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THE ECONOMICS OF NUCLEAR REACTORS: RENAISSANCE OR RELAPSE?

On June 29, the Government of Ontario (Canada) announced that it has suspended the competitive bidding process to procure two replacement nuclear reactors planned for a Darlington, Ontario site. On June 30, Exelon cited "economic woes" as a major factor in postponing for up to 20 years plans to build two nuclear reactors in Texas, USA. And on June 23, Moody's Investor Services issued a report titled *"New Nuclear Generation: Ratings Pressure Increasing."* The summary to the report included the following: "Moody's is considering "taking a more negative view for those issuers seeking to build new nuclear power plants ... Rationale is premised on a material increase in business and operating risk ... most utilities now seeking to build nuclear generation do not appear to be adjusting their financial policies, a credit negative."

(692-93.5970) Dr. Mark Cooper - These three major developments in the nuclear power industry in late June underscore the key findings of the study *"The Economics of Nuclear Reactors, Renaissance or Relapse?"*, released on June 18 by economist Dr. Mark Cooper, a senior fellow for economic analysis at the Institute for Energy and the Environment at Vermont Law School. The analysis of over three dozen cost estimates for proposed new nuclear reactors shows that the projected price tags for the plants have quadrupled since the start of the industry's so-called "nuclear renaissance" at the beginning of this decade - a striking parallel to the eventually seven-fold increase in reactor costs estimates that doomed the "Great Bandwagon Market" of the 1960s and 1970s, when in the U.S.A. half of planned nuclear reactors had to be abandoned or cancelled due to massive cost overruns.

Key Findings

Within the past year, estimates of the cost of nuclear power from a new generation of reactors have ranged from a low of 8.4 cents per kilowatt hour (kWh) to a high of 30 cents. The paper tackles the debate over the cost of building new nuclear reactors, with the key findings as follows:

* The initial cost projections put out early in today's so-called "nuclear renaissance" were about one-third of what one would have expected, based on the nuclear reactors completed in the 1990s.
* The most recent cost projections for new nuclear reactors are, on average, over four times as high as the initial "nuclear renaissance" projections
* There are numerous options available to meet the need for electricity in a carbon-constrained environment that are superior to building nuclear reactors. Indeed, nuclear reactors are the worst option from the point of view of the consumer and society.
* The low carbon sources that are less costly than nuclear include efficiency, cogeneration, biomass, geothermal, wind, solar thermal and natural gas. Solar photovoltaics that are presently more costly than nuclear reactors are projected to

decline dramatically in price in the next decade. Fossil fuels with carbon capture and storage, which are not presently available, are projected to be somewhat more costly than nuclear reactors.
* Numerous studies by Wall Street and independent energy analysts estimate efficiency and renewable costs at an average of 6 cents per kilowatt hour, while the cost of electricity from nuclear reactors is estimated in the range of 12 to 20 cents per kWh.
* The additional cost of building 100 new nuclear reactors, instead of pursuing a least cost efficiency-renewable strategy, would be in the range of $1.9-$4.4 trillion over the life the reactors.

Whether the burden falls on ratepayers (in electricity bills) or taxpayers (in large subsidies), incurring excess costs of that magnitude would be a substantial burden on the national economy and add immensely to the cost of electricity and the cost of reducing carbon emissions.

Approach

This paper arrives at these conclusions by viewing the cost of nuclear reactors through four analytic lenses.

* First, in an effort to pin down the likely cost of new nuclear reactors, the paper dissects three dozen recent cost projections.
* Second, it places those projections in the context of the history of the nuclear industry with a database of the costs of 100 reactors built in the U.S. between 1971 and 1996.
* Third, it examines those costs in comparison to the cost of alternatives available today to meet the need for electricity.
* Fourth, it considers a range of qualitative factors including environmental concerns, risks and subsidies that affect decisions about which technologies to utilize in an environment in which public policy requires constraints on carbon emissions.

The stakes for consumers and the nation are huge. While some have called for the construction of 200 to 300 new nuclear reactors over the next 40 years, the much more modest task of building 100 reactors, which has been proposed by some policymakers as a goal, is used to put the stakes in perspective. Over the expected forty-year life of a nuclear reactor, the excess cost compared to least-cost efficiency and renewables would range from $19 billion to $44 billion per plant, with the total for 100 reactors reaching the range of $1.9 trillion to $4.4 trillion over the life the reactors.

“Half of the reactors ordered in the 1960s and 1970s were cancelled, with abandoned costs in the tens of billions of dollars.”

Hope and Hype vs. Reality in reactor costs

From the first fixed price turnkey reactors in the 1960s to the May 2009 cost projection of the Massachusetts Institute of Technology, the claim that nuclear power is or could be cost competitive with alternative technologies for generating electricity has been based on hope and hype. In the 1960s and 1970s, the hope and hype analyses prepared by reactor vendors and parroted by government officials helped to create what came to be known as the "great bandwagon market." In about a decade utilities ordered over 200 nuclear reactors of increasing size.

Unfortunately, reality did not deliver on the hope and the hype. Half of the reactors ordered in the 1960s and 1970s were cancelled, with abandoned costs in the tens of billions of dollars. Those reactors that were completed suffered dramatic cost overruns. On average, the final cohort of great bandwagon market reactors cost seven times as much as the cost projection for the first reactor of the great bandwagon market. The great bandwagon market ended in fierce debates in the press and regulatory proceedings throughout the 1980s and 1990s over how such a huge mistake could have been made and who should pay for it.

In an eerie parallel to the great bandwagon market, a series of startlingly low-cost estimates prepared between 2001 and 2004 by vendors and academics and supported by government officials helped to create what has come to be known as the "nuclear renaissance." However, reflecting the poor track record of the nuclear industry in the U.S., the debate over the economics of the nuclear renaissance is being carried out **before** substantial sums of money are spent. Unlike the 1960s and 1970s, when the utility industry, reactor vendors and government officials monopolized the preparation of cost analyses, today Wall Street and independent energy analysts have come forward with much higher estimates of the cost of nuclear reactors

The most recent cost projections are, on average, over four times as high as the initial nuclear renaissance projections.

Glossary of terms:

Busbar costs: the price of the power leaving the plant; all capital, fuel, and operating costs taken into account.
Overnight costs: the cost of a construction project if no interest was incurred during construction, as if the project was completed "overnight."
Great Bandwagon Market: a periode with a surge in reactor orders, when industry and utilities thought they had to jump on the 'bandwagon'

All **prices are in US-dollars**, unless stated otherwise. At the time of publication of the original report (late June) 1 US$ equaled 0,71 Euro.

Even though the early estimates have been subsequently revised upward in the past year and utilities offered some estimates in regulatory proceedings that were twice as high as the initial projections, these estimates remain well below the projections from Wall Street and independent analysts. Moreover, in an ominous repeat of history, utilities are insisting on cost-plus treatment of their reactor projects and have steadfastly refused to shoulder the responsibility for cost overruns.

One thing that utilities and Wall Street analysts agree on is that nuclear reactors will not be built without massive direct subsidies either from the federal government or ratepayers, or from both.

In this sense, nuclear reactors remain as uneconomic today as they were in the 1980s when so many were cancelled or abandoned.

The economic costs of low carbon alternatives
There is a second major difference between the debate today and the debate in the 1970s and 1980s. In the earlier debate, the competition was almost entirely between coal and nuclear power generation. Today, because the debate is being carried out in the context of policies to address climate change, a much wider array of alternatives is on the table. While future fossil fuel (coal and natural gas) plants with additional carbon capture and storage technologies that are not yet available are projected to be somewhat more costly than nuclear reactors (see Figure ES-2), efficiency and renewables are also primary competitors and their costs are projected to be much lower than nuclear reactors.

Figure ES-2 presents the results of half a dozen recent studies of the cost of alternatives, including two by government entities, three by Wall Street analysts and one by an independent analyst. Figure ES-2 expresses the cost estimated by each study for each technology as a percentage of the study's nuclear cost estimate. Every author identifies a number of alternatives that are less costly than nuclear reactors.

One of the central concerns about reliance on efficiency and renewables to meet future electricity needs is that they may not be available in sufficient supply. However, analysis of the technical potential to deliver economically practicable options for low-cost, low-carbon approaches indicates that the supply is ample to meet both electricity needs and carbon reduction targets for three decades or more based on efficiency, renewables and natural gas.

Analyses of the potential contribution and cost of efficiency and renewables, (by the Rand Corporation, McKinsey and Company, the National Renewable Energy Laboratory, the Union of Concerned Scientists and the American Council for an Energy Efficient Economy), clearly shows there is huge potential for low carbon approaches to meet electricity needs. To put this potential into perspective, long-term targets call for emissions reductions below 2005 levels of slightly more than 40 percent by 2030 and 80 percent by 2050. Even assuming that all existing low carbon sources (about 30 percent of the current mix) have to be replaced by 2030, there is more than ample potential in the efficiency and renewables.

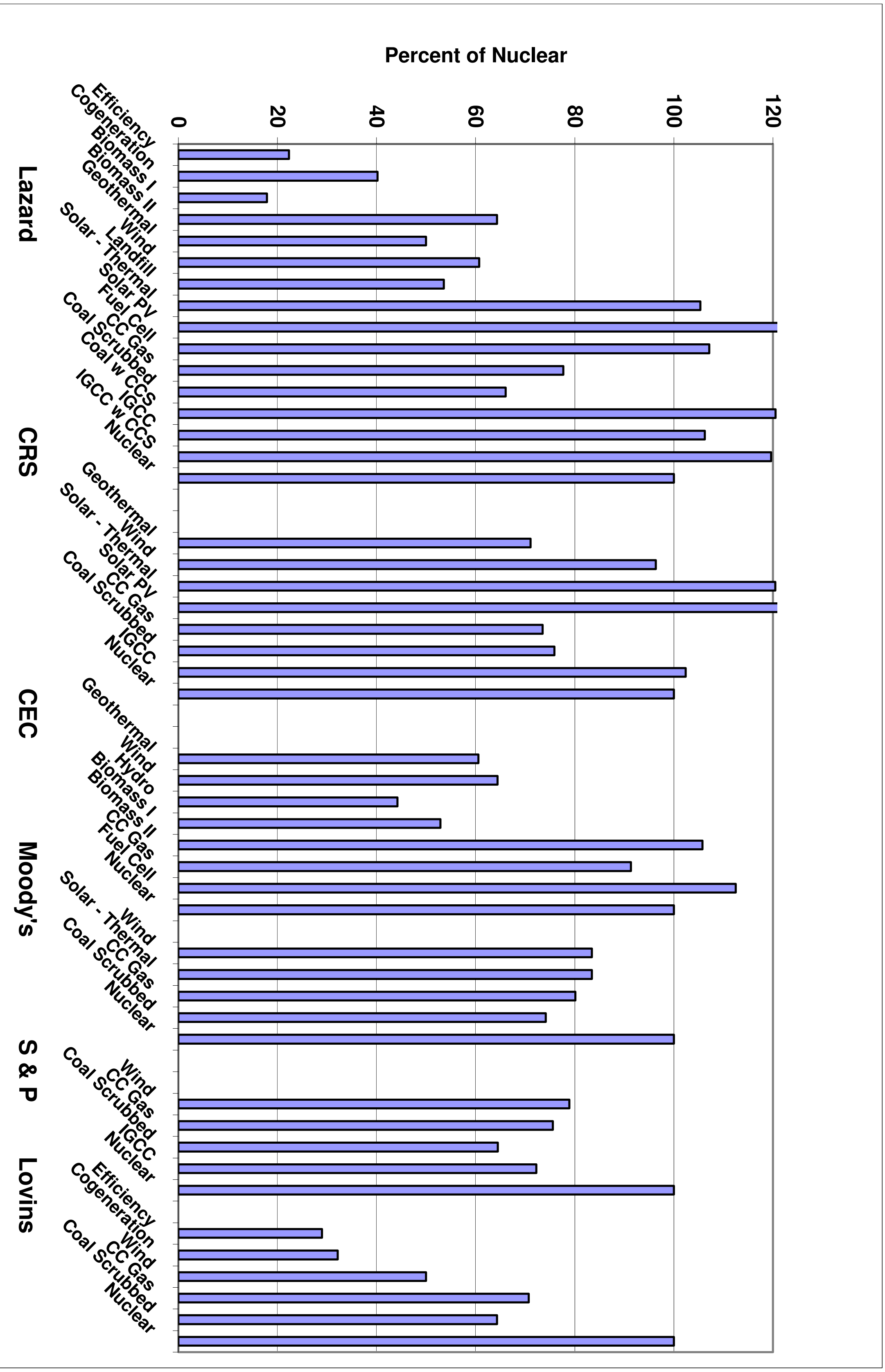
With continuing demand growth, it would still not be until 2040 that costly or as yet nonexistent technologies would be needed. Thus, pursuing these low cost options first meets the need for electricity and emissions reductions, while allowing time for technologies to be developed, such as electricity storage or carbon capture, that could meet electricity needs after 2040. The contending technologies that would have to be included in the long term are all shown with equal costs, above the technologies that have lower costs because it is difficult to project costs that far out in future and there will likely be a great deal of technological change before those technologies must be tapped to add substantial incremental supplies.

Meeting electricity needs
In addition to their cost, nuclear reactors possess two other characteristics that make them an inferior choice among the options available.

* The high capital costs and long construction lead times associated with nuclear reactors make them a risky source of electricity, vulnerable to market, financial, and technological change that strengthen the economic case against them.
* While nuclear power is a low carbon source of electricity, it is not an environmentally benign source. The uranium fuel cycle has significant safety, security, and waste issues that are far more damaging than the environmental impact of efficiency and renewables.

Figure ES-4 depicts three critical characteristics of the alternatives available for meeting electricity needs in a carbon-constrained environment. The horizontal axis represents the economic cost. The vertical axis represents the societal cost (with societal cost including environmental, safety, and security concerns). The size of the circles represents the risk. Public policy should exploit the options closest to the origin, as these are the least-cost alternatives. Where the alternatives are equal on economic cost and societal impact, the less risky should be pursued.

Figure ES-2: Busbar Costs of Alternatives by Estimating Entity (Nuclear Reactor Cost = 100 Percent)

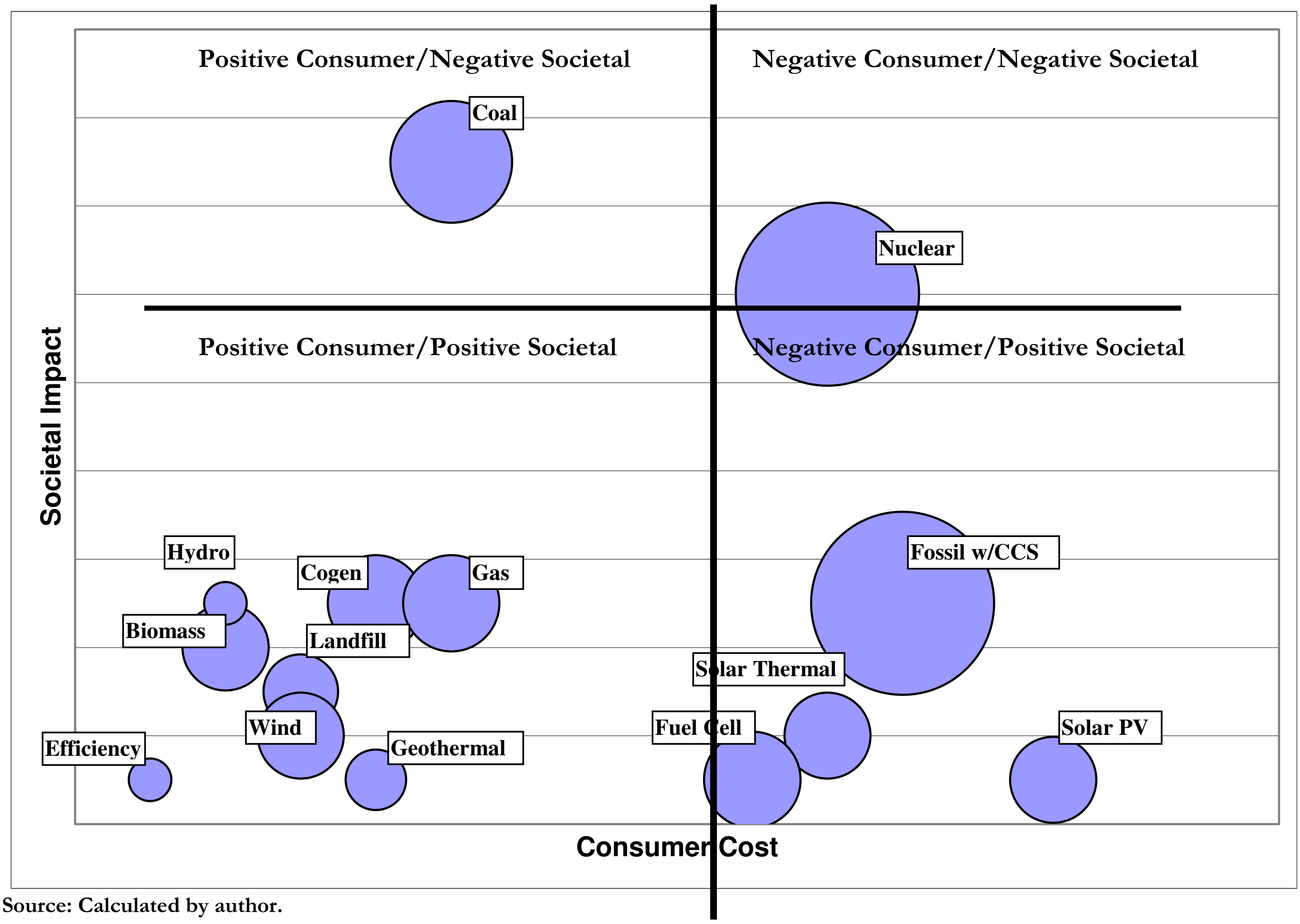


Sources: Lazard, Levelized Cost of Energy Analysis - Version 2.0, June 2008, p. 2; CRS: Congressional Budget Office, *Nuclear Power's Role in Generating Electricity*, May 2008; CEC: California Energy Commission, N.D. *Cost of Generation Model: User's Guide*, Version 1, N.D.; Moody's, *New Nuclear Generating Capacity: Potential Credit Implications for U.S. Investor Owned Utilities*, May 2008, p. 15.; Standard and Poors, *The Race for the Green: How Renewable Portfolio Standards Could Affect U.S. Utility Credit Quality*, March 10, 2008, p. 11.; Lovins Amory, and Imran Shiekh, and Alex Markevich, *Nuclear Power: Climate Fix of Folly?*, December 31, 2008.

Nuclear reactors are shown straddling the positive/negative line on societal impact. If the uranium production cycle - mining, processing, use and waste disposal - were deemed to have a major societal impact, nuclear reactors would be moved much higher on the societal impact dimension. If one believes that nuclear reactors have a minor impact, reactors would be moved down on the societal impact dimension. In either case, there are numerous options that should be pursued first.

Thus, viewed from a multidimensional perspective, including economic, environmental, and risk factors, there are numerous preferable alternatives.

Figure ES-4: A Multi-dimensional View of Alternatives (Size of Circles Denotes Risk)



Source: Calculated by author.

The impact of subsidies

As noted, nuclear reactors are very unlikely to be built without ratepayer and taxpayer subsidies. Many of the hope and hype analyses advance scenarios in which carbon is priced and nuclear reactors are the beneficiaries of large subsidies. Under those sets of extreme assumptions, nuclear reactors become less costly than fossil fuels with carbon capture and storage costs. However, they do not become less costly than efficiency and renewables. High carbon costs make efficiency and renewables more attractive.

Moreover, public policy has not tended to be quite so biased, although the supporters of nuclear power would like it to be. Imposing a price on carbon makes all low carbon options, including efficiency and renewables, more attractive as options. Subsidy programs tend to be applied to all low carbon technologies. As a result, although the carbon pricing and subsidy programs implemented and contemplated in recent years tend to impose cost on consumers or shift them from ratepayers to taxpayers; they do not change the order in which options enter the mix. In other words, given pricing and subsidies that simply values carbon emission or its abatement, the economic costs as estimated above dictate the order in which options are implemented. Nuclear reactors remain the worst option. It is possible to bias policies so severely that the order of priority changes, but that simply imposes unnecessary costs on consumers, taxpayers, and society.

Conclusion

The highly touted renaissance of nuclear power is based on fiction, not fact. It got a significant part of its momentum in the early 2000s with a series of cost projections that vastly understated the direct costs of nuclear reactors. As those early cost estimates fell by the wayside and the extremely high direct costs of nuclear reactors became apparent, advocates for nuclear power turned to climate change as the rationale to offset the high cost. But introducing environmental externalities does not resuscitate the nuclear option for two reasons. First, consideration of externalities improves the prospects of non-fossil, non-nuclear options to respond to climate change. Second, introducing externalities so prominently into the analysis highlights nuclear power's own environmental problems. Even with climate change policy looming, nuclear power cannot stand on its own two feet in the marketplace, so its advocates are forced to seek to prop it up by shifting costs and risks to ratepayers and taxpayers.

The aspiration of the nuclear enthusiasts, embodied in early reports from academic institutions, like MIT, has become desperation, in the updated MIT report, precisely because their reactor cost numbers do not comport with reality. Notwithstanding their hope and hype, nuclear reactors are not economically competitive and would require massive subsidies to force them into the supply mix. It was only by ignoring the full range of alternatives -- above all efficiency and renewables -- that the MIT studies could pretend to see an economic future for nuclear reactors, but the analytic environment has changed from the early days of the great bandwagon market, so that it is much more difficult to get away with passing off hope and hype as reality.

> The highly touted renaissance got a significant part of its momentum in the early 2000s with a series of cost projections that vastly understated the direct costs of nuclear reactors.

The massive shift of costs necessary to render nuclear barely competitive with the most expensive alternatives and the huge amount of leverage (figurative and literal) that is necessary to make nuclear power palatable to Wall Street and less onerous on ratepayers is simply not worth it because the burden falls on taxpayers. Policymakers, regulators, and the public should turn their attention to and put their resources behind the lower-cost, more environmentally benign alternatives that are available. If nuclear power's time ever comes, it will be far in the future, after the potential of the superior alternatives available today has been exhausted.

THE HIGH AND RISING COST OF NUCLEAR REACTORS

A- The range of current cost estimates

Table III-1 presents more than sixty estimates of nuclear reactor costs from over three dozen entities that have been published since 2001, when the nuclear industry first claimed a nuclear renaissance was imminent. The table shows the overnight, all-in, and busbar costs, where they are available, and attempts to impose order on the projections by stating costs in constant 2008 dollars, using the GDP deflator to restate the costs. When the dollar vintage was not specified in the study, it was assumed to be the year of the study. Figure III-1 shows the overnight costs for both the completed plants and the projections for future plants. The estimates are roughly equally divided between government consultants, utilities, government entities, utilities, and Wall Street/independent analysts, plus a small number of academic institutions. Many of the estimates are not very well explained or documented, while a few are analyzed in great detail.

Figure III-1: Institutional Origins and Levels of Recent Cost Projections

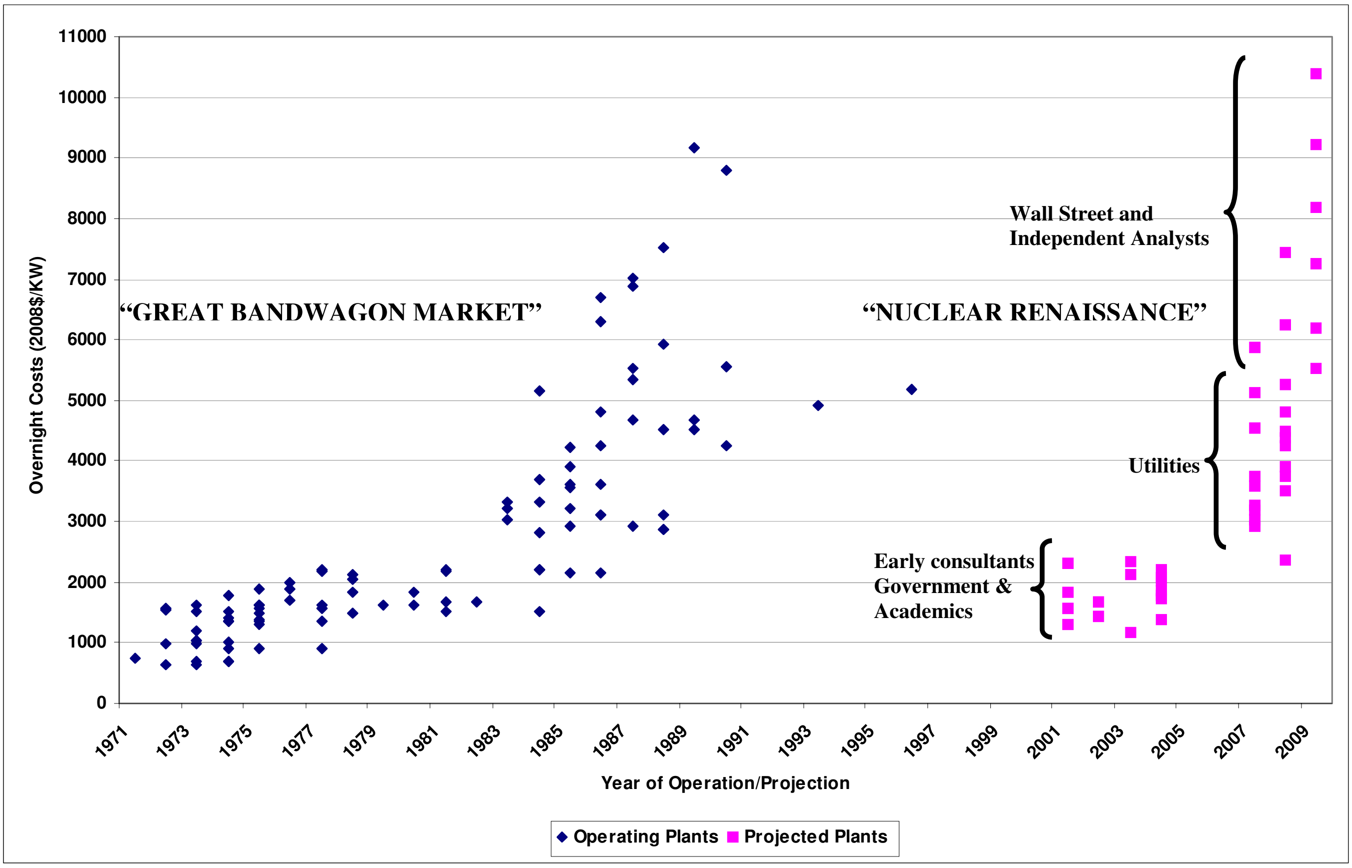


Table III-1: Estimates of Nuclear Reactor Overnight, All-in and Busbar Costs: 2001-2008

Original Estimate	Date of Estimate	Source of Estimate	Overnight Cost 2008$/kW			All-in Cost 2008$/kW			Busbar Costs (2008$/mWh)		
			Low	Mid	High	Low	Mid	High	Low	Mid	High
SAIC	2001	U of C	2300	2300	2300				75	81	89
SAIC	2001	U of C	1840	1840	1840				69	61	63
SAIC	2001	U of C	1570	1570	1570				53	56	63
SAIC	2001	U of C	1295	12995	1295				45	52	74
Scully	2002	U of C	1434	1434	1674				41	46	51
Sandia	2002	U of C	2131	2131	2131				68		95
EIA	2003	U of C	215	2015	2217				72		78
EIA	2003	U of C	1241	1563	1784				49		61
MIT	2003	MIT	1175	2350					65	79	
U of C	2004	U of C	1380	1725	2070				61	71	82
TVA	2005	TVA		1853							
CEC	2007	CEC		3021			3840			106	
Keystone	2007	Keystone	3018		3018	3653		4092	85		114
Harding	2007	Harding		3329		4349		4655	96		125
South Texas 3&4	2007	CRS	2931	3214	3754						
Turkey Point 3&4	2007	CRS	3179	3179	4644						
Calvert 3	2007	CRS		5778							
Levy 1&2	2008	CRS		4260							
Summer 2&3	2008	CRS		4387							
Vogtle	2008	GA PUC		4381			6447				
Callaway 1	2008			4250			6125				
Duke	2008	Lovins		4800							
S&P	2008	S & P		4100							
DOE Loans	2008	DOE					6528				
EIA	2008	EIA		3400							
CRS	2008	CRS		3900						83	
CBO	2008	CBO		2358						74	
Lazard	2008	Lazard	3750		5250	5750		7550	100		126
Moody's	2008	Moody's		6250			7500			151	
Severance	2008	Severance	6233	7440		8858	10553		250	300	
MIT II	2009	MIT		4092						86	
Bell Bend	2009	PPL			9375						
Harding - Medium	2009	Harding 09	5524	7263	9217				137	173	212
Harding - High	2009	Harding 09	6189	8184	10383				150	190	235

The projected costs have quickly escalated over the past decade. The low estimates from vendors, academics, and government agencies have approximately doubled. However, they remain below the estimates from many of the utilities and well below the estimates from Wall Street and independent analysts. Several aspects of the cost estimates are worthy of note.

* First, there has been a sharp increase in projected costs in a short period of time.
* Second, the early government and academic costs were quite low.
* Third, the recent utility cost estimates have doubled or tripled the first estimates but still tend to be lower than the estimates from Wall Street and the independent analysts.
* Fourth, the governmental entities tend to use the average of other analyses, particularly the utilities.
* Finally, the independent analysts tend to be the highest.

Even adjusting for inflation and stating all of the estimates in constant 2008 dollars, the projections are all over the map. However, it turns out that it is not very difficult to reconcile the estimates. A small number of variables account for the differences.

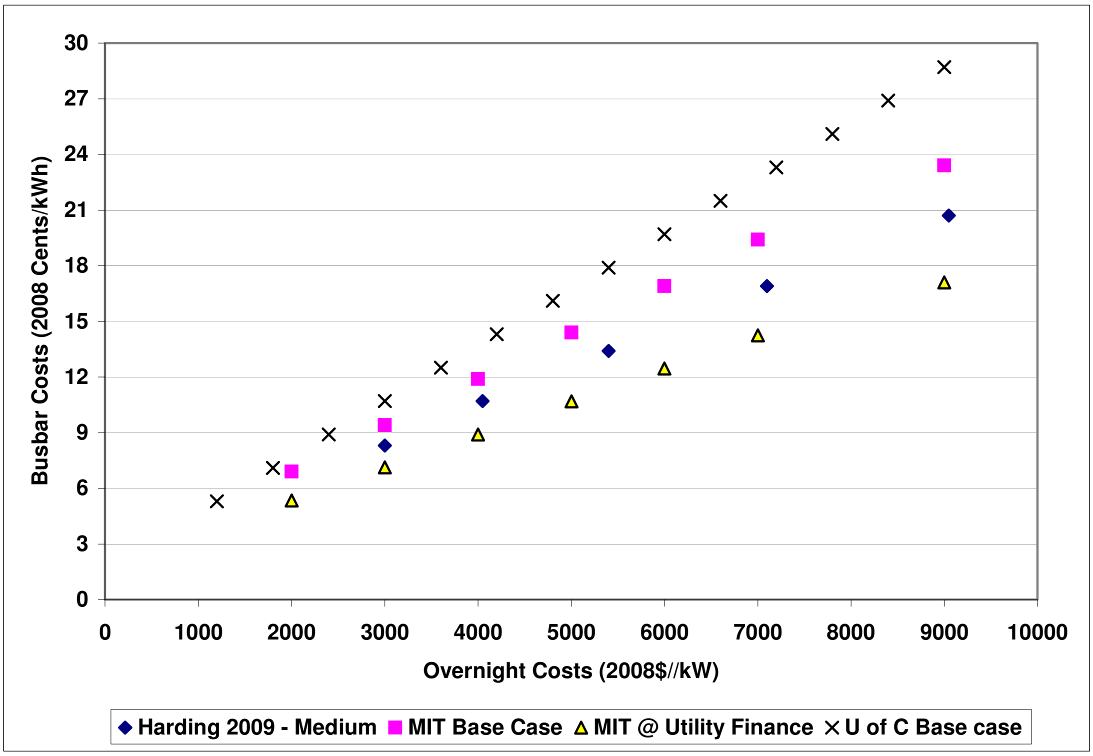
What these differences in estimates correlating with the type of institution making the estimate indicate is difficult to say. Utilities, especially in the early phase of the regulatory process, have an interest in understating costs, as long as the estimates are nonbinding. Low-balling the costs helps to get the power plant approved. In theory, Wall Street analysts are objective, but the recent crisis in the financial sector has called that into question. Wall Street analysts and rating agencies may have agendas related to their efforts to win clients.

B. Construction costs
Of the three dozen estimates included in Table III-1, several have publicly available and detailed documentation that enables us to isolate the key causes of differences in cost estimates. Most of the studies do not. Rather, they create high and low cost cases that assume different values for a number of variables simultaneously. These "high and low what if" scenarios may seem to bracket the range of possibilities, but if there is no reason to believe that the elements of the high or the low scenario should go together, the exercise may not be informative. It would be better to identify the individual impact of each cost element and project costs on a probabilistic basis.

B1. Overnight and busbar costs
Overnight costs are the single most important cost element. Overnight costs exhibit a strong direct relationship to busbar costs. Some of the studies provide a basis for describing the impact of overnight costs on busbar costs holding other elements constant. Figure III-3 graphs the results of four such studies. Each of the studies included in Figure III-3 provided a narrow range of overnight costs with which the effect of overnight costs on busbar costs can be estimated, holding all other things constant. Those projections have been extended over a wider range of overnight costs estimates to assess the magnitude of the effect of overnight costs on busbar costs across the studies.
The MIT model suggests that for every $1,000 of increased overnight costs, the busbar costs go up by 1.8 cents in the utility finance model and 2.4 cents in the merchant finance model. Moving from overnight costs of about $2,000 to about $7,000 raises the estimated busbar costs around 8 cents/kWh in the utility model and about 12 cents in the merchant model. In the Harding study, busbar costs go up about 2.4 cents per kWh for every $1,000 increase in overnight costs. In the University of Chicago study, the increase in busbar costs per $1,000 in overnight costs was 3.0 cents per kWh.

2. Financial models
There are two key elements that affect the extent to which financial costs magnify overnight cost differences. The higher the rate of return and cost of debt, the higher the financial costs. The larger the share of equity as compared to debt, the higher the financial cost.

Figure III-3: Reconciling Overnight and Busbar Costs of Selected Studies



Much of the impact of financial cost models can be encapsulated in the difference between utility and independent company finance. Some argue that independent power producers will build plants on a speculative basis.(*1) Others argue that only utilities will build them, and only with clear guidance to public utility commissions about needs and cost recovery.(*2) To date, the latter appears to be closer to the mark. Joskow and others do not believe that merchant nuclear reactors are very likely to be built, which is contrary to the assumption in the MIT analysis, so they applied a utility finance model to the MIT cost estimate. The Joskow numbers are shown in Figure III-3. With a lower cost of capital in utility finance version of the MIT analysis, nuclear reactors have lower capital costs and produce lower priced electricity.

The MIT model suggests that at $2,000 for overnight costs the difference between a utility and a merchant financial model is about 1.5 cents per kWh. The California Energy Commission Cost of Generation Model puts this figure at about 1.4 cents at an overnight cost of $2,950 per kW. As the overnight costs increase, the impact of the financial model is magnified. Thus, at $7,000 for overnight costs, the difference between the merchant and utility models in busbar costs is almost 5 cents per kWh.

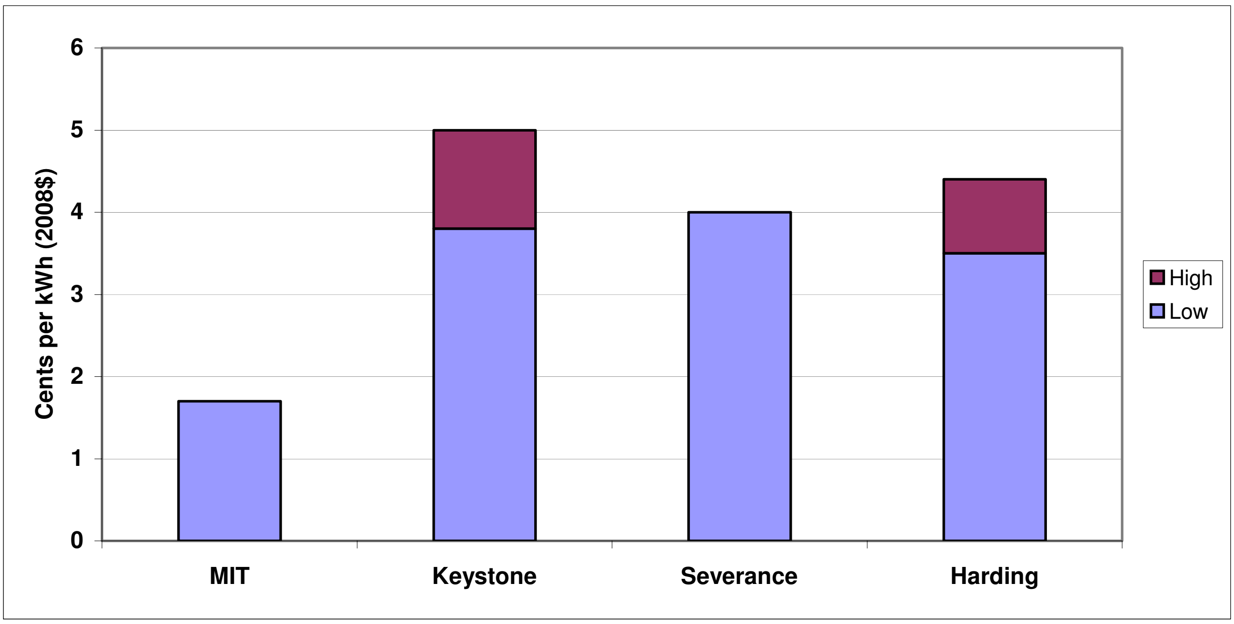
C. Operating costs

Another cost element that can easily be factored into the framework of this analysis is the operating and maintenance costs. While construction and capital costs tend to attract the most attention, operating costs are significant. The MIT study used a low operating cost (including fuel) that it admitted was optimistic.(*3) Others have estimated operating costs (including fuel) to be much higher (See Figure III-4). The difference is between about 1.5 cents per kWh to almost 3 cents per kWh. The Keystone base case for operation and maintenance costs (including fuel) was 2.1 cents higher than the MIT base case. Adding this operation and maintenance cost difference to the overnight costs in the MIT study, based on the utility finance model (which was the approach taken in the Keystone study), we largely resolve the difference between the projected busbar costs as shown in Figure III-5.

D. Escalators

This analytic exercise is just arithmetic until it is tied to real world causes. The MIT study started with low overnight costs (as hypothesized by the earlier Department of Energy funded studies) and then hypothesized ways overnight costs might decline.(*4) Many of the later studies derive their estimates by applying escalators to the early studies. In many of the studies since 2001, a wide range of overnight costs is presented as scenarios because there is uncertainty about construction costs, and construction costs have been rising.

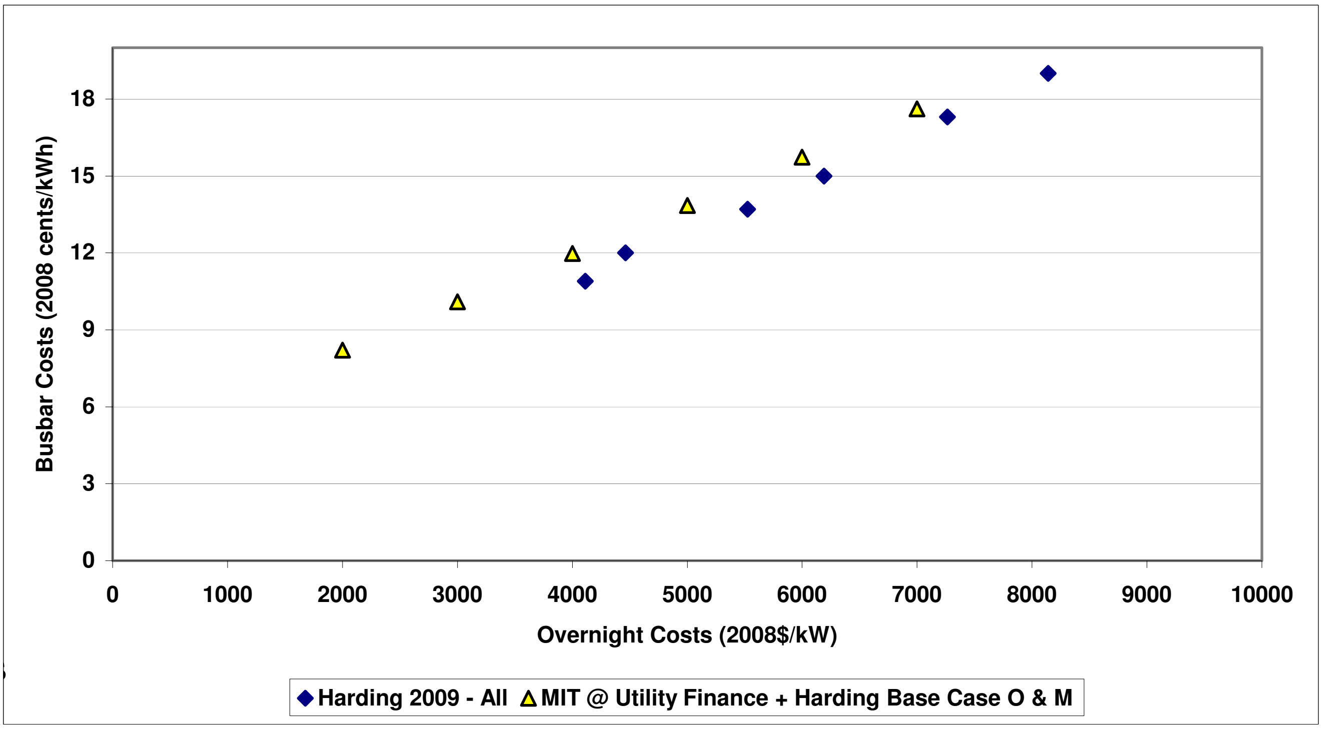
Figure III-4: Operating Cost Assumptions in Various Studies



Source: MIT, "The Future of Nuclear Power", 2003; Keystone Center, "Nuclear Power Joint Fact-Finding", June 2007; Severance, Craig A., "Business Risks and Costs of New Nuclear Power", January 2, 2009; Harding, Jim, "Economics of Nuclear Reactors and Alternatives", February 2009.

The choice of an escalation rate for costs is an effort to properly inject reality into the model. Many of the discussions of escalation refer to the Cambridge Energy Research Associated (CERA) index of power plant construction costs. Harding points out that the CERA index for nuclear plant escalation has been as high as 14 percent per year.(*5) Harding identifies four levels of escalation of costs: zero, 4%, 8%, and 14%. Harding's early analysis used the 4% figure and his later analysis argues that the 8% figure is closer to reality.(*6) He points out that the heavy construction cost index calculated by American Electric Power has been increasing at a rate of 10.5% per year. Thus, his conclusion that the 8% figure is a better basis for estimating overnight costs is moderate. In the Harding mid-scenario, the 8% escalation puts the overnight costs at $7,100 and the busbar costs at 17.3 cents per kWh. In the Harding high scenario, the 8% escalator yields overnight costs of $8,000 per kWh and busbar costs of 19.0 cents. Harding's high model with high escalation puts the cost in the range of 21.2 to 23.5 cents. The MIT model with utility costs and Harding O&M costs predict the same busbar costs as specific overnight costs. An update to the MIT study underscores how important these escalators can be.(*7) It cites the CERA index showing an increase in nuclear construction costs of 22.5% per year between 2002 and 2007, the years for which it estimated costs. However, it escalated costs at 15% per year to arrive at a cost of $4,000 in 2007 dollars, which results in a cost in the low end of recent estimates from utilities. If it had used the higher observed escalation rate for 2002-2007, it would have arrived at a figure that was about $1,500 per kW higher, or more than one-third higher.(*8)

Figure III-5: Reconciling Overnight and Busbar Costs Including O&M Adjustment



Similarly, Severance uses an 8.8% figure for escalation, which puts the overnight costs at $7,400 in his most likely case and the busbar costs at 25 cents per kWh. The Severance analysis yields high busbar costs because it includes two other costs not included in other analysis. Severance adds 2 cents for property taxes and 2 cents for decommissioning costs, which are higher costs than used by others. Excluding these, Severance's costs of 21 to 25 cents are close to Harding's high-end estimates (21.2 cents to 23.5 cents).

There are two different escalations that are being estimated in these studies. First is the increase in costs that is projected because of past escalation. Since many of the studies launch from the earlier low-ball estimates, they must deal with the increase in cost estimates that have already taken place. As the various cost indices suggest, that increase has already been substantial. Whether costs will continue to escalate in the future is a separate question.

The estimates by Florida Power and Light (FPL) illustrate this distinction. The non-binding cost estimate was derived by escalating and modifying the earlier cost estimate from TVA for its proposed Bellefonte reactors.(*9) Moving from a 2004 estimate to a 2007 estimate, the projected cost of the plant doubled in real terms, suggesting an extremely high rate of escalation of 25% per year.(*10) Looking forward, however, FPL projects only a 2.5% real rate of escalation to arrive at a mid-point overnight cost estimate of just under $3,600 per kW in 2007 dollars.(*11) FPL acknowledges that Moody's has questioned the low figures being used by utilities.(*12) If FPL used the rate of escalation of 8% for the next decade, its estimate would be well over $6,000, close to the number used by Moody's.

Ironically, much of the analysis in the early 21st century sought to explain how very low capital and busbar costs might come about, since the historical experience suggested much higher costs. More recent analysis has attempted to explain why the earlier cost estimates were too low and how quickly costs had escalated and could escalate in the future. The current estimates of construction costs, which are much higher than the early estimates, should not have been a surprise. They are perfectly consistent with the historical trend, as shown in Figure III-6.

There is a twist in the escalation of costs. The current recession has lowered material costs and reversed the dramatic upward trend in costs, but the CERA index shows only a moderate decline in the cost index.(*13) The index is down by less than 10%. However, utilities, whose cost estimates in 2007-2008 failed to reflect the full impact of prior cost escalation, are suddenly offering assurances that the slack markets caused by the recession will moderate future cost increases.(*14) They are admitting much higher numbers in their current statements than were used to launch their efforts to gain approval of the plants, but then attempting to cushion the impact with the assurance that declining commodity costs will lower costs. Although some have pointed out that commodity costs are a small part of total costs,(*15) the utility approach renders nuclear construction cost almost as volatile as fossil fuel prices, leaving one to wonder what will happen when the recession ends or if a flurry of orders puts pressure on prices.

E. Capacity factors and plant life

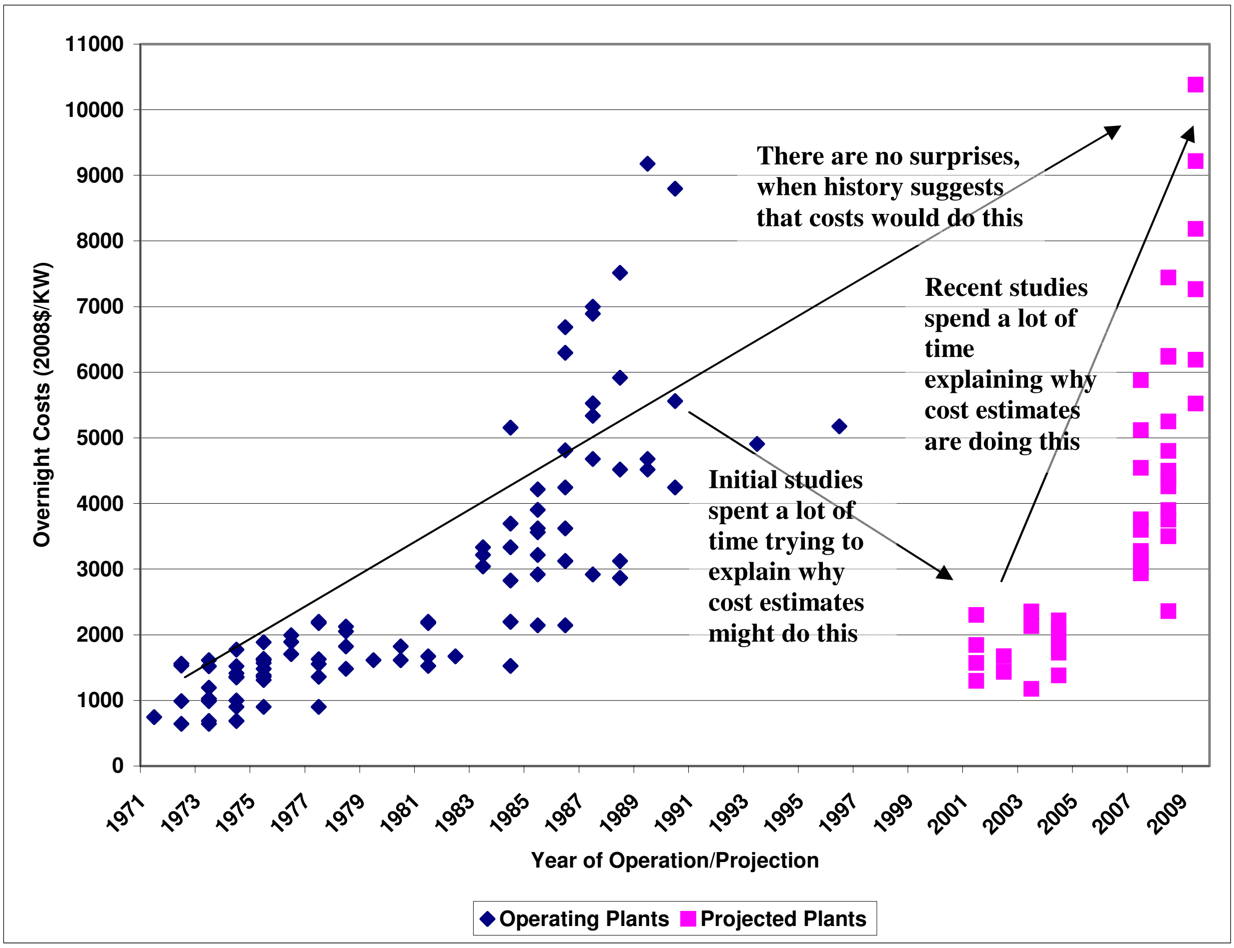
The methods used above to reconcile the differences between the various estimates have all relied on the base or mid-case estimates. We use these estimates for the comparative analysis because the studies' authors tend to run their scenarios as modifications of the base case. These base cases tend to use the high capacity factors and long facility lives that are observed at present, which is the end stage of the cohort of reactors.

“Capacity factors of 90% that are observed today took two decades to achieve. It may be a mistake to assume that new reactors will achieve those high capacity factors from day one.”

Capacity factors are an important assumption. Capacity factors of 90% that are observed today took two decades to achieve. It may be a mistake to assume that new reactors will achieve those high capacity factors from day one. In so far as the reactors and technologies are new and unique, there may be a substantial learning process before such high levels of reliability are achieved. The average capacity factor for reactors that have been operating in the U.S. is about 79%. The average for the reactor brought on line in the ten years between 1989 and 1999 is 88%.

Although capacity factors and reactor operating lifetimes do not have as dramatic an impact as the construction and capital costs, they are important. In the MIT study, with the base case assumption of a 40-year life for the reactor, decreasing the capacity factor from the base case assumption of 85% to 75% increases the busbar cost from 7.7 cents (2008 $) to 8.6 cents. Assuming the 85% base case capacity factor, lowering the lifespan of the reactor from 40 years to 25 years increases the cost from 7.7 cents to 8.6 cents. The worst case considered by MIT (75% capacity/25-year life) had a busbar cost of 9 cents, compared to the base case of 7.7 cents. The Keystone study varied both lifespan and capacity factor together. Moving

Figure III-6: Price Trajectories and Explanations



from the base case of 40-year life and 90% capacity to the worst case, 30-year life and 75% capacity, raised the busbar cost from 9.7 cents to 11.4 cents. The busbar costs are higher in the Keystone study in large part because the overnight costs were assumed to be higher, as shown above in Table III-1.

This review can be used to suggest the impact of various key variables that affect the cost of nuclear reactors, although a range of projected costs will not be specified until the history of the industry is reviewed in more detail in the next section. Here the relative importance of each of the key factors in the general context of a move from overnight costs of $2,000 to overnight costs of $7,000 can be explored. The analysis must start with the range of overnight costs because the impact of the financial and plant characteristic assumptions varies depending on those costs. Starting from the MIT utility model, adding $5,000 of overnight costs would add about 9.6 cents per kWh to the estimate. In the merchant model it would add 1.5 to 3 cents per kWh. Assumptions about plant life and capacity factors could add another 1.7 to 3.4 cents per kWh. O&M costs are independent of the other costs, but the difference between the studies runs in the range of 2 cents. Given these large differences in cost projections, it is easy to reconcile the low 5.2 cents per kWh estimate of a utility finance model based on the MIT 2003 overnight costs to the high estimate of 16 cents per kWh, based on the CEC utility finance model. Starting at 6.1 cents in Joskow's application of the utility model to the MIT base case, adding 9.6 cents for an additional $5,000/kW of overnight costs and 2.1 cents for operation and maintenance costs would yield an estimate of 17.8 cents, just above Harding's estimate of 17.3 cents.

THE PAST AS PROLOGUE: THE PERSISTENT UPWARD SPIRAL OF NUCLEAR REACTOR

A. The vexing history of nuclear reactor costs

The current cost controversy cannot be fully comprehended without placing it in the context of the history of reactor costs in the U.S. The cost of electricity generated by nuclear reactors in the United States has been a vexing problem for almost half a century.(*16) Touted as producing power that would be "too cheap to meter,"(*17) 240 reactors were ordered in about a decade from the late-1960s to the late-1970s.(*18) If all of the reactors had been completed on time, well over half of all power generated in the U.S. by the mid-1980s would have been from nuclear reactors.(*19)

Things did not work out that way. The "great bandwagon market" for nuclear reactors, as it came to be known, sputtered badly. Construction delays and cost overruns, as well as regulatory changes, drove the cost of reactors up dramatically.(*20) "Too cheap to meter" quickly became "too expensive to build." More than half of all the orders for reactors were cancelled. Many of the projects had incurred significant costs,(*21) setting up lengthy fights over who should pay for facilities that were never used to supply electricity.(*22) The cost overruns were also reviewed in lengthy, contentious state regulatory prudence proceedings, where the failures of management to control costs and to provide power at as reasonable cost were investigated.(*23) As a result, no orders for nuclear reactors were placed in the U.S. after 1977. The last reactor brought on-line in the U.S. was completed in 1996. Construction on that reactor had begun in 1974.

The vexing nature of the cost of nuclear reactors has reemerged in what is now being called the "nuclear renaissance." Less than a decade after the last reactor was brought on-line, nuclear reactors were back in the news and at the center of public policy debates with calls for large subsidies to promote nuclear technology. Along with a number of other factors, very low cost estimates put forward by the industry and academics and funded by the Department of Energy helped to create the illusion of a nuclear renaissance. Those studies certainly gave the Department of Energy an opportunity to broadcast headlines such as "University of Chicago: Nuclear Power Competitive with Coal & Natural Gas."(*24) The initial cost projections, however, have not held up.

Much like the initial cost projections from the earlier round of nuclear reactors, projected costs escalated rapidly. By 2008, projected costs were three to four times higher than the initial cost projections in 2001-2004. Estimates that had put the cost of nuclear reactors as low as 6 cents per kilowatt hour (kWh) have been joined updated by estimates that put it as high as 30 cents.

Placing the ongoing conflict over projections of nuclear reactor costs in historic perspective takes on special importance. The management failure that Forbes refers to was much more than just the inability to execute massively complex construction projects. It was, first and foremost, a failure of analysis, a failure to distinguish hope and hype from reality.

For nearly a quarter of a century the theology of nuclear power - unchallenged and unchallengeable - was accepted by a variety of diverse interests to advance a variety of diverse causes. Rarely did those who seized on nuclear power as a means to their ends know its

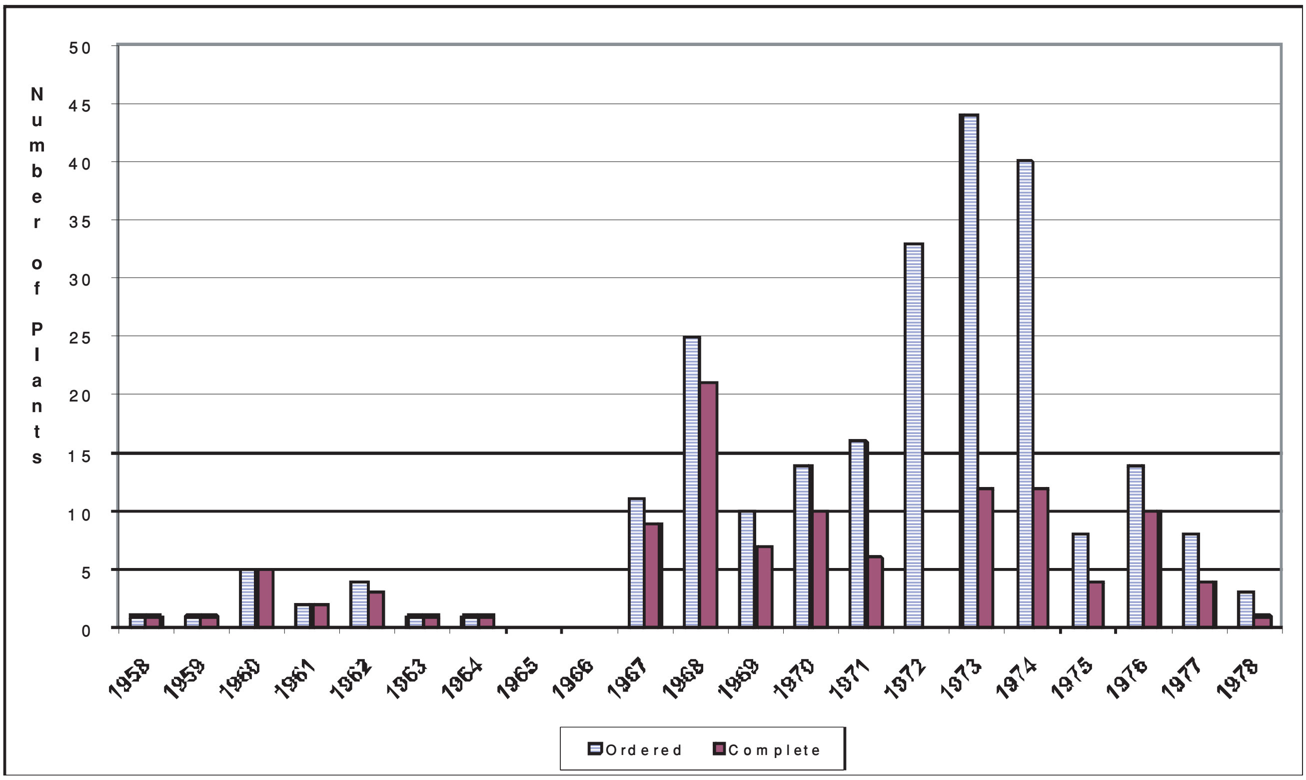
> "Rarely did those who seized on nuclear power as a means to their ends know its actual economic and technical status. Instead, the information available to them was part of a catechism whose basic function was to answer infidels and sustain the faith of the converted."

actual economic and technical status. Instead, the information available to them was part of a catechism whose basic function was to answer infidels and sustain the faith of the converted. The result, a circular flow of self-congratulatory claims, preserved the discrepancy between promise and performance.

Systematic confusion of expectation with fact, of hope with reality, has been the most characteristic feature of the entire 30-year effort to develop nuclear power.
The identification of promise with performance began in the United States. The economic "analyses" which controlled discussion during the critical early years of light water commercial sales had nothing to do with the detached confrontation of proposition with evidence which we think of as analysis. The public agencies with putative responsibility for facing the facts had neither the means nor the motivation to respond critically to the nuclear industry's propaganda; they could only sanctify it. This they did with notable eagerness.(*25)

B. Too cheap to meter becomes too expensive to build
The rapid escalation of cost projections for new reactors in recent years raises major concerns, especially in light of the history of cost escalation in the nuclear industry. The last time the industry tried to ramp up production in the U.S., costs skyrocketed. From the mid-1960s to the mid-1970s, a small number of turnkey reactors were brought on-line. From the mid-1970s onward, more than 200 reactors were ordered, but half of them were never completed (see Figure IV-1).

Figure IV-1: History of Reactor Orders and Cancellations



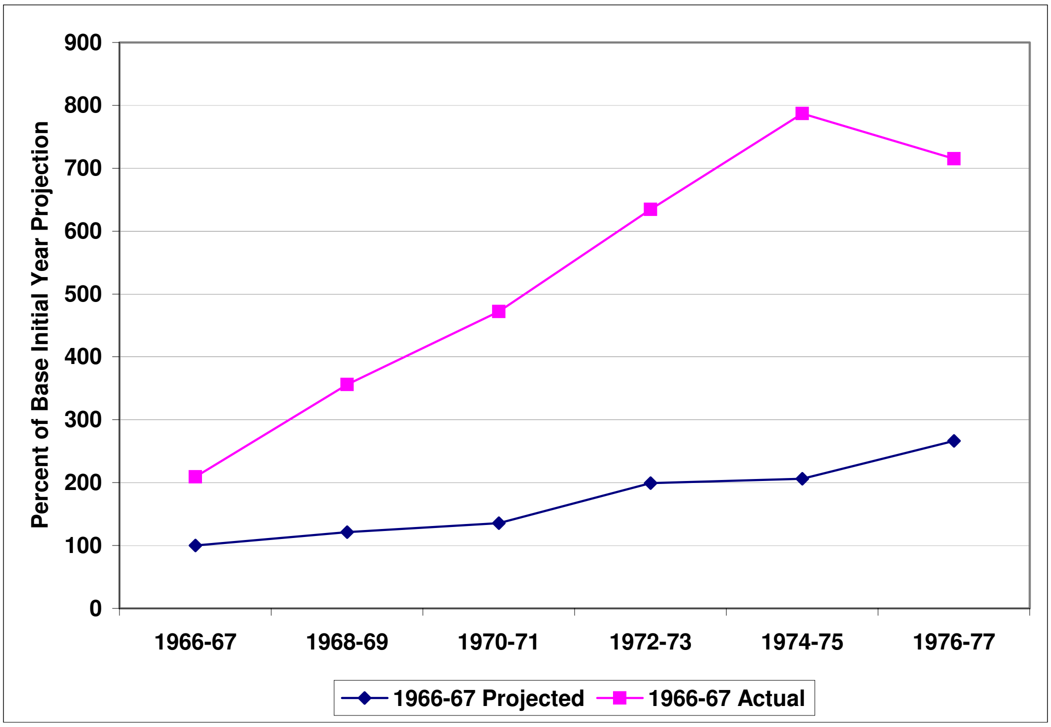
Source: Completed: Koomey, Jonathan, and Nathan E. Hultman, *"A Reactor Level Analysis of Busbar Costs for US Nuclear Plants, 1970-2005,"* Energy Journal, 2007.; Cancelled: *"Cancelled Nuclear Units Ordered in the U.S."*, http://clonemaster.homestead.com/files/cancel.htm

The reactors that did make it on-line proved to be much more costly than originally projected. Figure IV-2 shows the increase in projected and actual costs by the date of commencement of construction for completed reactors, expressed as a percentage of the projected cost of the initial reactors. That is, Figure IV-2 uses the projected costs of the 1966-1967 reactors as the base and expresses all future projections and actual costs as a percentage of that base. This captures the fact that not only were projected costs increasing, but actual costs were increasing faster than projected costs.

The reactors commenced in 1966-1967 actually cost twice as much to build as originally estimated. The reactors commenced in 1968-1969 were projected to cost slightly more than the reactors commenced in 1966-1967, but they actually cost over three times as much as the projected costs of the reactors commenced in 1966-1967. Performance got worse, not better, over the decade.(*26)

The learning that usually lowers initial costs has not generally occurred in the nuclear power business. Contrary to the industry's own oft-repeated claims that reactor costs were "soon going to stabilize" and that "learning by doing" would soon produce cost declines just the opposite happened. The magnitude of cost underestimation was as large for reactors ordered in the early 1970s as it had been for much earlier commercial sales.(*27)

Figure IV-2: Actual and Projected Capital Costs by Date of Commencement of Construction, Completed Reactors

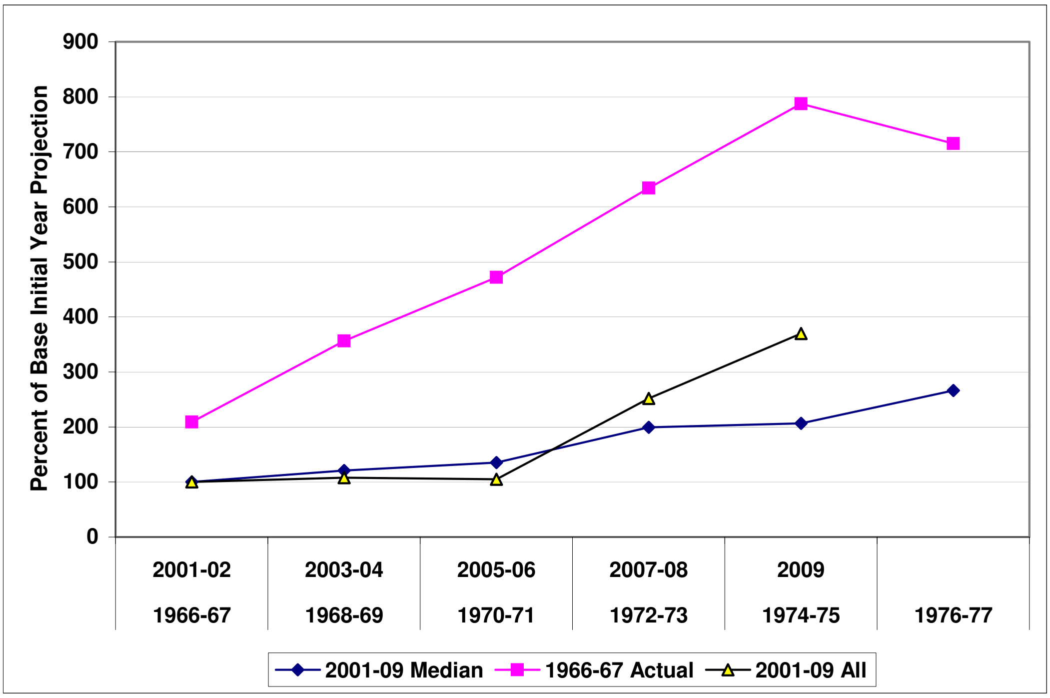


Source: Energy Information Administration, 1996, *"An Analysis of Nuclear Power Plant Construction Costs, January 1, 1986".*

On average, the actual costs for each reactor were almost three times higher than the original projection for that reactor. The final cohort of reactors cost seven times as much as the projected cost of the original cohort. In short, the first round of nuclear reactors went quickly from being "too cheap to meter" to being "too costly to build."

Figure IV-3 overlays the recent cost projections on the historical pattern completed reactor costs. It uses the estimates from 2001 as the base and then expresses all subsequent estimates as a percentage of that base. For each of the two year cohorts the graph shows two projections, one based on the average of the mid-point estimates for all of the studies completed in that year; the other based on the average of all projections in that two year cohort. The initial 2001-2002 midpoint estimates averaged about $1,761 per kW. The initial 2001-2002 estimates for all projections were about $1,775 per kW. The midpoint and the all estimates track closely until 2009, when a number of high estimates pull the all estimate average up. The estimate based only on midpoints for 2009 was $6,500. The estimate based on all projections for 2009 was over $8,000. Interestingly, one of the high estimates for 2009 comes from an independent analyst and one comes from a utility. The increase in projected prices falls about half way between the projections from the 1960s and 1970s and the actual increases in that period.

Figure IV-3: Actual and Predicted Capital Costs, Completed Reactors, and Projected Costs of Future Reactors



Source: Energy Information Administration, 1996, *"An Analysis of Nuclear Power Plant Construction Costs, January 1, 1986".*

C. The importance of construction periods

In the 1960s and 1970s, one of the major causes of the cost increases and missed projections was the inability of the industry to deliver reactors on time (*see Figure IV-4*). Large capital costs, sitting on the books, generated capital charges and a rate shock when the utilities finally finished the reactor. These charges cumulate, creating more and more expensive power.

By the end of the

construction cycle that was started in the 1960s, the projected construction time increased by 50%, from just over 4 years to just over 6 years -- but actual construction periods were almost 10 years. In other words, actual construction time at the end of the cycle was more than twice as long as the original projection. The correlation between construction periods and overnight costs is strong for both completed reactors and projections for future reactor costs.
For the completed plants the length of the construction period explains just over half the variance in overnight cost projections. For the future projections, the length of the construction period explains almost two thirds of the variance in overnight cost projections.

We are now witnessing a dispute over the projected construction periods. Some analysts project construction periods of five or six years, while others project construction periods of ten years or more.(*28) Figure IV-7 shows the year-by-year construction expenditures in two recent studies with longer construction periods. Severance is for a two-unit project; Moody's is for a single unit.

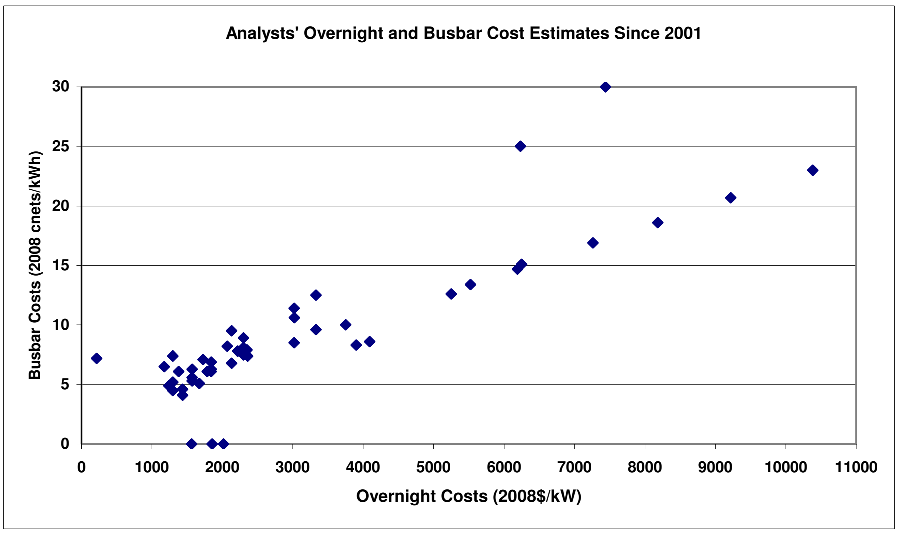
D. A range of cost estimates
Given this history, the initial low cost projections and their recent updates should be viewed with suspicion. Figure IV-8 shows the relationship between overnight and busbar costs for two different sets of cost estimates in the "nuclear renaissance" period. The bottom panel presents the estimates since 2008. The two low cost estimates can be readily explained. The CRS study relied on the utility overnight costs and then applied a utility finance model. The MIT II study is the update of the 2003 MIT study, which was optimistic then and remains so. Wall Street and independent analysts provide much higher estimates. The high outliers are from the Severance study. The exhibit also includes an estimate of busbar costs based on the CEC utility cost of generation model.

The relationship between overnight costs and busbar costs is predictable. The MIT and CRS estimates appear to be low both because the overnight estimates are low and because they translate overnight costs into busbar costs at a lower rate. With overnight costs of about $4,000, the busbar costs in the CEC model are about 12 cents per kWh. The MIT II and CRS costs are about 3.5 cents lower. Thus, 12 cents per kWh would appear to be a lower bound. The Moody's estimate of about 15 cents is the midpoint. Harding's 2009 mid-estimate is 17.3 cents. Several of Harding's 2009 estimates are above 20 cents. Even adjusting for the unique costs that Severance includes, his estimates are above 20 cents as well. The range of reasonable estimates appears to be 12 cents to 20 cents, with a mid point of 16 cents.

E. Conclusion
The 1960s and 1970s may seem like ancient history, but the new proposed cohort of reactors could easily be afflicted with the same problems of delay and cost overruns. Inherent characteristics of large complex nuclear reactors make them prone to these problems. Reactor design is complex, site-specific, and non-standardized. In extremely large, complex projects that are dependent on sequential and complementary activities, delays tend to turn into interruptions. Inherent cost escalation afflicts mega projects, a category into which nuclear reactors certainly fall.(*29)

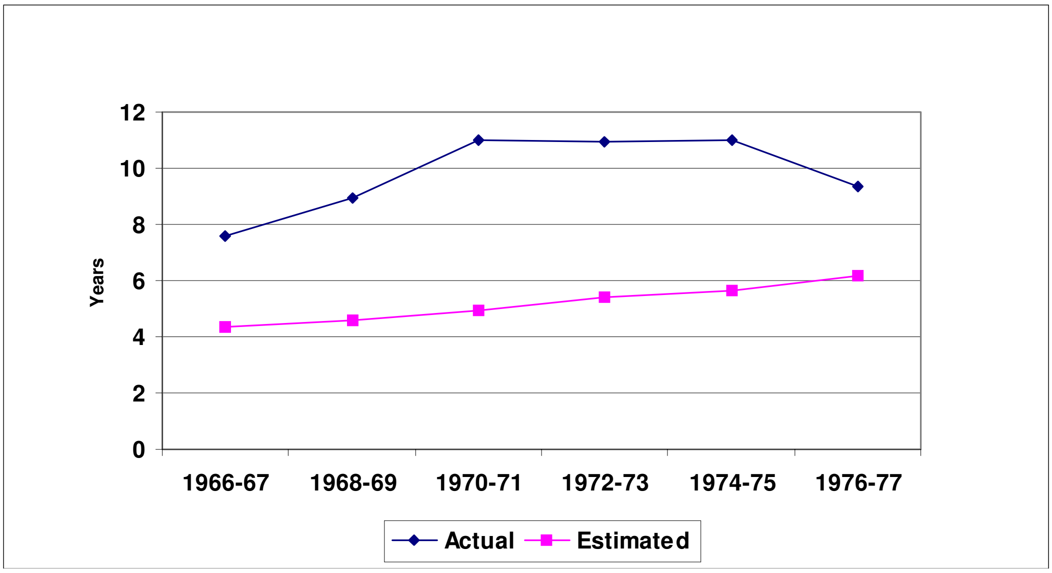
The endemic problems that afflict nuclear reactors take on particular importance in an industry in which the supply train is stretched thin. Material costs have been rising and skilled labor is in short supply. These one of a kind, specialized products have few suppliers. In some cases, there is only one potential supplier for critical parts. Any increase in demand sends prices skyrocketing. Any interruption or delay in delivery cannot be easily accommodated and ripples through the implementation of the project.(*30)

Figure IV-8: Analysts' Overnight and Busbar Costs



The severe difficulties of Finland's Olkiluoto nuclear reactor being built by Areva SA, the French state-owned nuclear construction firm, provide a reminder of how these problems unfold.(*31) Touted as the turnkey project to replace the aging cohort of nuclear reactors, the project has fallen three years behind schedule and more than 50% over budget.(*32) The delay has caused the sponsors of the project to face the problem of purchasing expensive replacement power; the costs of which they are trying to recover from the reactor builder. The cost overruns and the cost of replacement power could more than

Figure IV-4: U.S. Nuclear Reactor Construction Periods



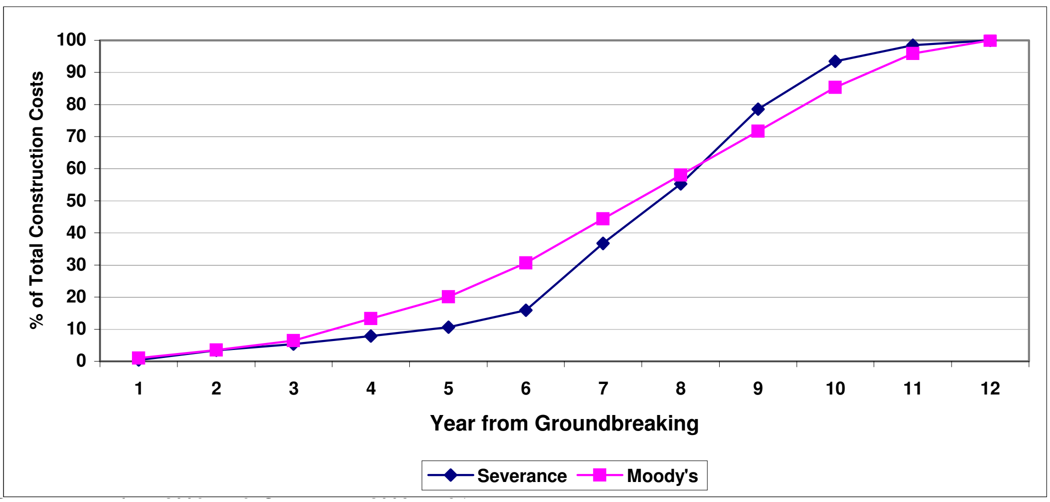
Source: Nuclear Energy Economics and Policy Analysis, *"The Effects of Inflation in Engineering Economic Studies"*, February 18, 2004.

double the cost of the reactor.(*33)

A description of the process by which the U.S. ended up with hundreds of reactors that were "too expensive to build," written in 1978, before the accident at Three Mile Island changed the terrain of nuclear reactors in the U.S., bears an eerie resemblance to the past decade in the U.S.:

> At the beginning of 1970, none of the plants ordered during the Great Bandwagon Market was yet operating in the United States.
>
> This meant that virtually all of the economic information about the status of light water reactors in the early 1970s was based upon expectation rather than actual experience. The distinction between cost records and cost estimation may seem obvious, but apparently it eluded many in government and industry for years…
>
> In the first half of this crucial 10-year period, the buyers of nuclear power plants had to accept, more or less on faith, the seller's claims about the economic performance of their product. Meanwhile, each additional buyer was cited by the reactor manufacturers as proof of the soundness of their product…The rush to nuclear power had become a self-sustaining process...
>
> There were few, if any, credible challenges to this natural conclusion. Indeed, quite the contrary. Government officials regularly cited the nuclear industry's analyses of light water plants as proof of the success of their own research and development policies. The industry, in turn, cited those same government statements as official confirmation. The result was a circular flow of mutually reinforcing assertion that apparently intoxicated both parties and inhibited normal commercial skepticism about advertisements which purported to be analyses. As intoxication with promises about light water reactors grew during the late 1960s and crossed national and even ideological boundaries, the distinction between promotional prospectus and critical evaluation become progressively more obscure.

Figure IV-7: Construction Expenditures across Time



Source: Moody's, *"New Nuclear Generating Capacity: Potential Credit Implications for U.S. Investor Owned Utilities"*, May 2008. p. 8; Severance, Craig A., *"Business Risks and Costs of New Nuclear Power"*, January 2, 2009. p. 35.

From the available cost records about changing light water reactor capital costs, it is possible to show that on average, plants that entered operation in 1975 were about three times more costly in constant dollars than the early commercial plants competed five years earlier.(*34)

The similarities between the great bandwagon market and the nuclear renaissance, and the fact that utilities not only steadfastly refuse to accept the risk of cost overruns but also are demanding massive taxpayer and ratepayer subsidies to build the next generation of reactors, should give policy makers pause. The one major difference between the great bandwagon market and the nuclear renaissance is that there has been an extensive challenge to the extremely optimistic cost estimates of the early phase, a challenge from Wall Street and independent analysts. It may be impossible to escape the uncertainty of cost estimation, but it is possible to avoid past mistakes.

Reflecting the poor track record of the nuclear industry in the U.S., the debate over the economics of the nuclear renaissance is being carried out before substantial sums of money are spent. Unlike the 1960s and 1970s, when the vendors and government officials monopolized the preparation of cost analyses, today Wall Street and independent analysts have come forward with much higher estimates of the cost of new nuclear reactors. And, because the stranglehold of the vendors and utilities on analysis has been broken, the current debate includes a much wider range of options.

As important as bad analysis was, it might have had little impact if it had not been combined with another critical mistake. The nuclear reactor vendors had delivered a small number of reactors at fixed prices and eaten massive cost overruns. After a few loss leaders were delivered, they shifted tactics. Unwilling and unable to sustain those losses, as the Forbes article put it,

> the Great Bandwagon Market was impelled by evangelisms, optimism and seemingly irresistible economics… But the suppliers had learned their lesson. The new generation of plants would be built under reimbursable-cost-plus-fixed-fee contracts. Without that, the nuclear power program would probably have sputtered out in the mid-Seventies, when cost lurched out of control.(*35)

The contemporary policy debate takes the effort to insulate utilities from the high cost of nuclear reactors even farther. In addition to a broad range of general subsidies and the cost plus rate treatment, they are seeking large federal loan guarantees and treatment by state public utility commissions that would grant preapproval and recovery of construction costs.

Doubts about nuclear renaissance, even in nuclear industry.

There are some uncomfortable feelings in the nuclear industry surfacing, regarding the pace and results sofar of the 'nuclear renaissance'. In the latest edition of the IAEA Bulletin (May 2009), Sharon Squassoni concludes: "A nuclear renaissance would require significant changes by both governments and multinational agencies as well as aggressive financial support." And just read for example the first lines of this article in the June issue of Nuclear News, the monthly magazine of the American Nuclear Society.

“Longtime readers of *NuclearNews* may have watched with some bemusement over the past few years as the ‘Renaissance Watch’ summation in the Power section has grown from a modest sidebar to a sprawling two-page spread. In this issue-and, the editors hope, *only* in this issue-the summation has been enlarged further to allow some issues to be addressed at greater length, along with the usual updates on specific projects. In what was supposed to be a streamlined, straightforward process for design approval and licensing, under 10 CFR Part 52, nearly every initiative has taken on unintended complexities. Industry leaders have long bemoaned ‘regulatory uncertainty’ (in day-today operations as well as in license applications), but there are sources of uncertainty in virtually every aspect of the new-reactors endeavor.

In the past few months in particular, the actions of state governments have had great influence on new reactor projects. In the abstract, there seems to be a trend in favor of nuclear power, but in practical terms, efforts to remove reactor bans or encourage nuclear development in places such as Kentucky and West Virginia, where there are no current plans by electricity providers to build reactors, are less significant than rate recovery proposals. Georgia has approved rate recovery, so Vogtle-3 and -4 are on track; Missouri has not, so Callaway-2 has been suspended. Other recent state-level actions include the rejection (for the fifth time) of a bill introduced in the California legislature by Assemblyman Chuck DeVore to repeal the state's new-reactor ban, and a split between the two houses of the Minnesota legislature on a proposed ban repeal.”

The article concludes (in the lead): *"State governments, federal agencies, reactor vendors, license applicants, and the economy are all contributing to the air of doubt surrounding new reactor projects in the United States."*

The whole article can be found at: http://www.new.ans.org/pubs/magazines/download/a_632

Endnotes:

(*1) MIT, 2003: "The Future of Nuclear Power", uses merchant financing for nuclear reactors and utility financing for coal and natural gas. Joel Klein, 2007: "Comparative Costs of California Central Station Electricity Generation Technologies Cost of Generation Model", ISO Stakeholders Meeting Interim Capacity Procurement Mechanisms, October 15, models merchant, investor owned utility, and publicly owned utility financing for all technologies.

(*2) Joskow, Paul: "Prospects for Nuclear Power a U.S. Perspective", May 19 2006

(*3) The MIT update appears to forget that the operating costs assumptions were optimistic, far lower than the estimates of other studies and then it lowers it operating cost estimate even further. In essence, it has double counted the optimism. The original study said, we expect/hope that O& M costs will decline so we will use a low number. The later study says, see, operating costs at existing plants have gone down, so we will lower the number some more.

(*4) MIT, 2003. All of the scenarios involved cost reductions. No cost increases were considered.

(*5) Harding, Jim, "Economics of Nuclear Reactors and Alternatives", February 2009.

(*6) Harding, 2009, p. 5, "utility data suggests 8% real might be more realistic."

(*7) Du Yangbo and John E. Parsons, 2009: "Update on the Cost of Nuclear Power", Center for Energy and Environmental Policy Research, May 2009. p.17

(*8) The study is much more optimistic about the construction cost of nuclear reactors than about the construction cost of coal plants. In the case of nuclear, it assumed an escalation rate that was far below the escalation in the most frequently cited cost index. On the other hand, it assumed an escalation for coal slightly above the escalation for non-nuclear plant construction costs in that index. The potential distortion that results is striking. Differential Assumptions about Capital Costs:

	Base 2003	Updated Cost at	Full Index
	xAssumption	Assumption	Escalation
Nuclear	2000	4000	5520
Coal	1300	2300	2080

(*9) TVA later demurred from building this reactor, Brewer, David, "Bellefonte not Picked for Nuclear Pilot Project", Huntsville Times, May 1, 2009.

(*10) This is slightly above the rate of increase observed by MIT 2009 for the same period.

(*11) Scoggs, Steven, 2009, "Direct Testimony", In Re: Florida Power & Light Company's Petition to Determine Need for Turkey Point Nuclear Units 6 and 7 Electrical Power Plan, Florida Public Service Commission, October 16, 2007. Exhibit SD-8.

(*12) Scoggs, 2007, p. 47.

(*13) The HIS/CERA Power Plant Capital Cost index shows a decline of 5 percent in the most recent quarter.

(*14) Electric Utility Week, May 25, 2009, reporting costs for the V.C. Summer nuclear reactors as high as $12.5 billion compared to the cost laid before the South Carolina PUC of $9.8 billion, with assurances that declines in commodity prices will return the reactor to its original estimate; Thomas Content, "Nuclear Plant Foes Prepare for Fight; Groups Rail at Lobbying to Change Moratorium", Milwaukee Journal Sentinel, May 23, 2009, reporting prices having risen as high as high as $71,000 per KW then falling back to $4,138.

(*15) Keystone Center, 2007, "Nuclear Power Joint Fact-Finding", June 2007; Harding, 2007.

(*16) Bupp, Irvin C. and Jean-Claude Derian, "Light Water: How the Nuclear Dream Dissolved", New York: Basic Books, 1978: Komanoff, Charles, "Power Plant Escalation: Nuclear and Coal Capital Costs, Regulation, and Economics", Van Nostrand, 1981.

(*17) Attributed to Levi Straus in 1954. See Ford, Daniel, "Cult of the Atom", New York, Simon and Schuster, 1982. See also Makhijani, Arjun, "Carbon-Free and Nuclear-Free", IEER Press, 2007, Appendix A; Smith, Brice, "Insurmountable Risk", IEER, Press, 2006, Chapter 1.

(*18) Koomey, Jonathan, and Nathan E. Hultman, 2007, "A Reactor Level Analysis of Busbar Costs for US Nuclear Plants, 1970-2005", Energy Journal, 2007.

(*19) In 1990, nuclear reactors accounted for approximately 20 percent of all generation. If all the cancelled plants had been completed, the amount of capacity that nuclear reactors would have represented would have been 2.5 times as great.

(*20) Komanoff, 1981, Chapter 6.

(*21) See Kopolow, Doug, "Nuclear Power in the U.S.: Still Not Viable Without Subsidy, Nuclear Power and Global Warming Symposium", November 7-8, 2005, for nuclear; Kopolow 2006, "Subsidies in the U.S. Energy Sector: Magnitude, Causes and Options for the Future, Subsidies and Sustainable Development: Political Economy Aspect" (OECD, 2007) for a comparison across energy sectors; and Kopolow 2009 "Subsidies to Nuclear Power in the United States: The Case of Calvert Cliffs Unit III, Costing Nuclear Power's Future", February 11, 2009, for the discussion of a specific reactor. See Schlissel, David, Michal Mullett and Robert Alvarez, "Nuclear Loan Guarantees: Another Taxpayer Bailout Ahead", Union of Concerned Scientists, March 2009, for a discussion of pending loan guarantees.

(*22) Tomain, Joseph, P. 1988, Nuclear Power Transformation, Bloomington: Indiana University, 1988.. Federal Reserve Board of New York, 1984, "Nuclear Power Plant Construction: Paying the Bill," Quarterly Review, Summer 1984.

(*23) Tomain, 1988.

(*24) United States Department of Energy, "Nuclear Power Competitive with Coal and Natural Gas", September 20, 2004.

(*25) Bupp, Irvin C. and Jean-Claude Derian, "Light Water: How the Nuclear Dream Dissolved", New York: Basic Books, 1978, pp. 188-189.

(*26) Bupp and Derian, 1978, pp. 78-79 see this as an important indication that learning was not taking place.

(*27) Bupp and Derian, 1978, pp.71… 72…74…75…76…78…79.

(*28) For example contrast Severance, Craig A. "Business Risks and Costs of New Nuclear Power", January 2, 2009. and Moody's, "New Nuclear Generating Capacity: Potential Credit Implications for U.S. Investor Owned Utilities", May 2008., v. MIT, "The Future of Nuclear Power", 2003. and University of Chicago, "The Economic Future of Nuclear Power: A Study Conducted at the University of Chicago", August 2004.

(*29) Interestingly, during the 1970s, large, complex software programs suffered similar problems. As programs grew larger and more complex, they began to bog down. Throwing more programmers at the problem did not solve the problem and the dilemma came to be known as the "Mythical Man Month." The solution was to modularize, standardize, and offer smaller programs. The nuclear industry has attempted some of these fixes, but the nature of the projects simply does not allow similar changes.

(*30) Harding, Jim, "Economics of Nuclear Power and Proliferation Risks in a Carbon-Constrained World", Public Utilities Fortnightly, December 2007, p. 72

(*31) Areva's difficulties are not limited to this plant, Schneider, Mycle, "Nuclear France Abroad: History, Status and Prospects of French Nuclear Activities in Foreign Countries", May 2009.

(*32) International Herald Tribune, "France: Areva Profit Falls Due to New Reactor," February 25, 2009.

(*33) Kanter, James, "Not So Fast, Nukes: Cost Overruns Plague A New Breed of Reactor", New York Times, May 29, 2009.

(*34) Bupp and Derian, 1978, pp.71…72…74…75…76…78…79.

(*35) Cook, James, "Nuclear Follies", Forbes, February 11, 1985.

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The Nuclear Information & Resource Service was founded in 1978 and is based in Washington, US. The World Information Service on Energy was set up in the same year and houses in Amsterdam, Netherlands. NIRS and WISE Amsterdam joined forces in 2000, creating a worldwide network of information and resource centers for citizens and environmental organizations concerned about nuclear power, radioactive waste, radiation, and sustainable energy issues.

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Mark Cooper. Reproduced with his kind permission. Dr. Cooper is Senior Fellow for Economic Analysis at the Institute for Energy and the Environment at Vermont Law School, USA.
Although the report is focusing on the United States, the situation in other countries is not different from the experiences in the US.
The boxes are written by WISE Amsterdam.

The full report is online available at:
http://www.vermontlaw.edu/Documents/Cooper%20Report%20on%20Nuclear%20Economics%20FINAL[1].pdf

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