Will Low Natural Gas Prices Eliminate the Nuclear Option in the US?

A probabilistic comparison of the investment risks of nuclear power and natural gas-based electricity generating plants has been carried out using a total-lifecycle power plant model. Although the cost of the gas plant (with carbon tax) is found to be slightly cheaper, that choice of fuel carries a far greater cost uncertainty, suggesting a greater long-term investment risk than nuclear power.

By Rob Graber and Tom Retson

This study is intended to compare the cost of electricity from natural gas and nuclear power taking each technology's inherent risks into account. There is investment risk inherent in both technologies, but from different sources. The risk of nuclear power resides in uncertain capital costs. For natural gas, the risks are from the uncertain forward cost of natural gas and the potential for environmental compliance costs, primarily from the emissions of greenhouse gases (principally CO_2). Because of these uncertainties it is more revealing to use risk-adjusted (probabilistic or stochastic) forecasts of the comparative costs of electricity. These estimates show the probable range of costs for both technologies, given the uncertainties described above. The costs used are the levelized costs of generating electricity (LCOE).[1] The results were obtained using the EnergyPath Market Model (EPMM), which simulates the operation of electric generating plants, in part, to calculate the LCOE (see Appendix A for a description of EPMM). Since the newest technology nuclear plants are designed to be licensed for 60-year lifetimes, and natural gas generating plants have 30-year lifetimes, it was necessary to assume that the first gas unit (Unit 1) was retired after 30 years and a second unit (Unit 2) was constructed. Other Key Assumptions are shown in Table 1 below. Assumptions used for the risk assessment study are shown in Appendix B.

Table 1: Key Assumptions used in study ($2012)

		Nuclear	Natural Gas (CCGT)
Capital Costs	$/KW$_e$	$5,000	Unit 1: $1107 Unit 2: $2045
O&M	$/KW$_e$/yr	$75	$30
Capital Improvements	$/KW$_e$	$20 per fuel reloading	$10 per year
Fuel Costs (2012)		Uranium: $48/lb U_3O_8 Conversion: $11/KgU Enrichment: $132/SWU Fabrication: $336/KgU	Natural Gas: $4.35/mmbtu
Heat Rate	Btu/KW$_e$h	10,400	6700
Carbon Tax	$/Ton CO_2		$25

[1] Levelized costs are useful as comparisons of costs between generating technologies. They can be thought of as the equivalent annual cost incurred over the life of the generating technology having the same present value as actual costs which differ from year to year.

The results are shown in Figure 1 and 2, below. Figure 1 shows that the expected levelized generating cost of nuclear power over its 60-year lifetime to be about $87/MWh (all figures are in 2012 dollars). There is a 5% probability that the actual realized generating cost will exceed $99/MWh and a 5% probability that the realized generating costs will be below about $77/MWh. Stated equivalently, there is a 90% probability that the realized generating cost will be between $77/MWh and $99/MWh - a range of $22/MWh.

Figure 1: Levelized Cost of Nuclear Power Plant ($/MWh) ($2012)

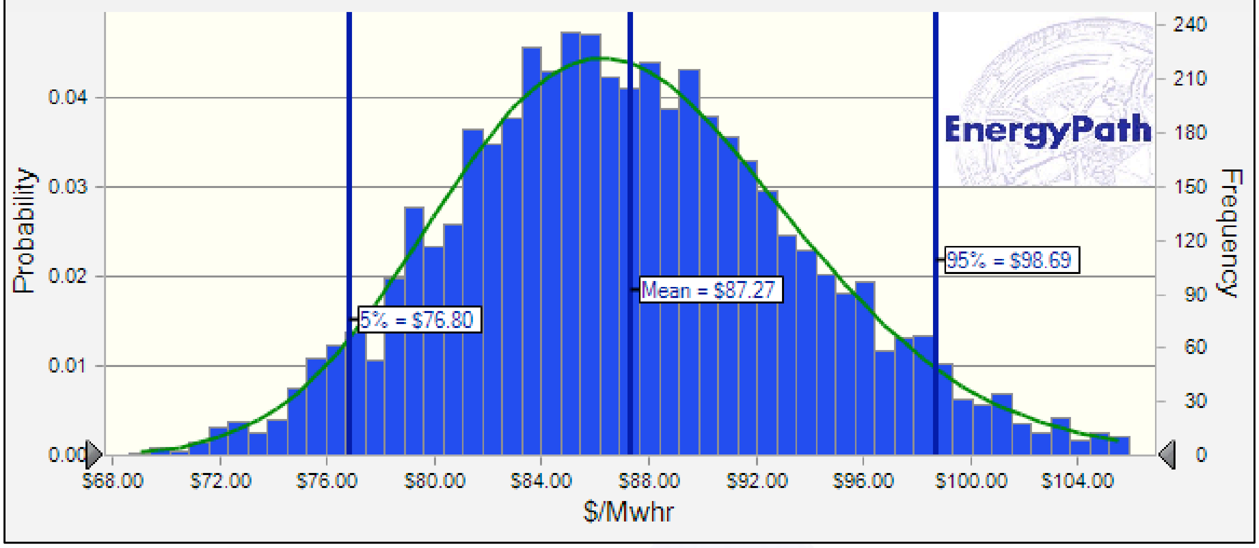
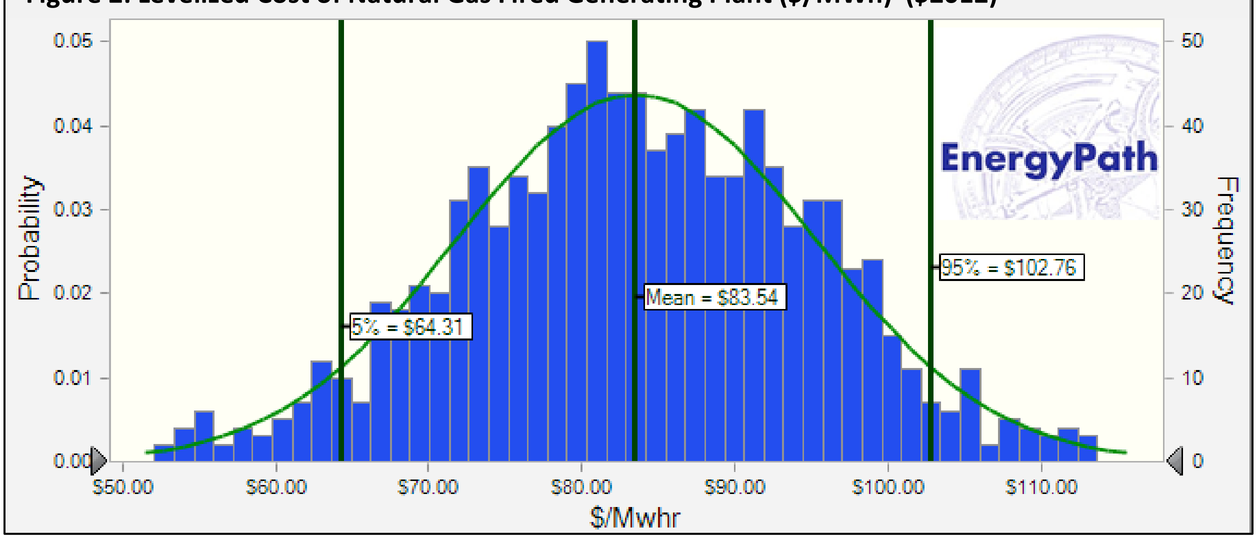


Figure 2, is the same comparison for a high efficiency natural gas plant using a combined cycle technology (and including a carbon tax). Because a second natural gas unit was assumed to be constructed after 30 years, this, introduces the prospect of the second plant having a higher capital cost than the first unit. This was accounted for by assuming that that the capital cost of a natural gas plant grows by 2% per year (in real dollars).

Figure 2: Levelized Cost of Natural Gas Fired Generating Plant ($/MWh) ($2012)



In the case of natural gas the expected value of generation is about $84/MWh, lower than for the nuclear plant. However, the range of uncertainty is higher for the natural gas plant. In this case the 90% probability range is over $38/ MWh, or nearly twice the range of the nuclear plant. This is the result of the volatility of natural gas over a long time frame and *implies a greater investment risk if a natural gas plant is chosen over a nuclear plant (*as will be discussed below*).*

This is one key result for this study; but perhaps more important, not only is the investment risk higher, *all the risk occurs after the build decision is made*. Thus, natural gas plant investors are in the position of having to manage fuel and potential environmental compliance costs for 60 years after the plant is constructed. To illustrate this point more dramatically, Figure 3 shows the risks associated with a nuclear plant in the post- build decision period. The uncertainty range now has been reduced to about $4/MWh, which represents the risk of nuclear fuel cost increases. The reason for this result is that nuclear fuel costs comprise only about 10% of the levelized cost of generating electricity from a nuclear plant. For natural gas, the cost of natural gas comprises 60% or more of the levelized generating cost.

From an investor's standpoint all the risk of a nuclear plant is in the build decision and can be managed with contractual arrangements between investors and the plant suppliers before any major costs are expended. Unlike the previous generation of nuclear plants which experienced significant cost overruns due to a flawed licensing process (particularly following the Three Mile Island nuclear accident in 1979) and led to major rate implications for electric utilities bearing the financial risk, arrangements in today's nuclear markets place the majority of risk on the plant supplier, providing investors with greater certainty about final construction costs they will bear. In addition, there is a new US licensing process that combines the construction and operating license into a single process, further enhancing investor security.

This brings into play the ultimate risk management tool: withdrawal or delay the project. As a risk management tool this option is unavailable to natural gas plant investors as nearly all the risk occurs after plant construction costs are sunk.

Figure 3: Risk Characteristics for Nuclear Plant in Post-build Decision Period ($/MWh) ($2012)

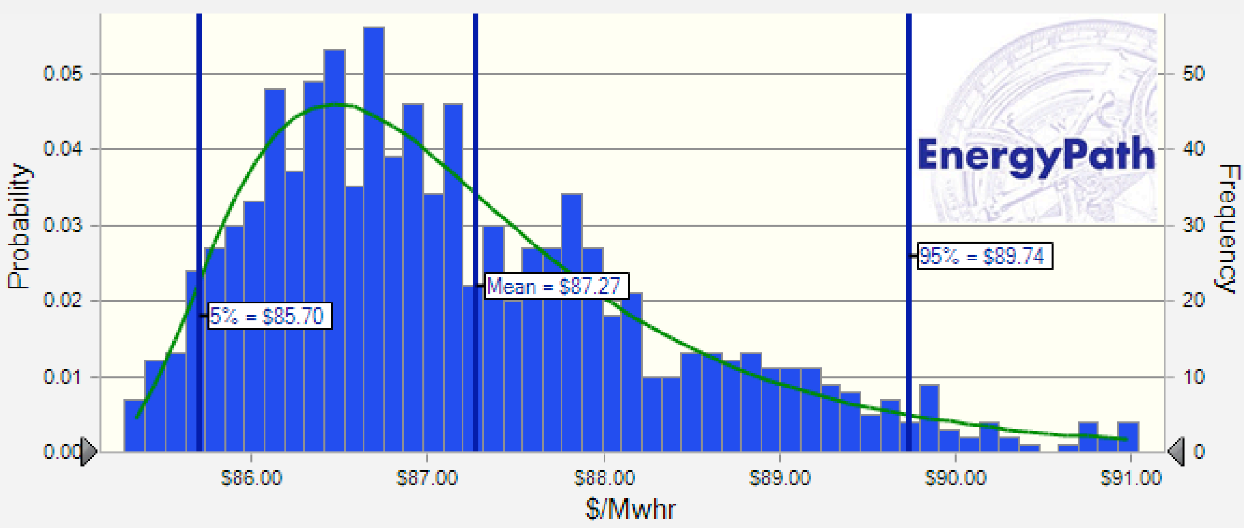


Table 2, below illustrates typical results obtained using only the static (non-simulated) LCOE.[2] There are two columns for natural gas, showing the costs both with and without environmental compliance costs - in this case a $25/ton CO_2 carbon tax beginning in 2020. This chart clearly shows the tradeoff between capital costs and variable costs (fuel and environmental compliance) between nuclear and natural gas plants. But more important, it illustrates the risks of relying on static LCOE results. The contrast between the risk-adjusted results in Figures 1 through 3 and the point values of results in Table 2 is stark. It is particularly dangerous when making generating technology decisions owing to their dependence on a commodity with a market-derived price over a very long time. This is particularly true for natural gas exposed to not only supply and demand; but also the potential for climate change initiatives directed at carbon-emitting fuels.

Table 2: Cost Components of Levelized Costs ($/MWh) ($2012)

Cost Component ($/MWh)	Nuclear	Natural Gas (No Environmental cost)	Natural Gas (With $25/Ton CO_2)
Capital	$ 57.78	$ 12.72	$ 12.72
O&M	$ 10.03	$ 3.46	$ 3.46
Fuel	$ 5.55	$ 46.99	$ 46.99
Taxes[3]	$ 9.79	$ 10.39	$ 10.39
Decommissioning	$ 1.46	-	-
Waste Disposal	$ 1.00	-	-
Environmental Compliance	-	-	$ 9.80
TOTAL	**$ 85.61**	**$ 73.55**	**$ 82.35**

The price of natural gas delivered to US electric utilities in 2012 was approximately $4.35/mmbtu. However, this price is unsustainable as it is below the average cost of producing shale gas – currently the major source of new drilling in the US-estimated at between $5-8/mmbtu[4]. While the prospects that shale gas will extend the supply of natural gas are positive, like any commodity the cheapest and most easily mined supply will be produced first. Further, LNG facilities in the US, once constructed to import LNG, are being converted into export facilities as natural gas prices measured in US dollars are as high as $16.50/mmbtu in Japan and $9.00/mmbtu in the UK[5]

[2] By "static results" it is meant that EPMM used only deterministic input and did not run in the simulation mode. For instance a single capital cost was used instead of a probabilistic capital cost. When EPMM is in simulation mode it draws a sample from the probabilistic capital cost input (and all other probabilistic inputs) and calculates an LCOE for each simulation. The LCOE output is thus probabilistic also.

[3] Includes both sales taxes and income taxes

[4] See, for example, Berman, A.E. and Pittinger, L.F., "US Shale Gas: Less Abundance, Higher Cost", The Oil Drum (www.theoildrum.com/node/8212 , August 5, 2011. Berman and Pittinger contend that the breakeven cost of shale gas is currently between $5-$8/mmbtu and that production from shale gas wells is declining faster than predicted.

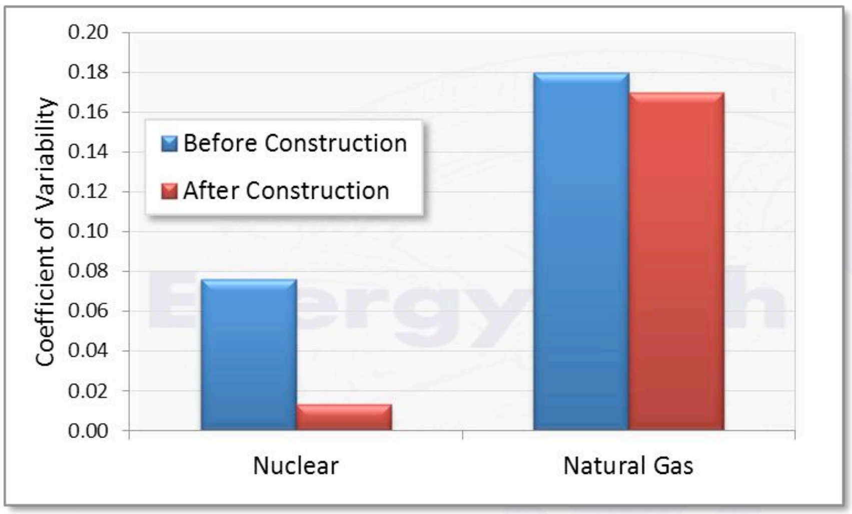
[5] BP (British Petroleum), "Energy Outlook 2030, Statistical Review of World Energy 2012", Natural Gas Prices http://www.bp.com/sectiongenericarticle800.do?categoryId=9037181&contentId=7068643 .

A single metric can be useful in summarizing these results – the coefficient of variability (COV). The coefficient of variability is defined as

$$\text{COV}=\frac{\text{Standard Deviation}}{\text{Mean}}$$

The coefficient of variability measures the amount of risk (standard deviation) that an investor has to bear in order to get the expected levelized costs (mean). The higher the coefficient of variability, then, the riskier is the project to investors. The COV results for the cases described above are shown below in Figure 4. As shown, nuclear power represents a significantly smaller financial risk relative to natural gas, and particularly so after construction.

Figure 4: Coefficient of Variability



It may be argued that decommissioning also represents a higher risk for investors in the case of nuclear power. However, this is already accounted for in Figures 1 and 3, and moreover, investors have possibly up to 80 years before the decommissioning decision must be made-resulting in an annuity that is easily managed.

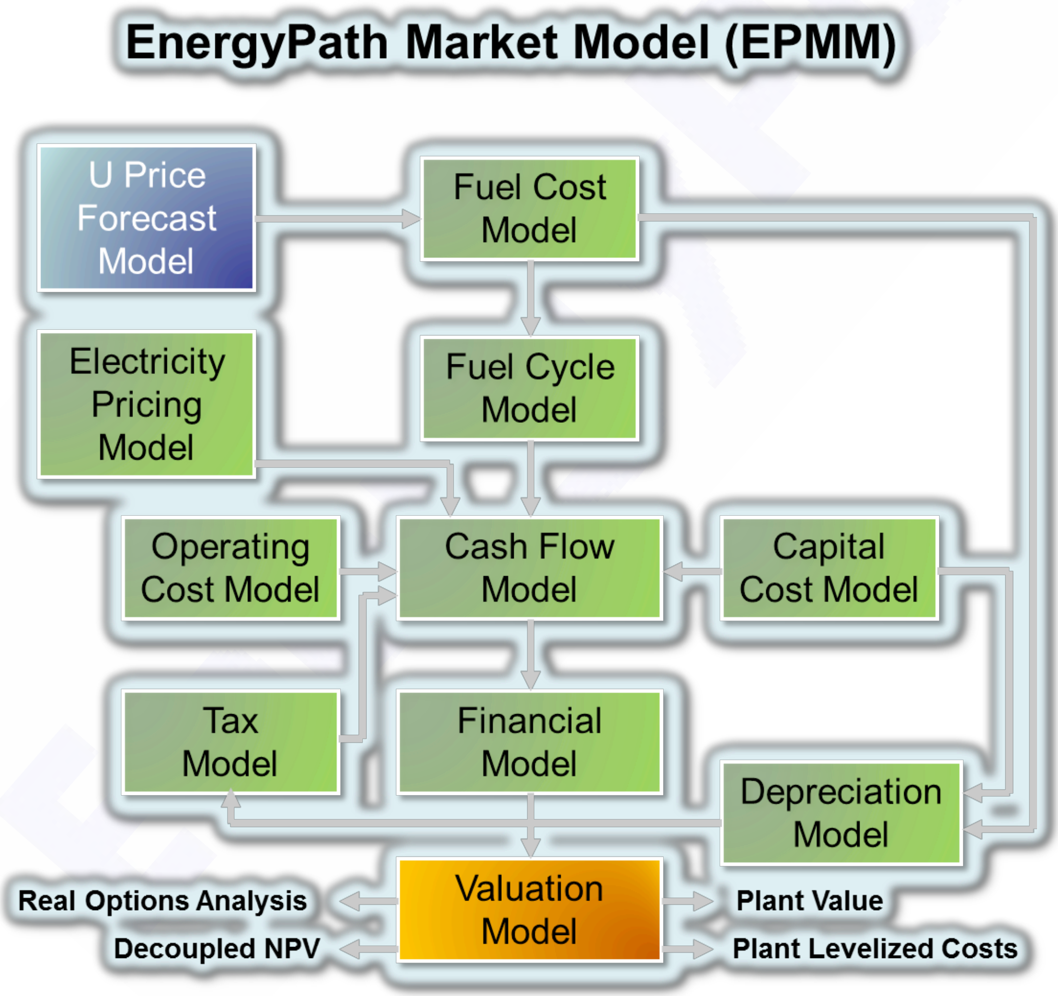
These results are being validated in real life. In March, 2012 the US Nuclear Regulatory Commission awarded combined construction and operating licenses (COL) to two privately-owned nuclear plants in the Southeast US: the Vogtle 3 & 4 units owned by Southern Company and the Summer 2 & 3 units owned by South Carolina Electric and Gas. (First nuclear concrete has recently been poured for Summer 2 and Vogtle 3.) Both utilities obtained regulatory approval from their respective state regulatory bodies, largely on the basis of fuel diversity. It was precisely a reluctance to develop additional gas resources on the very basis that it left both companies vulnerable to increased fuel and regulatory compliance costs that was instrumental in choosing nuclear—in spite of considerable opposition from parties opposed to nuclear power. While coal would have been an option, both utilities already have substantial coal capacity and there is warranted anticipation that coal will be increasingly targeted by the US Environmental Protection Agency for stringent emissions controls, including, potentially, controls on CO_2 emissions. A third utility—Florida Power and Light—is likely to also be granted a COL for the construction of Turkey Point 5 & 6, and FPL has made exactly the same fuel diversity case to the Florida Public Service Commission. All of these regulatory agencies feel strongly enough that nuclear power is essential that they granted the utilities the ability to place their construction costs in the rate base for recovery prior to actual plant operation—a first for U.S. electric utilities.

In conclusion, while natural gas currently has lower generating costs, there is a significantly higher investment risk in natural gas that does not appear to be reflected in the current "bandwagon effect" that natural gas is enjoying owing to very low current natural gas prices and no environmental compliance costs.

Appendix A: EnergyPath Market Model (EPMM)

The EnergyPath Market Model (EPMM) is an Excel-based valuation model which simulates the construction, operation and decommissioning of an electric generating plant. The model also performs levelized cost of electricity (LCOE) calculations. For this study the model was configured to simulate both nuclear and natural gas plants over a 60 year lifetime. The model incorporates Crystal Ball© risk simulation software [14]. A diagram of EPMM's modules is shown in Figure A-1 below.

Figure A-1



[14] Crystal Ball© is a product of Oracle Corporation (www.oracle.com)

Appendix B EPMM Simulation Model Key Assumptions

Figure B-1 shows the data used in the EPMM simulation model for the nuclear plant (Figures 1 and 3).

Figure B-1 Data Used in EPMM Simulation Model for Nuclear Plant ($2012)			
	Mean	**Std Dev/Volatiliy**	**Type Distribution**
Overnight Capital Costs	$5,000/$Kw_e$	$500/$kw_e$ (std dev)	Normal
Uranium Price	2012 Price: $42.50/lb U_3O_8 Long Run Mean: $33.03/lb U_3O_8 Reversion Speed: 1.1%/yr Real Growth in Long Run Mean: 0.5%/yr	Volatility 11%/yr	Mean Reversion

Figure B-2 shows the simulation model data used for the natural gas plants (Figure 2).

Figure B-2: Data Used In EPMM Simulation Model for Natural Gas Plants ($2012)			
		Standard Deviation	**Model**
Overnight Capital Cost	Unit 1: $1107/$Kw_e$ Unit 2: $2045/$Kw_e$	Unit 1: $110/$Kw_e$ Unit 2: $211/$Kw_e$	Normal Distribution
Natural Gas Price	2012 Price: $4.35/mmbtu Drift Rate: 1.57% Volatility: 31%/yr		Brownian Motion with Growth

Finally Figure B-3 provides financial data used in both the nuclear and natural gas comparisons.

Figure B-3: Financial Data Used In EPMM Simulations	
Financial Data	**Value**
Real Cost of Equity	9.27%
Real Cost of Debt	5.37%
Debt/Total Capital	60%
Real Interest During Construction	7.32%
Sales Tax	5%
Fed Income Tax	35%
State Income tax	6%