Testimony of
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Nuclear Economics after Fukushima

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My name is Dr. Mark Cooper. I am a Senior Fellow for economic analysis at the Institute for Energy and the Environment at Vermont Law School. In my 30 years of public policy analysis, I have testified over 350 times before federal and state legislatures and regulatory bodies on energy and communications issues, always on behalf of consumer, low income and public interest groups, as well as People's Counsels and Attorneys General. Over the past three years I have been examining the issue of how to meet the need for electricity in a carbon-constrained environment through my affiliation at the Vermont Law School. I have focused on the economics of nuclear reactors, but recent events require an examination of how safety issues affect the economic analysis. Indeed, it seems to me that policy makers, regulators and financial analysts would be irresponsible if they did not thoroughly re-examine the economics of nuclear reactors in light of these dramatic events. I show in my testimony that such a review will make the construction of new nuclear reactors, which has been uneconomic in market economies, even less attractive.

THE BURSTING OF THE NUCLEAR BUBBLE

The Never Ending Story

The high cost and large capital expenditures associated with the construction of nuclear reactors makes the technology vastly more expensive and risky than alternative approaches to meeting the need for electricity. Because nuclear reactor projects are extremely complex and involve significant environmental and safety concerns, they are prone to cost overruns and other implementation risks. Their huge size and long lead times mean that marketplace or policy developments can eliminate the need for much of their capacity. Because of these characteristics, utilities cannot raise sufficient funds in capital markets to build them.

Reacting to this marketplace reality, nuclear utilities have sought to sidestep the judgment of financial markets by securing massive subsidies that shift the risk of nuclear construction away from utility stockholders onto taxpayers, in the form of governmental loan guarantees, and ratepayers, in the form of advanced cost recovery. Equipment vendors are also likely to subsidize the first set of reactors in an effort to get a "bandwagon" going, as they did with the nuclear construction boom of the 1970s.

While nuclear enthusiasts succeeded in gaining some initial commitments to federal loan guarantees in the United States and advanced cost recovery in a few Southeastern states, the uneconomic nature of constructing new nuclear reactors rapidly became apparent. Almost every one of the almost two dozen projects that were talked about or proposed has been suspended, cancelled, or delayed. The nuclear renaissance has proven to be a classic bubble that burst before even one yard of concrete was poured in the U.S., going through the following stages

- a promotional frenzy (2001-2005 per the streamlining of the licensing process and establishment of the loan guarantee program), and
- a surge in speculative interest (2006-2008, as measured by applications for licenses and loan guarantees), but
- that the industry could not deliver on its promotional cost estimates (as demonstrated by skyrocketing cost projections), and
- finally, the inevitable bursting of the bubble under the weight of economic reality (2009-2010 with plummeting natural gas prices, declining demand growth, and stable costs for other low carbon alternatives, resulting in reactor cancelations and postponements).

Empirical Evidence

Exhibit 1 shows that nuclear power has never been able to live up to the hype of its enthusiasts. Nuclear enthusiasts have consistently underestimated the cost early in the development and deployment stage. Utilities that need to recover the cost of reactors from ratepayers, raise the cost estimates, but they still seriously underestimate the cost of nuclear construction. Independent analysts have come the closest to estimating the actual cost of constructing new reactors. In the nuclear bubble the enthusiasts started with cost projections in the range of $1,000 to $2,000 per kW, but were forced to raise the estimates range of $4,000 per kW. Utilities started at around $3,000 per kW and they are now around $5,000 per kW. The analyses were always higher and most recently have used estimates of around $7,000 per kW.

Exhibit 2 shows that claims that costs will come down over time have proven to be incorrect, as demonstrated by a comparison of the nuclear industries in France and the U.S., the two capitalist nations that build more reactors than any others. Diseconomies of scale and negative learning processes afflict the industry, leading to costs that increase across time, rather than decline.

With nuclear construction costs rising dramatically, a range of alternatives have lower levelized costs, as shown in Exhibit 3. The top graph shows the overnight costs and the construction period. The bottom figure shows the levelized busbar cost and the construction period. Nuclear reactors cost a fortune and they take forever.

The long lead times and high costs of nuclear tie up the utility's resources, making the asset portfolio inflexible. Worse still, utility management and resources become so absorbed with the nuclear project that they become hostile to alternative that might reduce the need for the large, central station facility. With each passing year, options are foreclosed. The low-carbon alternatives including efficiency, renewables, and natural gas have the added advantage of allowing much greater flexibility in resource portfolio management because they take much less time to bring on-line and they can be acquired in smaller increments. In a market place that is characterized by risk and uncertainty – about cost, about need, about societal (environmental and safety) impacts, nuclear reactors with their long lead times, high cost and severe uncertainty, are the worst type of asset to acquire.

Building new nuclear reactors is one of the last things utilities should be thinking about in the current economic environment. Responsible utility management had reached this conclusion long before Fukushima. One particularly outspoken executive is John Rowe, CEO of the largest nuclear utility in the U.S. As shown in Exhibit 4, over the past three years, nuclear has moved to the end of the line compared to efficiency, natural gas and wind.

NUCLEAR ECONOMICS AND NUCLEAR INCIDENTS

A Reality Check

After a major nuclear incident, a thorough review of energy options is necessary. All six of the major categories of risk that affect nuclear reactors, as summarized in Exhibit 5, are affected by the re-examination that must be undertaken.

After a nuclear accident, policymakers would be irresponsible not to re-examine energy policy. They should focus on

- a re-assessment of standards of care and safety (regulatory risk),
- a re-examination of regulatory processes that sets safety standards (regulatory risk),
- a re-valuation of the weighting of societal costs and benefits all available options (policy risk), and
- consideration of the value of gathering more information before committing substantial resources that are locked in (policy risk).

After a nuclear accident, regulators would be irresponsible not to re-examine safety. When they do, they are likely to conclude that

- more safety measures are necessary, which requires more resources to be expended (marketplace risk),
- the construction period, which is a key determinant of costs, will be lengthened, and
- retrofits of existing plants may be required.

After a nuclear accident, rational financial analysts would be irresponsible not to re-examine the economics of nuclear reactors. Capital markets are likely to increase the cost of capital for nuclear reactor construction because reactors will be

- viewed as more difficult to complete,
- become less attractive compared to alternative options, and
- seen as imposing more financial risk on utilities.

Thus, if regulators, policymakers and financial analysts do what they are supposed to, nuclear reactor construction will be much more costly and much less inviting as a policy option as a result of the Fukusima accident.

Empirical Evidence on Nuclear Incidents and Cost

Cost escalation that flows from the conduct of complex, site-specific project is compounded by the need to continually review the safety of an industry that relies on a highly volatile and toxic fuel as its source of power. Nuclear enthusiasts complain about "needless" regulation, but regulators would be negligent if they did not carefully examine the safety implications of each major incident.

With 60 years of experience in the nuclear industry, and over 14,000 years of reactor operating experience, we have a database to examine the occurrence of incidents (as shown Exhibit 6). There are 10 incidents that are considered level 4 (Fukushima was first categorized as a 4, but has been raised to a 5 and may yet go higher). TMI was a 5 and Chernobyl a 7.

Exhibit 6 presents two views of the occurrence of incidents. The top graphs show the simple chronology of incidents. The bottom graph plots the cumulative number of operating years in the industry and the operating years between incidents, against the number of reactors in operation during the year of a major incident. This gives a better view of the rate of occurrence of incidents. Exhibit 7 presents the same analysis showing only events that are categorized as five or greater. The purpose here is not to predict when the next incident will occur, but to demonstrate that the concern about incidents is grounded in the experience of the industry – they happen – and to suggest that the re-examination of safety is justified.

There is no doubt that the incidence of incidents has declined, but it is far from zero. One incident every 2500 to 5000 hours, since TMI and Chernobyl, is still substantial. As the number of reactors increases, if safety does not improve, then the frequency of incidents may increase, particularly when there is talk of doubling the number of reactors in a short period of time.

A concern about the rate of construction is justified by the bottom graph. The reduction in the number of incidents since Chernobyl is clearly associated with a reduction in growth of the number of reactors on line. In the number of reactors brought on line was in the teens and twenties around TMI/Chernobyl, but since Chernobyl it has fallen to almost zero. Gains from experience may be offset by rapid expansion. This is what I found in my study of *Cost Escalation* – the greater the activity, the higher the cost. Thus, the level of industry activity is associated with higher costs and more accidents.

Viewed through the lens of category five or higher incidents, the number of years of operating experience between incidents is longer, but the pattern is similar. Performance improved over time, but the improvement is also associated with a slowing down of construction. The point of this analysis is not to "predict" when the next accident will occur, but to suggest that they do occur with enough regularity to merit attention from responsible authorities.

Re-examination of safety in light of incidents has consequences. There is a clear correlation between major incidents and increases in costs, as shown in Exhibit 8, which includes the cost of 99 reactors in the U.S. It identifies sets of reactors according to the two most important incidents in the period when these reactors were under construction – Three Mile Island (TMI) and Chernobyl.

The construction costs for reactors completed after TMI, but before Chernobyl were 95 percent higher than those completed before TMI, which resulted in electricity costs that were 40 percent higher. The construction costs of the reactors completed after Chernobyl were 89 higher than those completed between TMI and Chernobyl, which resulted in electricity costs that were 42 percent higher. The cost escalation started with TMI and persisted. Its primary cause was the lengthening of the construction period. Contemporaneous accounts and analyses shortly after TMI point to design changes required by safety concerns. Since the trend remains the same after Chernobyl, one cannot say that it had a unique impact, although it can be argued that it prevented any backsliding.[1]

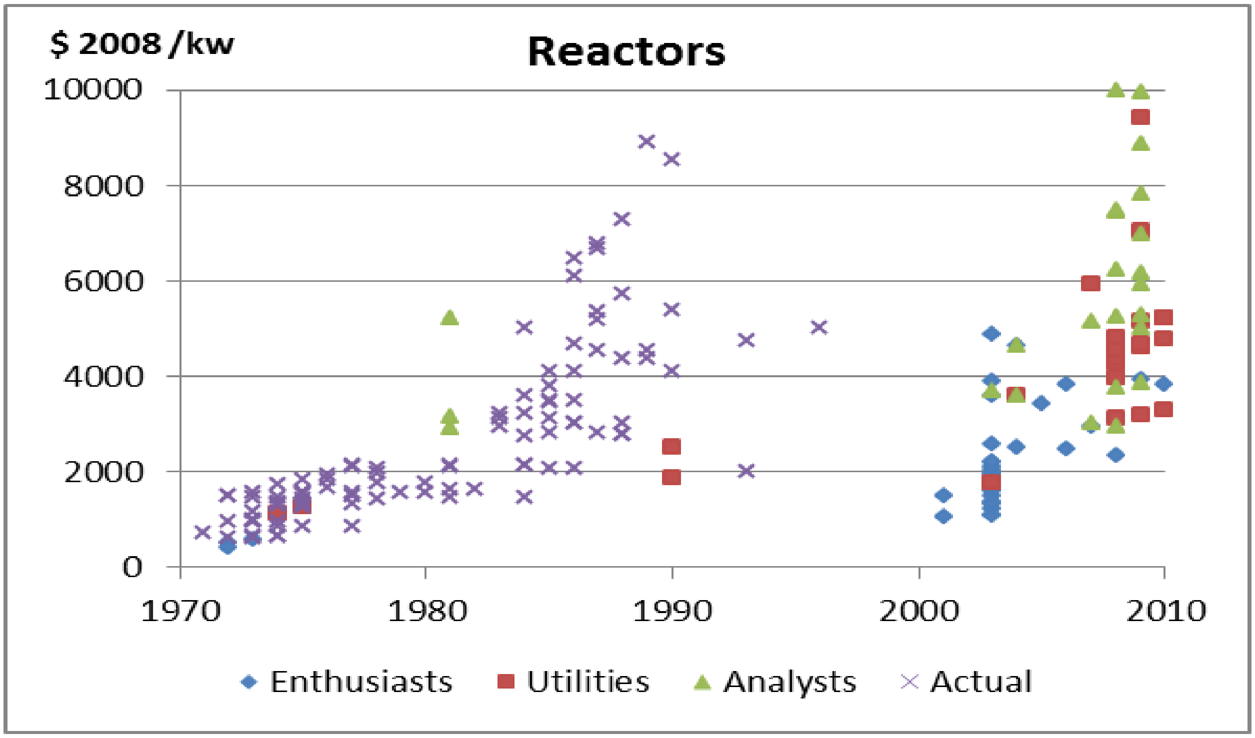
Requiring greater investment in safety frequently elicits complaints that the regulators are raising costs needlessly. When time passes without an incident, it would be equally, if not more plausible to conclude that it was the safety investments that prevented mishaps, as it is to claim that the investment were unnecessary. The fact that major incidents have occurred throughout the history of the industry suggests that the safety concerns are not unfounded.

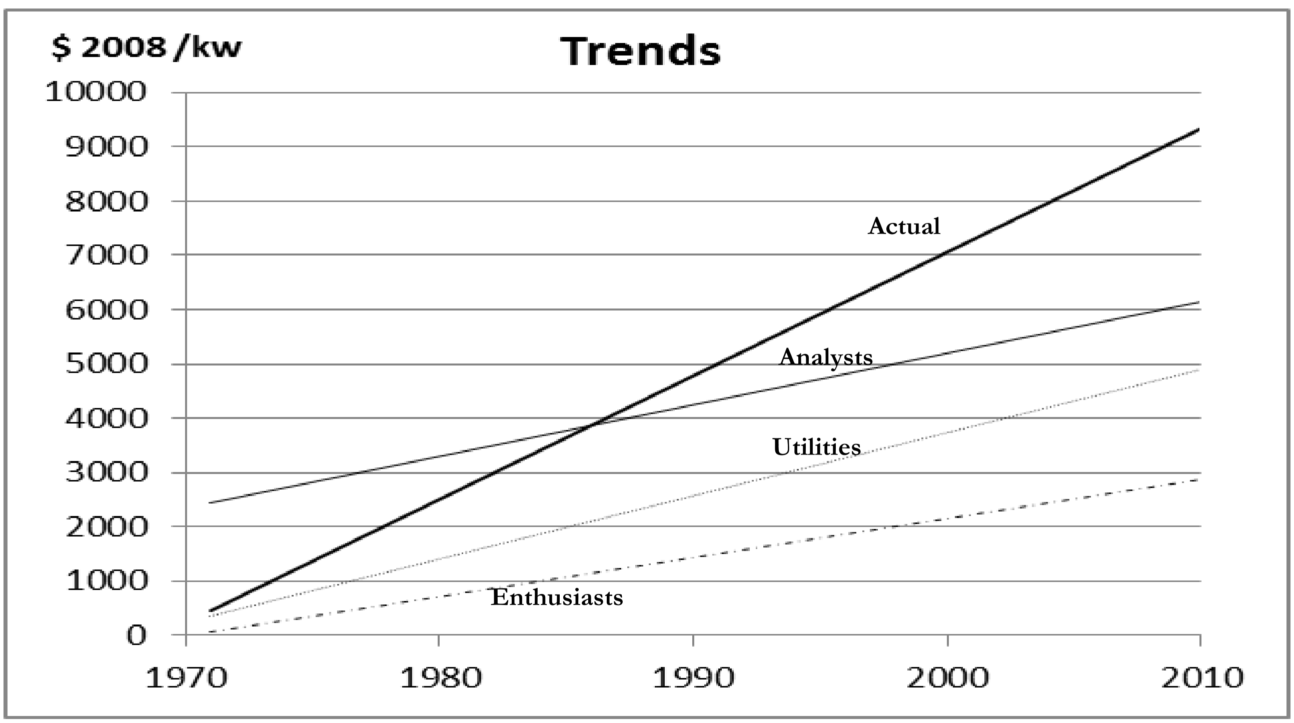
Conclusion

The high risk , cost, and long lead times of nuclear, combined with the rich portfolio of alternative resources available to meet electricity needs at much lower cost and risk for decades, means that the idea of a nuclear renaissance never made economic sense. The idea that a renaissance would involve construction of large numbers of reactors in a short period of time was particularly problematic from both the economic and safety points of view. There was no reason for the government to put taxpayers and ratepayers at risk by overriding the judgment of the capital markets, and there is less reason today. The economic analysis that was used to create the myth of the “nuclear renaissance” vastly underestimated the economic cost of nuclear reactors and totally ignored the societal impacts of nuclear reactors. The economics of nuclear reactors was bad and economics will likely be dealt another blow by the Fukushima incident.

[1] In multivariate analyses both TMI and Chernobyl are statistically significant causes of longer construction periods and higher costs, even controlling for interest rates and finance costs. Other variables that have not been included in the model have also been cited, including rate shock, which slowed demand growth.

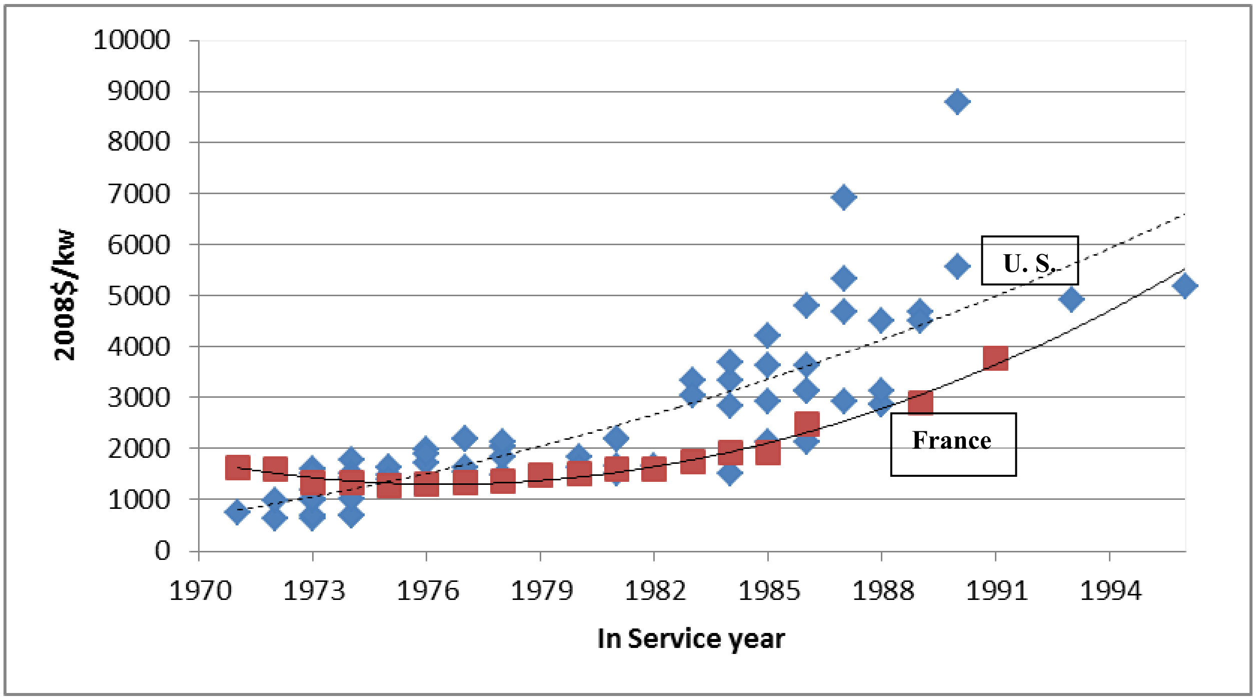
EXHIBIT 1: Actual and Projected Overnight Costs of Nuclear Reactors





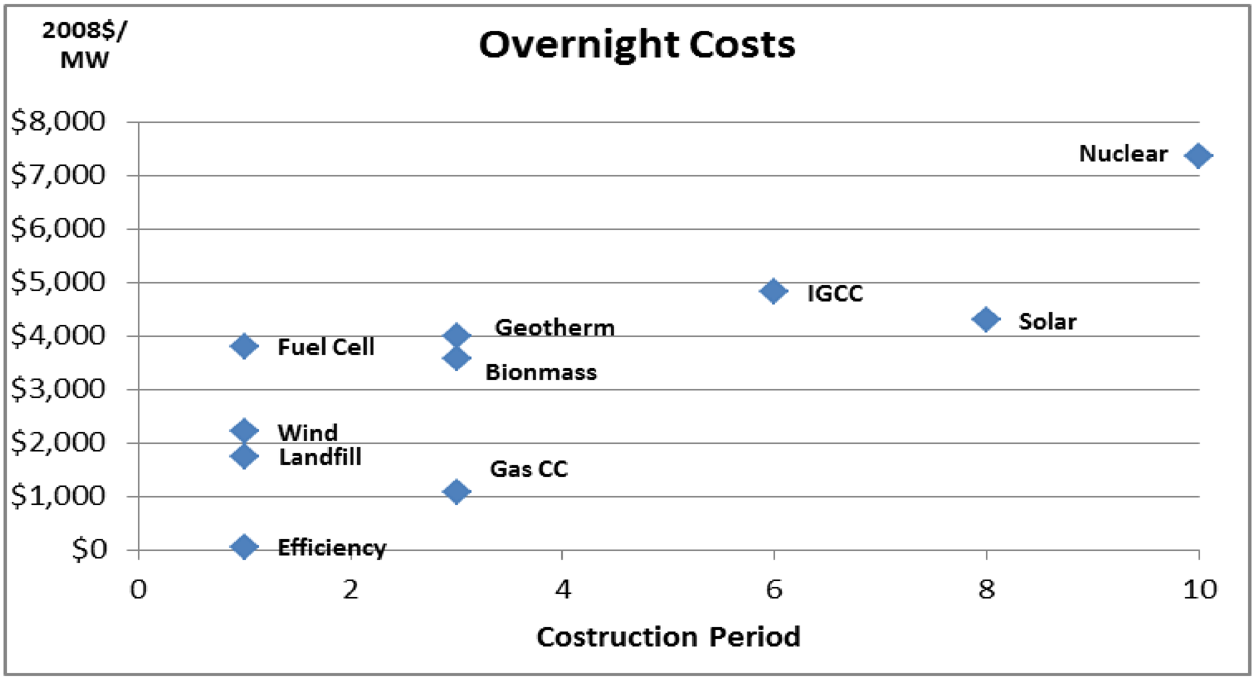
Sources: The database was described in detail in Mark Cooper, *The Economics of Nuclear Reactors: Renaissance or Relapse* (Institute for Energy and the Environment, June 2009). It is continuously updated and the most recent data is presented above.

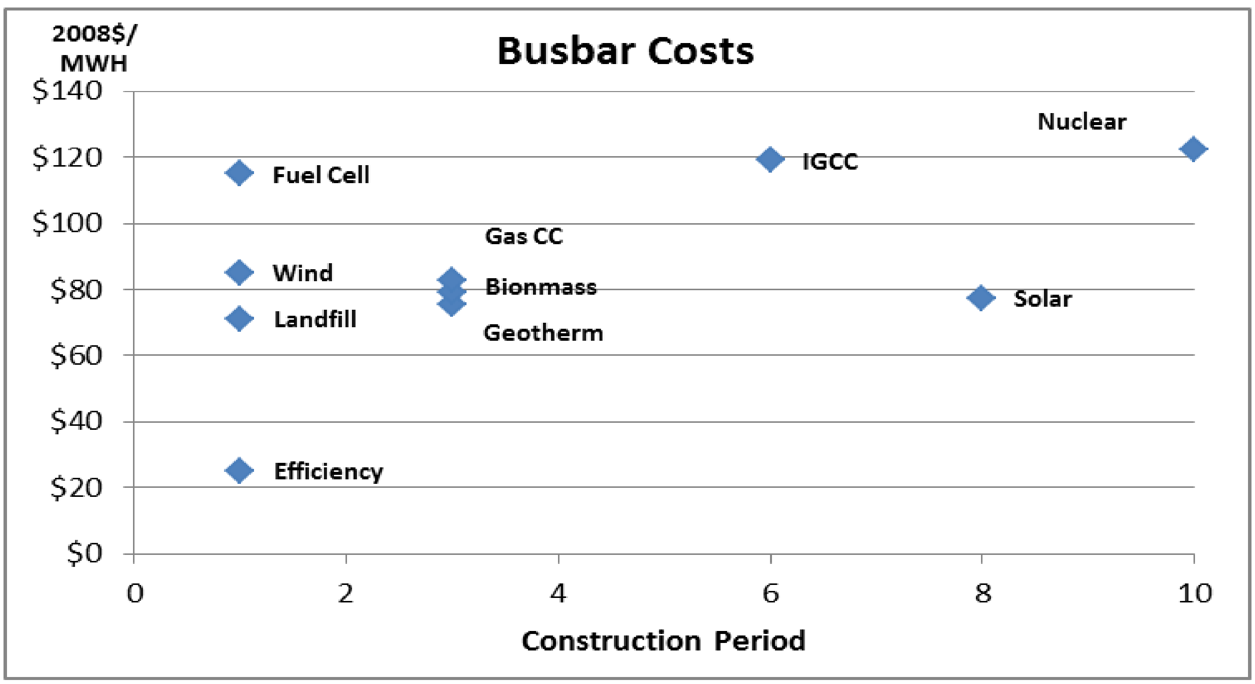
EXHIBIT 2: OVERNIGHT COSTS OF PRESSURIZED WATER REACTORS (2008$)



Source: Cooper, 2009a, database, updated; Grubler, 209.

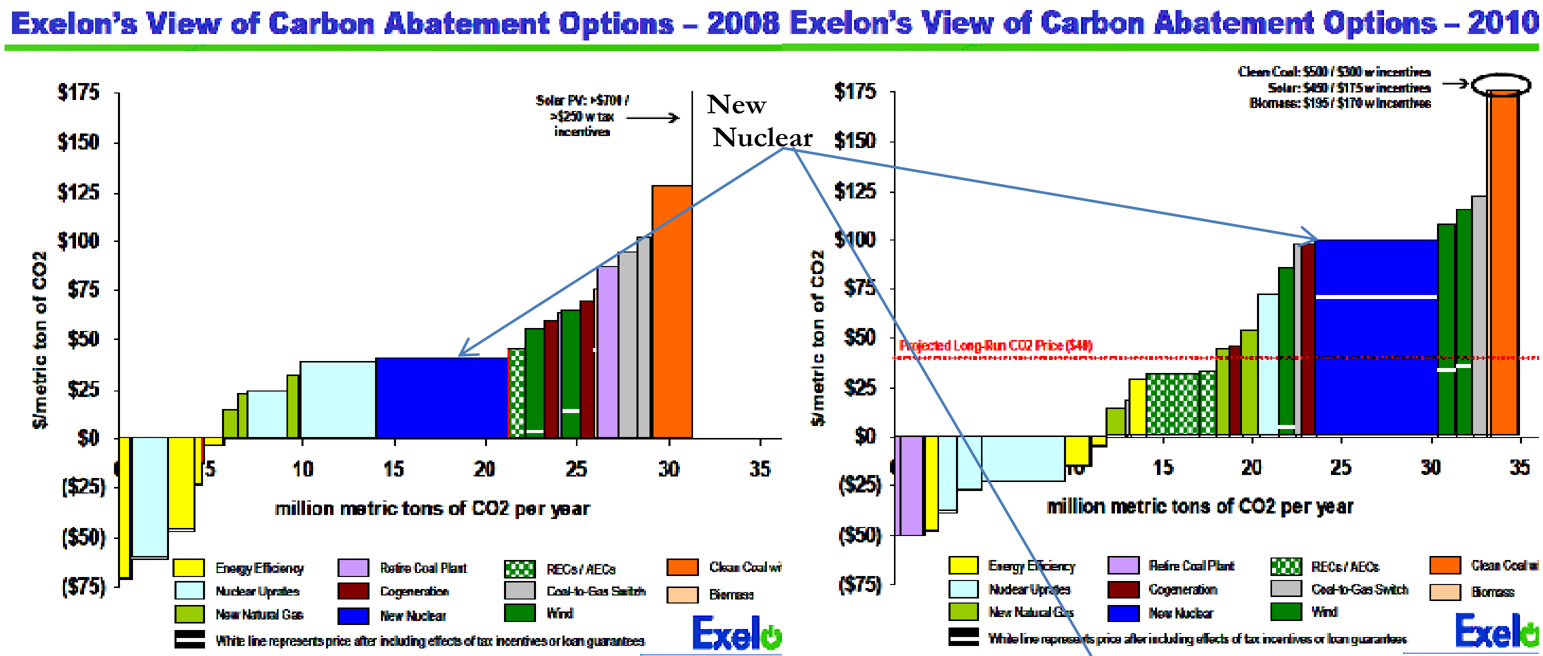
FIGURE 3: CONSTRUCTION PERIOD AND LEVELIZED COST OF ALTERNATIVE RESOURCES

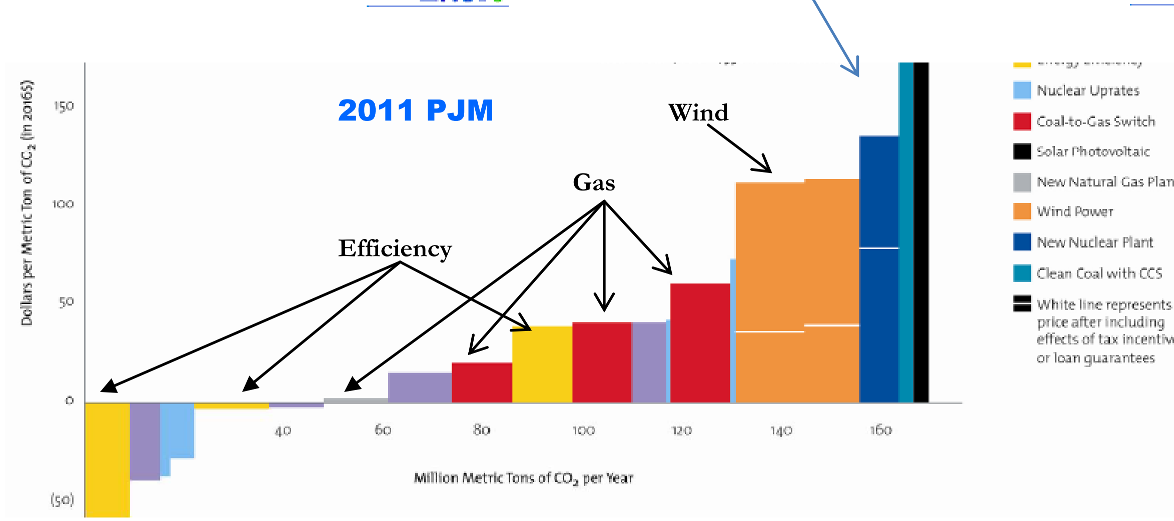




Source: Lazard, *Levelized Cost of energy Analysis – Version 3.0, June 2009,* nuclear construction period is adjusted to reflect experience of ongoing projects.

Exhibit 4: The Increasingly Dim View of Nuclear Economics and Improving View of Alternatives





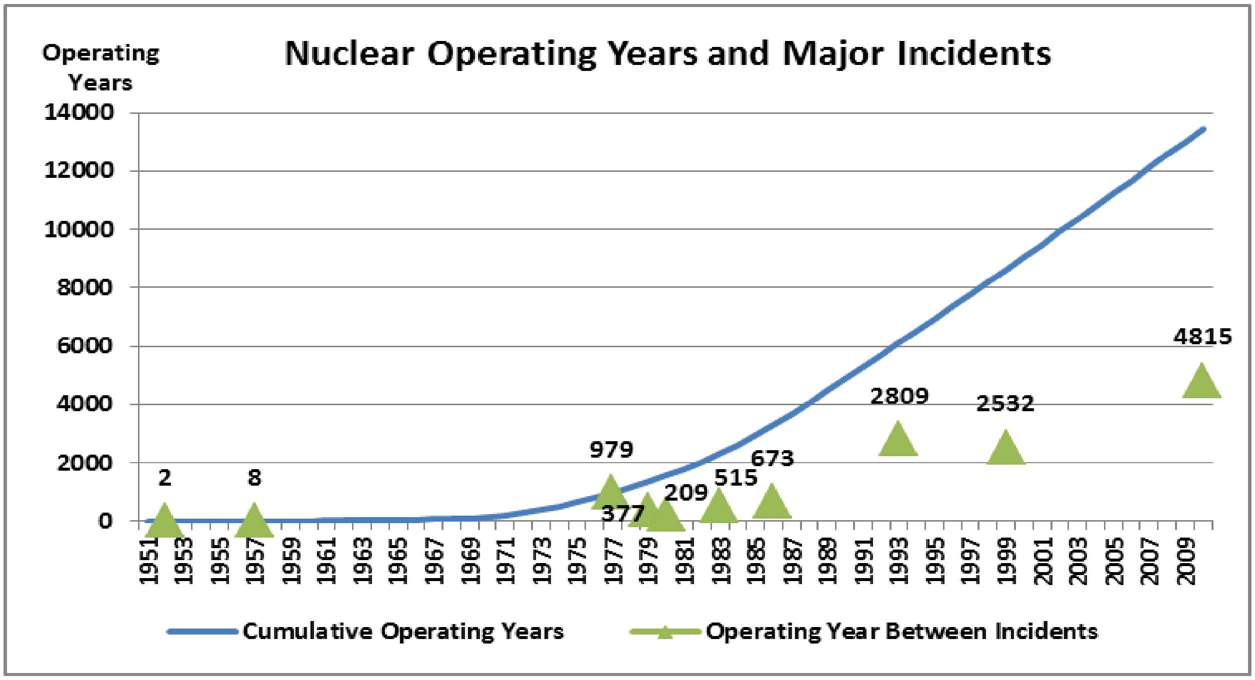
Rowe, John, *Fixing the Carbon Problem without Breaking the Economy*, Resources for the Future Policy Leadership Forum Lunch, May 12, 2010; *Energy Policy: Above All, Do No Harm*, American Enterprise Institute, March 8, 2011

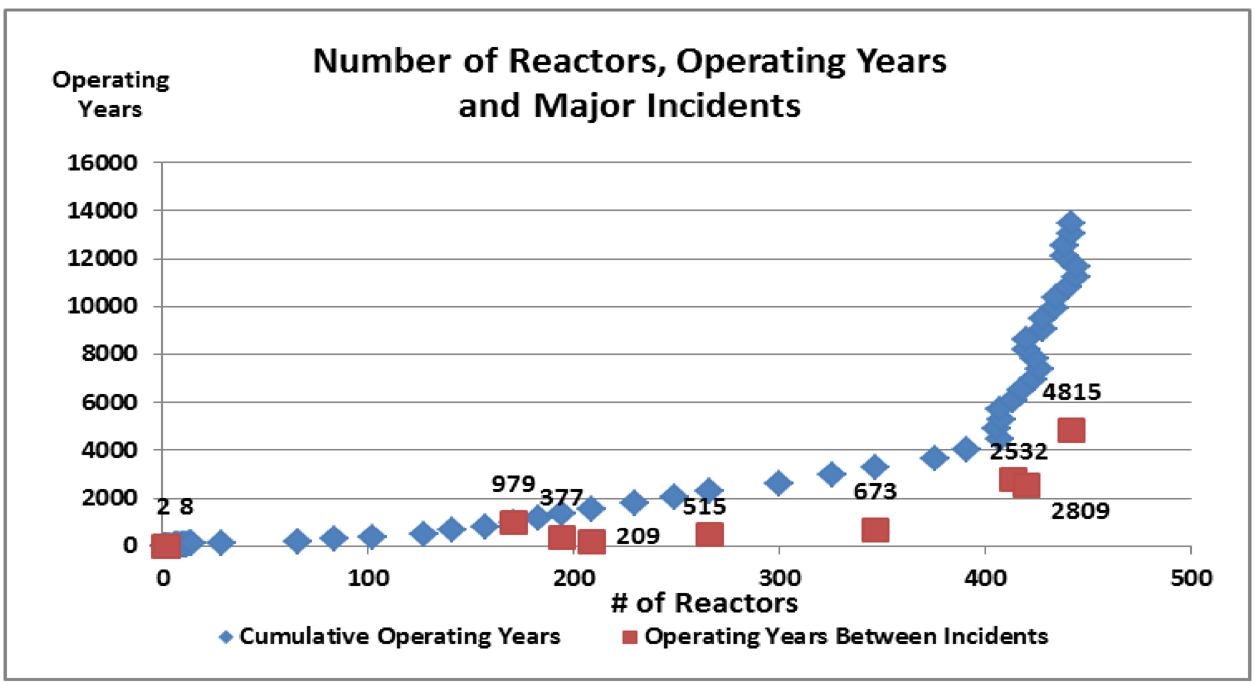
Exhibit 5: The Types of Risks Affecting New Nuclear Reactor Projects

Category	Source	Specific Risk
Technology risk stems from the fact that the new generation of nuclear reactors is new and uncertain. Cost estimates have increased dramatically over the past five years, doubling or tripling. At the same time, costs of efficiency and renewable technologies declining and availability is rising.	New technology risk	First-of-a-kind costs Long lead-time
	Alternative technologies	Efficiency potential identified Renewable cost declines
Policy risk stems from the fact that federal policy is in flux. While nuclear advocates have looked to climate policy, which may put a price tag on carbon emissions, as a primary driver of the opportunity to expand the role of nuclear power, they have failed to take account of the equally strong possibility that climate policy will create a very substantial mandate for conservation and renewables, which will dramatically shrink the need for new, nonrenewable generating, large base load capacity.	Shifting focus	Emphasis on efficiency reduces need Emphasis on renewables reduces need
	Flexible GHG reductions	Lowers carbon cost
Regulatory risk stems from the chance that regulators will move slowly in approving reactors or authorizing their cost recovery. The new design have proven challenging, with the reference designs going through numerous revisions. Site-specific issues, which cannot be standardized, have proven contentious. While a few states have approved construction work in progress and other measures to ensure cost recovery, the vast majority has not.	Loan guarantee conditions	Taxpayer protections inhibit guarantees
	Rate review	Recovery of costs challenged
	NRC regulatory reviews	Lack of experience Change of requirements Design flaws and revisions Site-specific contentions
Execution risk stems from the fact that reactors have not been built in the U.S. in decades and the industry does not have a great deal of capacity. Of the 19 projects that have applied for licenses at the Nuclear Regulatory Commission, 17 have suffered from one or more of the following problems: delay, cancellation, cost escalation or financial downgrade.	Construction risk	Lack of experience
	Engineering, procurement & construction contract uncertainty	Cost escalation and volatility Cost overruns
	Size, cost and complexity	Delays, Rework costs
Marketplace risk on the demand-side flows from the current recession, the worst since the Great Depression, which has not only resulted in the largest drop in electricity demand since the 1970s, but also appears to have caused a fundamental shift in consumption patterns that will dramatically lower the long-term growth rate of electricity demand. On the supply-side of the market, there are a host of alternatives that have lower cost to meet the need for electricity in a carbon-constrained environment and there is growing confidence in the cost and availability of these alternatives.	Uncertain demand growth	Slowing due to recession Shifting due to debt and loss of wealth
	Uncertain fuel costs	Natural gas price decline
	Reactor costs	Long lead time, Cost overruns Rate shock reduces demand
Financial risk stems from all of the above risks and are magnified by tight conditions in money markets and the fact that utility balance sheets are weak and too small to support the large size of nuclear reactor projects. The nature of the projects imposes additional financial risks, so much so that, for most utilities, the projects are so large that Moody's has called them "bet the farm" decisions. operating exposure	General conditions	Tight money, High-risk premiums New liquidity requirements
	Utility finance	Rising cost of debt, Weak balance sheets Limited & declining cash & equivalents Financial ratio deterioration, Increased
	Project finance	High hurdle rate for risky projects, Impact of large project Impact of large project, Capital structure distortion Debt load and service burden impact

Source: Mark Cooper, *All Risk, No Reward* (December 2009)

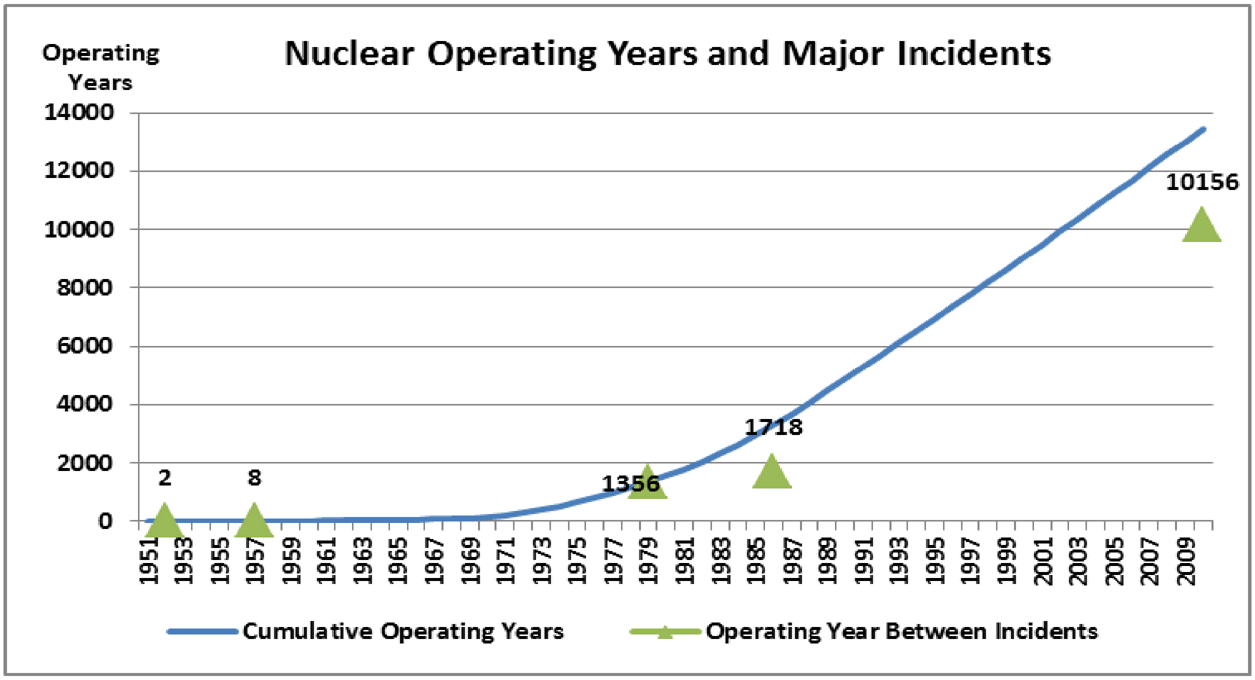
FIGURE 6: ANALYZING THE OCCURRENCE OF MAJOR INCIDENTS: LEVEL 4 OR HIGHER

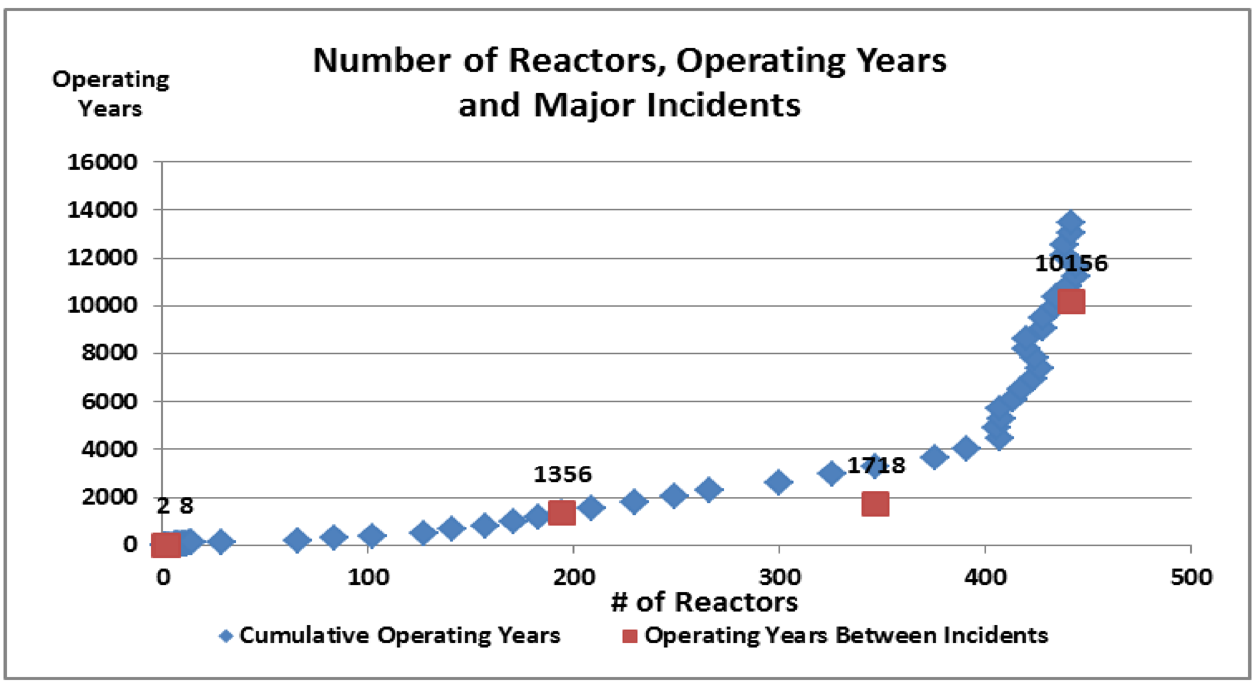




Data sources: Du, Yangbo and John E. Parsons, "Capacity Factor Risk at Nuclear Power Plants," *CEESPR, November 2010;* http://en.wikipedia.org/wiki/List_of_civilian_nuclear_accidents, http://www.euronuclear.org/info/encyclopedia/n/nuclear-power-plant-world-wide.htm Steady growth for pre-1969 operating experience is assumed.

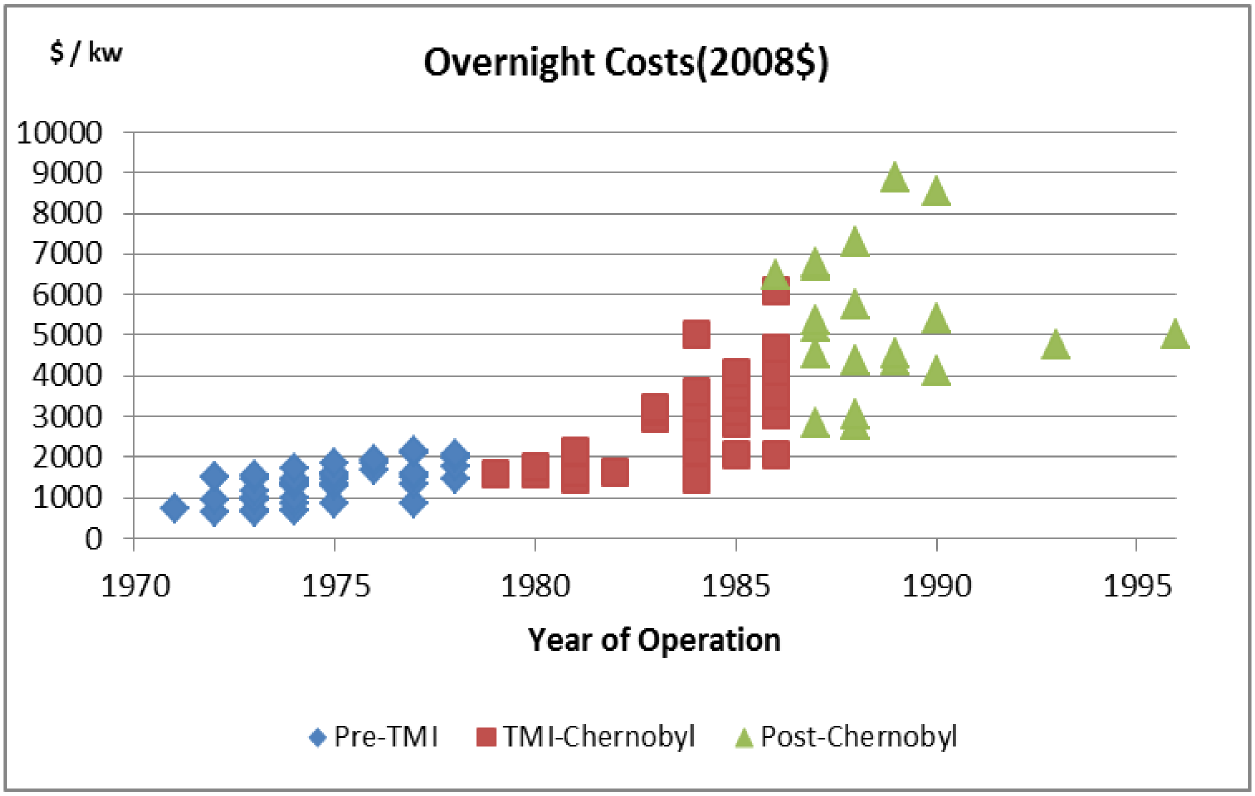
FIGURE 7: ANALYZING THE OCCURRENCE OF MAJOR INCIDENTS: LEVEL 5 OR HIGHER





Data sources: Du, Yangbo and John E. Parsons, "Capacity Factor Risk at Nuclear Power Plants," *CEESPR, November 2010;* http://en.wikipedia.org/wiki/List_of_civilian_nuclear_accidents, http://www.euronuclear.org/info/encyclopedia/n/nuclear-power-plant-world-wide.htm Steady growth for pre-1969 operating experience is assumed.

FIGURE 8: ACCIDENTS AND COSTS



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