordinary 27,000 terabecquerels of Cs-137. Fortunately, the winds blew most of the fission products out to sea. In the U.S., major population centers are often down-wind. Nevertheless, the area around Fukushima is abandoned, access severely restricted, and the land is turning feral. Evidence of contamination can be measured more than 100 miles away and has entered the Japanese food chain.

Fukushima will challenge the 50-year old approach to safety regulation. Current regulatory standards do not even attempt to preclude all accidents. Rather, they define a minimal set of standards for a so-called "design basis accident" (DBA) scenario under the presumption that accidents more severe are "unlikely". At Fukushima, the accident engulfed several reactors and their spent fuel pools – scenarios not considered in plant operating licenses. In the coming years, research into the Fukushima accident may provide insights into the effectiveness of current regulations, the relevance of DBAs as the central focus of safety standards.

From the beginning of the nuclear industry, regulatory standards have always been evolutionary. The bar has always been rising on the limited DBA scenarios for which plants are licensed. This evolution is a key driver in the high sunk costs and economic risk of a nuclear construction project.

But, while regulation is inherently dynamic, nuclear cost estimates are static. Viewing a nuclear project as a traditional construction effort, cost estimates assume the requirements in effect at the time the estimate is made will not change. The construction estimate assumes structures, systems, and components important to safety are built just once.

Responding to evolving requirements, many safety elements are often built and demolished several times in the ~10 years needed to construct a nuclear power plant. Even after a plant enters service construction continues in response to new information. The rebuilding of a nuclear power plant over its operating life may slow but never stops. Nobody really knows what it costs to build a nuclear power plant until the final tally is totaled with it ceases operation.

Regulatory history has been marked by repeated waves of "backfits" comprising imposition of new or tougher standards on nuclear safety systems built to simpler, "grandfathered" standards, sometimes going back several decades. The first such industry-wide backfit consisted of the industry wide imposition of standardized safety criteria in the 1970s, replacing the plant-specific safety standards applied to each plant design as it was licensed. The standardization continued for more than a decade.

Safety standards are also upgraded in response to findings from regulatory research involving reactor accident progression, analyses of industry design standards such as after the fire at Browns Ferry, and in response to operator failure to remove decay heat removal at Three Mile Island.

In the more recent era, the NRC imposed backfits to address a greater awareness of security threats following the terrorist attacks of September 11, 2001.

As of March 2012, we are beginning to see another wave of regulatory upgrades as the NRC revisits a broad range of safety requirements following the March 2011catastrophes at Fukushima.[1] NRC calls the enhancements identified from the Fukushima accidents "extended design basis requirements." If the past is indicative of the future, these extensions will require some years before they are fully defined.

But, before reviewing how these waves impacted the construction of plants, let's review the construction cost experience.

Construction Cost Experience

Companies that are experienced managing high risk capital projects explicitly consider risk as part of the investment decision. Two of the simpler measures are (1) applying a high discount rate to capture the risk in the capital price, and (2) imposing limits in the magnitude of the project taken on.

High risk projects facing uncertainty in final costs price capital at a premium. This practice reduces the future value of the project just as companies at risk of defaulting must pay a high yield on their bonds. As general thumb rules, high-risk capital projects in the energy sector (e.g., deep ocean oil exploration and production projects) employ discount rates in excess of 20 percent. In contrast, electric utilities employ much lower discount rates.

Companies also limit their exposure to high risk projects by ensuring they do not take on projects larger than they can afford. For example, in high risk offshore drilling for oil and natural gas, exploration and production companies limit project size to no more than ten

[1] "Recommendations for Enhancing Reactor Safety in the 21st Century," The Near-Term Task Force Review of Insights From The Fukushima Dai-ichi Accident, July 12, 2011, U.S. Nuclear Regulatory Commission, Washington, D.C., http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pfd.

percent of their market capitalization. For a company with a market capitalization in excess of $100 billion, the largest project they might take on is about $10 billion in size. If the project grows in size beyond that, it is often shelved.

Nuclear utilities are much smaller than exploration and production companies and lack the experience and expertise to develop high risk projects. But, with centrally planned subsidies and guarantees, it's not unusual for utilities with market capitalization in the $20-$35 billion range to trying building nuclear power plants costing upwards of $10 billion. This practice amounts to "betting the farm" on nuclear construction. In cases where loan guarantees or ratepayer financing of construction is employed, the "bet the farm" strategy drags taxpayer and ratepayer farms for good measure.

In the first generation of U.S. plants, nuclear plant construction costs rose approximately 24 percent per calendar year compared to six percent annual escalation for coal plants. Through the 1970s, these drivers doubled the quantities of materials, equipment, and labor needed, and tripled the magnitude of the engineering effort.

And, these were the "success stories". In addition to the over-runs, over 120 nuclear units, approximately half the U.S. reactors ordered through 1985, were never started or canceled. The total write-offs were more than $15 billion. The red ink hit vendors and utilities alike, and cut across geographies, company structure, company size, reactor design, and experience.

In 1980, the Atomic Industrial Forum (AIF), a nuclear industry advocacy group and predecessor to the Nuclear Energy Institute INEI), fingered several reasons for the industry's inability to deliver on its construction estimates, notably:

(1) growing understanding of nuclear accident hazards, reflecting a growing awareness of the risk of nuclear operations,

(2) the response to that greater understanding by imposing regulatory standardization (leading to the General Design Criteria), and

(3) imposition of more stringent documentation standards to ensure as-built plants actually met nuclear safety standards.

Written more than 30 years ago, AIF's assessment of nuclear construction cost overruns remain true to this day. It is worth delving into some of the details of that history.

Nuclear Construction Overruns in Prototype and Turnkey Plants

Construction of the current U.S. fleet of operating reactors started ahead of regulatory safety standards. Ironically, construction finished roughly in parallel with completion of those standards.

The first plants built can be separated into two groups:

(1) Prototype and Turnkey Plants – constructed started in the period 1954-1967, and

(2) The GDC Generation – constructed in parallel with the development of safety standards.

The Prototype and Turnkey Plants were built to nuclear safety standards developed "on the fly". Each plant or set of plants was unique, and the safety standards were inconsistently applied. Little or no documentation was created confirming the as-built plant actually conformed to the design criteria, much less how that criteria was interpreted.

Even in this loose regulatory environment, construction projects suffered substantial overruns, proportionately comparable to later project overrun experience. This experience suggests some aspects of the overrun experience may not solely depend on the complexity or stability of regulation but reflect lack of experience planning and building a plant.

Consider, for example, Consolidated Edison Company's Indian Point Unit 1. Announced in October 1954, Con Edison originally expected to build this thorium-fueled 275 megawatt (MWe) prototype breeder reactor about 35 miles north of New York City for $55 million. It entered service in 1962 at $110 million. Other prototypical plants of that era experienced similar overruns.

With a handful of prototype designs in operation and a poor record for managing costs, nuclear power plant vendors sought economies of scale and scope by increasing plant size and standardizing the designs. Exelon's Oyster Creek plant is representative of this plant class, and still operating. Announced in December 1963, Oyster Creek was nearly twice as large as Indian Point 1, and was the first of the so-called "turnkey projects" – plants designed and built to a common specification.

Most turnkey plants entered service between late 1969 and 1972. But, the economics were no better than the prototype plants, and vendors experienced severe financial setbacks due to the overruns. Reportedly, Oyster Creek was the single largest "loss leader" among such turnkey projects. By 1966 when the turnkey sales program ended, General Electric and

Westinghouse were reported to have taken nearly $1 billion in losses constructing the 13 turnkey reactors.[2]

Standardizing Nuclear Regulation

The U.S. Atomic Energy Commission (AEC) was originally charged under the 1954 revision of the Atomic Energy Act with responsibility for defining the safety requirements for commercial nuclear power plants.

While prototype plants, such as Indian Point Unit 1, were under construction, the AEC tasked Brookhaven National Laboratory to assess the magnitude of the exposures to a reactor accident as a guide to setting licensing standards. This study, "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants" (WASH-740), was published in March 1957.

WASH-740 assumed what was then considered to be a "worst case" reactor accident scenario at a hypothetical 185 MWe reactor located some 35 miles from a major city. Clearly, Brookhaven had Indian Point Unit 1 in mind along with other reactors proximate to major U.S. cities (e.g., Zion near Chicago, and Fermi outside of Detroit). The WASH-740 reactor was about the average sized prototype reactor then under construction. The study concluded a worst-case accident could result in 3,400 deaths, 43,000 injuries, and several billion dollars in property damage.

WASH-740 had two immediate effects:

(1) It estimated the exposures associated with a reactor accident, and

(2) It demonstrated that early nuclear site were too close to major cities.

The WASH-740 exposures were well beyond the capacity of insurance companies to underwrite. Since utilities also lacked the capital to cope with such damages, nuclear construction could not proceed without capping liabilities or federal provision of contingent capital.

There was some precedent for Congress to socialize such liabilities. For example, under the 1851 Limitation of Liability Act, an owner of a merchant ship is not liable for any losses beyond his vessel plus the value of the pending freight. This Act was intended to facilitate shipping within the framework of Admiralty Law. The Limitation of Liability Act was recently invoked in the loss of the Deepwater Horizon rig.

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[2] H. Stuart Burness, W. David Montgomery, and James P. Quirk, "The Turnkey Era in Nuclear Power," *Land Economics*, Vol. 50, No. 2, May 1980.

With such precedents in mind, Congress passed the Price-Anderson Act capping nuclear power plant owner liabilities and thereby socializing the risk from a nuclear accident.

WASH-740 also prompted the AEC to institute siting and other standards barring nuclear power plants from being built inside or close to major cities. This may seem obvious now but at the time some companies intended to park nukes in cities.

The Brookhaven study prompted AEC to fund reactor accident research to support the development of a consistent set of safety standards less reliant on speculations regarding how accidents progress. The original framework developed from this research was merged with the First Generation licensing experience to become the General Design Criteria. Some 40 years later, the GDC remains the core safety standard for a nuclear plant's operating license.[3]

The GDC immediately raised significant problems for the AEC. Since the prototype and many turnkey reactors were licensed before the GDC was issued, it was difficult to reconcile why one reactor could operate why construction of other plants were delayed by new requirements. For example, Indian Point Unit 1 lacked the ability to remove decay heat following a reactor accident of the kind envisioned by WASH-740. In contrast, Indian Point Unit 2 and Unit 3 were proposed to be built at the same site and would be equipped with redundant emergency core cooling systems (ECCS) to remove decay heat and cool a nuclear core in the event of an accident.

For the plants that were already under construction, AEC was reluctant to halt the licensing process while it ironed out the regulatory standards. Instead, so-called "provisional operating licenses" were issued with the understanding that a detailed review would be performed in a timely manner and necessary backfits would be imposed in consideration for converting the provisional license to a full operating license.

The GDC left out a lot of details concerning the design of safety systems, leading to further inconsistencies in safety system capabilities. Too often, these details did not emerge until late in the licensing process, which often led to costly rework.

The detailed design requirements for ECCS are a notable example. Early ECCS designs employing the GDC assumed that nuclear fuel damage could be averted in a reactor accident if the fuel cladding temperature did not exceed the cladding's melting point of 3,300 Fahrenheit. But experiments performed at the Idaho National Laboratory (INEL) through 1971 demonstrated that nuclear fuel cladding would quickly lose strength and

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3 "General Design Criteria for Nuclear Power Plant Construction Permits," 10 CFR Part 50, July 11, 1967, http://pbadupws.nrc.gov/docs/ML0433/ML043310029.pdf.

begin to fail at temperatures below the melting point. This loss-of-strength phenomenon also resulted in the structural failure of the World Trade Center following impact by the hijacked airliners and fires they ignited.

Early fuel failure was not the only problem. INEL's experiments also demonstrated that cladding temperatures in a reactor accident could very quickly exceed these critical temperatures because many ECCS pumps being installed in plants under construction were too small.

A detailed summary report of then-current ECCS technology and empirical findings was published in early 1971 as the "Brockett Report." At that the time, 53 plants were well along in their construction with undersized ECCS capacities. Other pre-GDC plants in operation were also at risk.

To satisfy the design basis accident for which the plants were licensed to, ECCS would have to inject more water, sooner, and at higher rates than assumed. This enhancement required larger pumps, larger power supplies and, ultimately, a sturdier building to house and support these upgrades.

For boiling water reactors, the more severe conditions of an accident led to a series of upgrades to the pressure suppression containment design that often took more that ten years to analyze, engineer and construct.

As such engineering details became better understood, the regulatory staff realized safety standards had to be more detailed than the simple statements of the GDC, significantly expanding the depth and scope of regulatory requirements and guidance. These enhancements to the GDC were published as regulatory guides and branch technical positions developed and revised, sometimes several times, through the 1970s. Among the more complex and detailed requirements include:

(1) equipment qualification to perform under accident conditions,

(2) seismic protection,

(3) pipe rupture in reactor accidents,

(4) risk of heavy loads damaging structures, systems, and components important to reactor safety,

(5) flood protection,

(6) tornado protection,

(7) fire protection,

(8) structural integrity of concrete,

(9) reactor containment penetration integrity, and

(10) electrical system independence and protection.

The "knock-on" effects from such detailed regulatory requirements rippled through plant designs for more than a decade. In the case of ECCS, the AEC imposed the new requirements on all operating reactors. For some plants, such as Indian Point Unit 1, the cost of compliance was too great and the unit ceased operations in 1974.

But, the lack of consistency in safety standards plagued NRC to this day. For example, plants holding provisional operating licenses were scheduled for review in the Systematic Evaluation Program (SEP). But, SEP never truly resolved the disparity between the safety system capabilities of early plants and those licensed to the mature requirements. Many plants scheduled for the third round of SEP were never reviewed in any detail.

Fukushima: Confirming Compliance and Extending the Design Basis

The Brockett Report was far from the last word on nuclear accident dynamics. Experiments performed over the last 15 years outline the following major steps following loss of cooling to a nuclear core:

(1) Melting of the Ag-In-Cd absorber alloy (~1475F)

(2) Fuel cladding deformation and bursting (~1400F-2000F)

(3) Steam oxidation of fuel rod cladding and structural materials (~2200F)

(4) Alloy phase transformations and interactions between cladding and fuel (~2375F)

(5) Cladding melts (~3200F)

(6) 90percent release of fission product gases (~4600F)

While much has been learned from research and accident experience, the actual progression of an accident is very dependent on the scenario and can take unusual turns, depending on operator action. Even the seemingly obvious response to a loss of decay heat removal can lead to competing safety imperatives.

For example, at Fukushima, the operators injected seawater when all other means for cooling the core were lost. Clearly, the seawater and containment venting eventually controlled the core temperatures in the heavily damaged core. But, flowing water through a damaged core and out through a containment breach can also accelerate the dispersion of radionuclides. While short-lived gaseous and volatile fission products often receive substantial attention in an accident, they are not the only threat. Many long-lived radionuclides can aggregate in aggregated complexes that are water soluble. Others are redox active. In short, seawater cooling through a damage core and compromised containment can presents ample opportunities for broader dispersion of chemically active, long-lived, highly radioactive nuclide (particularly actinides) away from the accident site. Such reactor accident dynamics involving water interactions are not well understood, nearly impossible to reliably model, and not easily rectified through regulatory guidance or new safety standards.

The more immediate concern is whether the current protection against tsunami and earthquakes specified by the GDC, and NRC staff positions in regulatory guides is sufficient in light of advances in geophysics over the past decade or so. Those advances suggest earthquake frequency may be greater in many areas of the U.S. than assumed in the 1970s, partly due to greater data, and partly due to increased seismic activity after several decades of low activity.

The so-called "Tier 1 Recommendations" presented by the NRC Fukushima Task Force and the anticipated subject of Tier 1 Orders and 10 CFR 50.54(f) letters call for reevaluations of seismic and flood hazards, station blackout accident prevention and mitigation, and additional safety measures. Some of these reviews are effectively re-activations of the deferred SEP program. Other requirements have long been on the books as required by existing operating licenses.[4] In effect, before even testing the adequacy of existing regulations NRC's immediate imperative is to determine whether U.S. nuclear power plants are truly in compliance with its safety criteria, much of which have been in effect for more than 40 years.

NRC's early response includes some activities that are as much a placebo as specific and sensitive to the hazard. For example, the immediate actions required include "walk-downs" of plant systems. These "walk downs" would often be performed by engineers with little or no seismic engineering expertise using acceptance criteria prone to interpretation. Similar walk-downs were performed in the aftermath of the Browns Ferry fire and led to mostly trivial enhancements in protection against the effects of fire to redundant means of

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[4] Memorandum from R. W. Borchardt to the Commissioners, Subject: "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," SECY-11-0137, October 3, 2011, U.S. Nuclear Regulatory Commission, Washington, D.C., http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2011/2011-0137scy.pdf

removing decay heat. Five years after those Browns Ferry walk downs were performed NRC raised the bar by promulgating 10 CFR 50 Appendix R which significantly upgraded the nature of physical and electrical separation and protection against fires. The cost impact of this background was significant for many plants.

A significant upgrade in safety standards several years from now can be problematic for plants with construction running in parallel. Any construction cost estimate is at substantial risk of revision.

Capital Adequacy of New Construction

High risk, capital construction projects can only proceed if sponsoring entity has sufficient liquidity and solvency to weather rising costs, schedule delays, and exposure to volatility in interest rates, labor costs, and commodity markets. Nuclear power plants rely on three such entities:

(1) The balance sheet of the operating utilities, and its capacity to raise capital,

(2) Access to ratepayer financing and subsidy of construction work and ultimately reimbursement of the operating utilities, and

(3) The federal government which may guarantee loans, and underwrite risk that might exceed capped liabilities and the limits of contingent capital.

The first two funding sources are sustainable to the extent the demand for electric power can support cost recovery at the rates charged through centrally planned ratemaking or competitive wholesale markets.

Historically, nuclear utilities often lacked sufficient capital to support nuclear construction projects, and lacked the core competencies essential to managing the risk.

In May 2008, CBO analyzed the effects of Energy Policy Act incentives with special attention to the production tax credit and a loan guarantee program.[5] The tax credit provides up to $18 in tax relief per megawatt hour of electricity produced at qualifying power plants during the first eight years of operation. CBO assesses that generating electricity with nuclear technology would be roughly 35 percent more expensive than using conventional coal technology and 30 percent more expensive than using natural gas capacity. CBO concludes that investment in nuclear capacity would be unlikely in the absence of carbon dioxide charges and Energy Policy Act incentives.

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[5] Congressional Budget Office, *Nuclear Power's Role in Generating Electricity*, A CBO Study, May 2008, http://www.cbo.gov/ftpdocs/91xx/doc9133/05-02-Nuclear.pdf

Some analysts claim Fed Chairman Volcker's interest rate policies killed the nuclear industry. But that claim merely acknowledges the inadequacy of the capital structures utilities relied upon to finance nuclear construction projects. These structures were unhedged, exposed to interest rate risk, and used to construct generating capacity at a time electric generation markets were in decline. Even before interest rates rose, the capital adequacy of electric utilities and electric generation demand growth were in decline.

In fact, as early as 1966, current liabilities at utilities exceeded current assets. At that point, utilities were insufficiently capitalized to support a construction program of any kind, especially a high risk program comparable to their market cap.

By 1974, in the aftermath of the oil embargo, the demand for power had fallen off coming off the credit cycle burst of the Vietnam War, removing any imperative to continue constructing power plants. Utilities still committed to nuclear construction at this point were doubling down on a weak hand.

By this time, the combination of weaker earnings performance and continued heavy bond financing demand for plant construction projects in-flight drove up the spread or "risk premium" on interest rates paid by electric utilities compared to industrial firms in the same bond-rating category. Continued construction would only increase the risk of insolvency and default. Many companies began to back down.

By 1975, nuclear construction neared an inflection point. Electric demand had dropped with rising electric rates due to higher fuel costs, squeezing utility margins and eroding cash flows.

With sector profits down some 25 percent and significant excess generating capacity in the electrical system, most utilities were rapidly trimming capital spending in the late 1970s, beginning with the more expensive nuclear construction programs. By 1979, the credit window for nuclear plants had effectively closed. Lenders were increasingly cautious about financing utilities.

Centrally-planned loan guarantees promise to reinforce the weak balance sheets of nuclear operators. But, such contingent capital would be provided by an increasingly insolvent federal government. Vendors extending credit to projects based on such guarantees should be mindful of the federal government's creditworthiness in the nuclear sector. For example, the federal government has a long history breaching contracts or defaulting on its commitments to the nuclear sector. Most notable are the continuing breaches by the Department of Energy of signed contracts for taking custody of spent nuclear fuel beginning in 1998 – over 13 years ago. Growing federal insolvency undermines the likelihood loan guarantees for nuclear construction will even be honored.

Thirty years later, it is reasonable to ask what, if anything, has changed? Utilities are not better capitalized today. The economy does not demand the construction of baseload power plants that won't come on line for another decade. And, we already know that any cost estimate is likely to escalate.

Will Future Nuclear Power Plants Follow a Cost Trajectory to the Past?

Any plant embarking on construction today will also face regulatory change over the next five years or more as a result of the Fukushima accident. In addition, plants under construction are already showing evidence of cost escalation.

For example, the original Design Certification rule approving the Westinghouse AP1000 design was issued on January 27, 2006. Those design changes are substantial and include a redesign of the pressurizer, a revision to the seismic analysis to allow an AP1000 reactor to be constructed on site with rock and soil conditions other than the hard rock conditions certified in the AP1000 design certification review (DCR), changes to the instrumentation and control (I&C) systems, a redesign of the fuel racks, and a revision of the reactor fuel design. Another area requiring attention will be the review of design acceptance criteria (DAC)-related items, such as the technical reports on human factors engineering (HFE), the I&C design, and piping.

About a year later, the vendor submitted an application to amend the AP1000 DCR and Revision 16 of the AP1000 DCD. Revision 16 contains changes proposed in technical reports, some of which have not yet been reviewed by the NRC staff. By February 2008, two years following certification, Westinghouse submitted 122 technical reports for NRC review. Although submitted as part of the Bellefonte Nuclear Power Plant's COL pre-application phase, these technical reports apply generically to the remaining COL applications that intend to reference the AP1000 design. Six months later, additional changes were submitted. Design Certification does not eliminate the need for detailed engineering design review, nor does it preclude design revisions. Revision 19 was ultimately submitted in June 2011 and NRC issued a final Safety Evaluation Report in August 2011 that was supplemented a month later.[6] Notably, there is no mention in the report of Fukushima or the NRC Task Force.

There is already evidence of rising cost estimates in response to greater understanding of design and construction complexity.

[6] "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Plant Design", Docket No. 52-006, NUREG-1793, Supplement 2, U.S. Nuclear Regulatory Commission, Washington, D.C., September 2011, http://pbadupws.nrc.gov/docs/ML1120/ML112061231.pfd.

Nuclear vendors in the early 2000s were quoting nuclear electricity generation's costs below $1500/kWe. Within a few years, a utility consortium building a General Electric advanced reactor design priced two units at $1,611/kWe. A Florida company subsequently estimated in 2010 a two-unit Westinghouse project would come in at $2,444-$3,852/kWe. The utility reported costs for materials, equipment, and labor had risen more than 50 percent. For all-in costs (i.e., transmission improvements, site enhancements, land, and risk) the project climbs to $3,108-$4,540/kWe. The company then dialed in 11 percent carrying charge and cost escalation allowances for a final tally of $5,780-$8,071/kWe. This analysis was updated in May 2011 with for project costs of $3,483-$5,063/kWe, an increase of some ten percent in one year alone.[7]

The CPS Energy project history is also instructive. In June 2006, a consortium of companies announced plans to build two more reactors at the South Texas Project site for an estimated cost of $5.2 billion. NRG, the lead company, made history by becoming the first company to file an application with the NRC. CPS Energy, a municipal utility, was one of the partners. In October 2007, CPS Energy's board approved $206 million for preliminary design and engineering. In June 2009, NRG revised the estimate to $10 billion for the two reactors, including finance charges. A few weeks later, this estimate rose to $13 billion, including finance charges. Later that year, the estimate reached $18.2 billion, which was reportedly at the break-even point with natural gas. Reportedly, the power would not be needed until about 2023. Whereas the reactors would require upwards of ten years of construction, price-competitive natural gas could be on-line in three to five years. CPS would reportedly spend about $1 million per day on the nuclear project, which would not be needed for some 20 years. Moody's had downgraded CPS's outlook to negative. When the municipal exited the project, its credit rating was lifted to stable.

This cost experience is not unique to the United States. Faced with stringent greenhouse gas (GHG) emissions standards under the Kyoto Protocol, Finland committed in 2004 to building Olkiluoto, the first Generation-III+ reactor, to enter production in 2009. French-based Areva won the contract to build the first Evolutionary/European Pressurized Water Reactor (EPR). At $3,000/kWe (2004), the plant was considered a "loss leader," similar to the "turnkey plants" of the 1960s. By 2007, project costs escalated 50 percent and construction schedule delayed three years. Construction cost projections doubled by 2008 mostly due to commodity cost escalations and weakening dollar to euro exchange rates in the intervening period. At the time, the plant was over $2 billion over budget.

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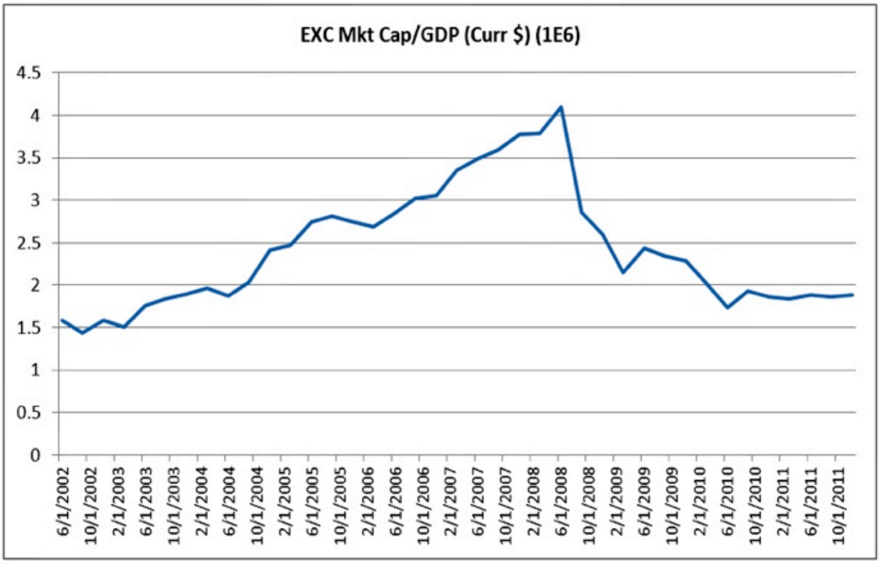
[7] Testimony of Steven R. Sim in Re: Nuclear Power Plant Cost Recovery for the Years Ending December 2011 and 2012, Before the Florida Public Service Commission, Docket No. 110009-EI, Florida Power & Light Company, May 2, 2011, http://www.psc.state.fl.us/library/FILINGS/11/03009-11/03009-11.pfd.

As the project proceeded, quality assurance issues began to emerge. Late 2008, the Finnish Nuclear Safety Authority (STUK) questioned the supervision and "safety culture." STUK reported mandatory welding guidelines were not developed until months after welding of the reactor began and that a contractor instructed workers not to report quality problems to inspectors. Other QA concerns involved the steel liner of the Olkiluoto reactor containment, and the remanufactured primary coolant piping.

The quality assurance concerns contributed to pushing back the delivery scheduled for the fourth time in two years out to 2012. In mid-2009, the latest estimate of construction costs reached EUR5.5 billion, more than twice the price of EUR2.5 billion originally presented. By the end of 2009, more weld faults led to STUK issuing a "stop work" order until the issue is resolved. As mid-June 2010, Areva set aside some EUR400 million ($491 million) for the Olkiluoto 3 construction project leading to an operating loss for the first half of 2010. Originally scheduled for completion in 2012, delays in instrumentation and controls, reactor piping and electrical system installation has put off completion to 2012. Current cost estimates are 5.6 billion EURs – some 2.6 billion EUR over budget.

Capital Adequacy and Need for Power

Capital adequacy is typically defined in terms of normalized market capitalization. The following graph presents the market capitalization of Exelon Corporation (EXC), the largest U.S. nuclear operator, as a fraction of GDP (measured in current dollars). As is evident from the graph, Exelon's normalized market capitalization is comparable to position a decade ago, down more than 50 percent from the period when the "nuclear renaissance" was first proposed.



With a stable capital base and reduced funding capacity, EXC has only a limited ability to raise capital to support a significant construction program. Without substantial guarantees and subsidies, EXC is not in the position to take on investments whose price tag grows faster than its market capitalization or exceeds ten percent of its cap.

EXC is representative of other U.S. nuclear operators and actually has a higher market cap than most. None are growing any faster than the economy which is not growing very fast.

As the following February 15, 2012 Federal Reserve data demonstrates,[8] there is no compelling need for additional capacity of any kind in the utility sector.

Capacity Utilization	Percent of Capacity											Capacity growth
	Avg 1972-2011	1988-1989 high	1990-1991 low	1994-1995 high	2009 low	2011					2012 Jan.	Jan. '11 to Jan. '12
						ug	ep	ct	ov	ec		
Total industry	0.3	5.2	8.8	5.1	7.3	7.6	7.7	8.0	7.9	8.6	8.5	1.2
Manufacturing	8.9	5.5	7.3	4.7	4.4	5.0	5.3	5.6	5.4	6.5	7.0	1.0
Mining	7.4	6.3	3.8	8.5	9.0	0.9	0.7	2.0	2.5	3.3	1.5	1.9
Utilities	6.4	2.9	4.3	3.3	9.2	1.0	9.8	8.7	8.7	6.7	4.6	7

8 Industrial Production and Capacity Utilization - G.17, Board of Governors of the Federal Reserve System, http://www.federalreserve.gov/releases/G17/Current/default.htm

Capacity utilization in the utilities sector is ~12 percentage points below the 1972-2011 average, and almost eight percentage points below the last low (1990-1991). At current annual growth rates, it will take ~7 years to reach the 40 year average utilization. Moreover, since the U.S. economy is growing at 2/3s the utility sector, current utilizations are declining and are some five percentage points below the 2009 low.

There is no immediate need for additional capital investment in this sector. Without loan guarantees, most nuclear operators would see no imperative to build into this market and would find it challenging to raise the necessary capital on their own.

Who bears the risk going forward, and who should bear it?

As the recent Solyndra bankruptcy demonstrates, federal loan guarantees are not free.

On February 16, 2010, $8.3 billion in federal loan guarantees were awarded for two new reactors to be added to Southern Company's Vogtle site in Georgia, conditional until the project is awarded a combined construction and operating license from the NRC. The DOE budget proposal for 2011 requests $36 billion in loan guarantee authority, up from the current authority of $18.5 billion, with the objective of underwriting the construction risk for ten nuclear power plants.

The nuclear construction loan program is but a small component of loan guarantees totaling some $1.1 trillion of which some $77 billion in loan authority is directed at clean energy projects, those that emit relatively few greenhouse gases. Solyndra and other under-capitalized renewable companies share in that program

But guarantees do have the potential for payout and, therefore, have intrinsic value. The U.S. Treasury has already expended $120 billion into Fannie Mae and Freddie Mac for the bailout of the mortgage market. The Congressional Budget Office (CBO) estimates that the final tab could run nearly $400 billion. Many analysts believe the number will be much higher.

Like nuclear construction cost estimates, loan guarantee risk has been rising over the years. In June 2005, CBO produced a cost estimate for the Senate Committee on Energy and Natural Resources related to their consideration of revisions to the 2005 Energy Policy Act.[9] This estimate covered a variety of loan guarantees under consideration, including projects involving coal degasification, renewable energy, ethanol, and nuclear plant construction. CBO observed the subsidy cost of loan guarantees could vary widely depending on the terms of the contracts and the financial and technical risk associated with

[9] Congressional Budget Office, "Cost Estimate for S.10, Energy Policy Act of 2005," June 9, 2005, http://www.cbo.gov/ftpdocs/64xx/doc6423/s10.pdf

different types of projects. Quoting Standard and Poor's, CBO estimates the cumulative default risk for projects rated as speculative investments can range from about 20 percent to almost 60 percent, depending on a project's cash flows and contractual terms. CBO defines the term "subsidy" to mean the net present value of the anticipated cost of defaults, net of recoveries.

A $2 billion loan guarantee for a nuclear construction project was estimated to have a 30 percent subsidy associated with a default event, roughly worth $600 million – comparable to the Department of Energy's failed central planning experiment with the solar panel manufacturer, Solyndra.

Two years later, CBO provided a revised cost estimate to the Senate Committee on Energy and Natural Resources related to their consideration of the Energy Savings Act of 2007.[10] In its analysis, CBO noted the "significant technical and market risks" presented challenges and constraints estimating the subsidy making it "likely that DOE will underestimate than overestimate" cost of insuring against credit risks.

The Fukushima accident further increased the value of the federal loan guarantees. Like the Brockett Report more 50 years ago, the exposures associated with a reactor accident present a potential liability impacting the risk premium for a utility's securities and the value of central planning.

In the immediate aftermath of the accident, nationally recognized statistical ratings organizations (NRSROs) such as Fitch, Moody's, and Standard & Poors issued reporting detailing their concerns of the increased potential liability associated with nuclear operations and construction. For example, here is Moody's take on the implications:

- "What is changing is our view of the sheer magnitude of liability associated with an event risk occurrence. For companies with nuclear activities, Fukushima highlights two important fundamental assumptions incorporated into our credit analysis: an assumption that a population is willing to accept the costs of radiation and that ***its government will stand behind long-term liabilities.*** These assumptions are expected to be tested over the next 12 to 18 months" [emphasis added]
- "The resolution regarding Japan's government support for liabilities can have contagion effects on other jurisdictions. For example, in the United States, ***the Price Anderson Act limits liability to nuclear operators at only $12.5 billion, a figure which now appears relatively low.*** Any liabilities

[10] Congressional Budget Office, "Cost Estimate of S.1321, Energy Savings Act of 2007," June 11, 2011, http://www.cbo.gov/ftpdocs/82xx/doc8206/s1321.pdf

above that level are expected to be absorbed by state and federal governments, a concept that could create a political backlash for the sector due to the weak economic recovery and deteriorating state of government finances. At this time, ***we would not rule out the potential for significant changes to the U.S. nuclear sector's liability insurance framework.***" [emphasis added]

- "***Issuers that own nuclear generating assets within the unregulated power market frameworks are more exposed*** than issuers operating within a traditionally regulated market framework. Recovery of increased costs associated with political intervention and heightened regulatory scrutiny are more assured in a regulated framework. Similarly, the U.S. municipal electric utility and G&T cooperative issuers, virtually all of whom have full rate setting autonomy, can recover increased costs provided they fully exercise that autonomy even in the face of a potential consumer backlash." [emphasis added][11]

Simply put, without government backing, the NRSROs would downgrade the ratings of nuclear issues, thereby increasing the risk premium and interest rate for a project.

With central planning, the minority of people who actually pay taxes bear the risk of going forward with a nuclear construction program. In states where electric generation is fully regulated, ratepayers are also exposed, especially the industrial sectors which typically subsidize residential rates.

Who benefits from such a construction program? Stockholders of nuclear utilities enjoy the benefits of centrally-planned contingency capital. Secondly, nuclear vendors benefit in the near-term, those they face rising exposure to federal default as time proceeds.

Threats to Continued Debt Financing?

At the close of Fiscal 2011, the U.S. Government carried in excess of $15.2 trillion in debt and a debt-GDP ratio greater than 100 percent. Federal debt in the form of off-balance sheet guarantees (notably, Fannie Mae and Freddie Mac), loan guarantees and other entitlements put that debt to over $20 trillion.

Some claim the U.S. economy has begun a recovery. Yet, net tax receipts through the first half of March 2012 are running $8.35 billion lower than a year ago while debt has grown some $300 billion thus far into Fiscal 2012. If this is a recovery, the low payroll tax withholdings suggest it's happening in part-time, low-income jobs.

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[11] "Re-evaluating Creditworthiness for Global Nuclear Generators" Moody's, New York, April 7, 2011

Where tax receipts fall short, federal borrowing makes up the difference. In 2011, the federal government borrowed 42 percent of its disbursements. And, for about thirty years, U.S. Treasury bonds enjoyed a bull market. Presently, the federal government borrows about $1.5 trillion more each year and that pace is accelerating as spending growth exceeds tax receipts.

With the Federal Reserve purchasing Treasuries in recent years, there has not been a let-up in the Treasury bull market, despite the Panic of 2008. In recent years, however, it's been the Federal Reserve purchases that has sustained as foreign purchases of U.S. Treasuries have fallen. China has been systematically reducing its exposure to U.S. debt for more than a year. Russia, another major purchased, has cut its holdings in half over the past year. Other major holders such as Japan, the UK, France, and Germany, have been forced to limit their acquisition of U.S. Treasuries due to their own economic and fiscal challenges.

But, the bull market in U.S. Treasuries may be ending as Treasury prices have experienced a rising number of sell-offs. Many analysts see the onset of a bear market for Treasuries as continued debt-based financing of the federal government is increasingly recognized as unsustainable.

At the current pace, the public debt (excluding off-balance sheet guarantees) will exceed $20 trillion within the next year or so. This spending has had little effect on GDP growth. In constant dollars (2005), the GDP in 2008 at the start of the last recession was $13.31 trillion. Today's, it's about the same. Worse, federal revenues have fallen some 25 percent

At roughly three percent interest rate (and rising), annual interest on the federal debt is $440 billion per year – about three times to cost of military operations in Iraq and Afghanistan combined. Were the interest rate to return to historic averages, federal interest payments alone would approach $1 trillion per year, essentially consuming the entire budget

U.S. Treasuries are particularly exposed to interest rate volatility. In recent years, the Treasury shortened the tenor of its bonds to take advantage of the Federal Reserve's Zero Interest Rate Policy (ZIRP). This tenor shortening led to greater recycling of debt which means any increase in interest rates will be quickly felt in federal spending.

Federal Reserve policies has also distorted in the U.S. economy in other ways, hobbling the ability to accumulate capital and slashing consumer income. For example, ZIRP has crippled household savings and the bond market so important to long-term capital investment. By fueling equity prices through its "quantitative easing" program, it has also shifted household balance sheets from saving and capital preservation in fixed income investments towards highly risky investments in equities. As a result in this shift, interest income to the U.S. consumer is down $450 billion per year from 2007-2008 levels while

U.S. household balance sheets are exposed to market risk as never before. Such distortions do not drive economic growth, less so, demand for electric power.

Nuclear's loan guarantee programs also face significant risk from rising interest rates. If the bull market in U.S. Treasuries is truly ending, the federal government faces a significant shortfall at the same time the U.S. economy's capital reserves have been reduced. As bond yields rise, an increasing amount of taxes will have to divert to pay the higher interest rates for the federal debt, leaving less money for operations and even less for subsidies. And as inflation effects set in, there will be even less economic growth for nuclear power plants to serve.

Conclusion

As an advisor to the current Administration, former Treasury Secretary Larry Summers expressed the view of many economists regarding the Department of Energy's proposal to guarantee loans to Solyndra, a solar panel manufacturer. Writing in a 2009 email, he said "the government is a crappy venture capitalist".

Throughout history, central planning has been marked by investments and subsidies to uneconomic and unsustainable technologies paid for by future generations of an ever smaller number of taxpayers. Central banking creates a credit boom and bust cycle that sparks inflation and leads to increasingly severe and lingering recessions. Central planners will always tilt at windmills believing "this time is different". And each time, the results are the same.

As with all depressions, recessions, and financial panics throughout history, central planning creates entities that undervalue risk, become "too big to fail" in pursuit of returns, and socialize losses. As the product of central planning, nuclear projects, backed by federal guarantees and contingent capital, are no less prone to undervaluing risk and not much different from other enterprises like Solyndra that are too important to the future, or a host of financial institutions who played the housing market that became too big to fail. The inevitable losses from subsidies we seek today will be paid for by our children for decades to come.

ABOUT THE AUTHOR

Stephen Maloney
Mr. Maloney is a Partner at Azuolas Risk Advisors. A longtime energy risk analyst in oil, natural gas, LNG and electric power, he also served as a nuclear risk analyst and participated in several accident rulemakings, including station blackout, fire protection/safe shutdown and other severe accidents. He has also consulted on several nuclear power plant M&A transactions, and investment decisions. He was a former commissioned officer in the U.S. Navy's nuclear propulsion program and qualified as Chief Engineer for the C1W reactor. He has an MS Operations Research, BS Physics, and BS Mathematics. He was licensed as a professional engineer and is a member of the Global Association of Risk Professionals, the American Mathematical Society and INFORMS.

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Federation of American Scientists
1725 DeSales Street, NW, 6th Floor
Washington, DC 20036
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