Valuation and Optionality of Large Energy Industry Capital Investments

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ABSTRACT: Although there is a renewed emphasis on nuclear power in US energy policy, no new plants are being built and no applications for new construction and operating licenses have been submitted to the Nuclear Regulatory Commission. And it is doubtful whether any new plants will be built in the near future without substantial government financial assistance. This is because of the risks attending a new nuclear plant, largely a legacy of the industry's past. All of this in spite of the fact that the DOE is dedicated to getting a nuclear plant under construction in the US by 2010. So, when the members of the Texas Institute of Advanced Chemical Technology (TIACT) requested a study to assess building a nuclear plant on the Texas Gulf Coast, and the DOE agreed to co-fund the effort, an opportunity arose. This was an opportunity to not only provide assistance to TIACT; but also to develop a framework for meeting the DOE's 2010 objective. By recognizing that an NPV analysis does not account for the substantial flexibility that is inherent in the estimated 56 months leading up to the commitment of substantial funds, initiating a nuclear plant project became feasible. This real options approach explicitly takes into account the market risks faced by a nuclear plant developer, as well as the flexibility to continue or abandon the plant as new information about power market prices and plant investment evolve. In the end, a nuclear plant construction project is viewed more appropriately as a set of sequential options which have a value that exceeds the cost of the options and justifies the initial investment in the nuclear plant.

KEY WORDS: Energy, investments, nuclear power, production costs, and valuation

It is no secret that nuclear power has been in a long period of quietude. The last nuclear power plant ordered in the US, that was not subsequently cancelled, was in 1979.

The source of this decline is twofold: the first oil crisis in 1973-74, sharply lowered the expectation of future energy consumption in the US; and the 1979 Three Mile Island nuclear accident resulted in a startling increase in the costs and risks of constructing nuclear power plants.

As shown in figure 1, from an average of less than $200 per kilowatt of capacity in the early 1970s, capital costs had risen to over $1000/kW in the early years after the Three Mile Island accident. By 1990, nuclear plants were costing upwards of $5000/kw and for all intents and purposes, nuclear power was priced out of the power markets. The last nuclear plant to be built in the US went into commercial service in 1996, at a cost of $5400/kW.

While the new nuclear plant business collapsed in the US, the major nuclear suppliers quickly resorted to building profitable nuclear services and fuel businesses and bidding for the occasional offshore nuclear plant opportunity, mostly in Asia.

Remarkably, with the funding provided by the ongoing businesses, the suppliers also begin programs developing new and advanced nuclear power plants that directly addressed the capital cost issue. Some of these advanced plants found markets in Europe and Asia, although years would pass between orders.

Deregulation of the US power markets began with the passage of the 1992 Energy Policy Act. The 1992 Energy Policy Act deregulated the wholesale market for electricity. The retail markets for electricity are the jurisdiction of the various state regulatory agencies. Deregulation of retail markets ensued in 1998, although only 18 US states were deregulated prior to the California energy crisis of 2001. Since then, states have ceased restructuring their power markets.

By introducing competition into power markets, owners of expensive nuclear plants could have been subject to billions of dollars of above-market (unrecoverable) costs. The market costs were recoverable under rate regulation. In a deregulated market, however, electric prices were established by markets without regard to sunk costs. However, with the aim of stabilizing the power markets, public utility commissions (PUCs) in regulated states permitted owners of nuclear plants to recover nearly all of their above-market costs ("stranded costs").

Under market pressure, nuclear plant owners in deregulated states undertook operating cost reduction programs and by 1990, the operating costs of nuclear plants were lower than their fossil-fueled competition.

US nuclear production costs have been declining dramatically since 1987, as nuclear plant operators closed a significant production cost advantage accruing to power plants fueled with coal. This trend accelerated starting in 1992, when US nuclear plant operators progressively reduced the duration for refueling (from 90 days to less than 30 days) which propelled nuclear plant capacity factors into the 90 percent range, exceeding those for coal.

However, this did not solve the problem of high capital cost, which was one of the key factors inhibiting nuclear orders. Suppliers claimed to have new designs that were as competitive, or more competitive. than alternative technologies such as coal, and certainly natural gas; but these claims were unverified and the financial markets (with long memories of past nuclear financial stresses) were reluctant to accept this risk.

Even so, the final push to renewed credibility may come as the result of a global awareness that climate change is a serious global issue and that fossil fueled power plants were primary contributors to the ecosystems growing carbon inventory.

With this in mind, and with natural gas feedstocks threatening the economic viability of the Texas gulf coast petrochemical industry (at least partly because 85 percent of all new power plants were gas-fired), the member companies of the Texas Institute for the Advancement of Chemical Technology (TIACT) began looking into the possibility of using nuclear power to offset the increased cost of very high and sustained natural gas prices (used as feedstock-not fuel).

The US Department of Energy, anxious to see the renewal of the commercial nuclear option by 2010, saw the possibility of a new nuclear order and became an active funding participant with TIACT.

VALUATION OF THE NUCLEAR PLANT

In order to establish the value of a nuclear plant on the Texas gulf coast, six steps were performed, as shown in figure 2.

While an asset valuation might typically end at step 3, the project flexibility present in the case of a new nuclear plant suggests that a real options approach be taken. There has already been some work performed using a real options framework to value nuclear plants [4].

In order to forecast long range electric prices in the Texas power market, we employed the Electric Power Market Model™ (EPMM) to generate the electric price forecasts based on the natural gas price forecasts from the *2004 Annual Energy Outlook*.

The forecasted electric prices are shown in figure 3. EPMM is a product of The Economic and Management Consulting Group of Hauppauge, New York. (www.emc-group.com). The 90 percent confidence intervals were developed by assuming (on the low side) that real natural gas prices did not increase from those forecast in the *2004 Annual Energy Outlook* over the period 2025-2055 [7]. The AEO forecasts natural gas prices only through 2025. Forecasts after that period were based on assumptions of the real growth rate of natural gas.

The high side forecast assumed that legislation to curb fossil power plant sulfur, nitride, mercury, and carbon emissions would be enacted in 2010. Also shown is a single price simulation (out of 1000) using Decisioneering's® Crystal Ball® Excel-based risk simulation software with a standard deviation of 0.5 \$/MWhr [5]. Prices were assumed to follow geometric brownian motion with drift. For long range electric forecasts this is a valid assumption. Short run prices tend to exhibit mean reverting behavior. The price forecasts used in the study were crucially driven off the *2004 Annual Energy Outlook* because the US Department of Energy was a participant in the study and was using these forecasts as the basis for its own policy and decision making. There is a bias among the study participants that the natural gas price forecasts in the *2004 Annual Energy Outlook* understate expected natural gas prices.

The free cash flow projections were developed using Value Analyzer® over the life of the plant and then transferred to

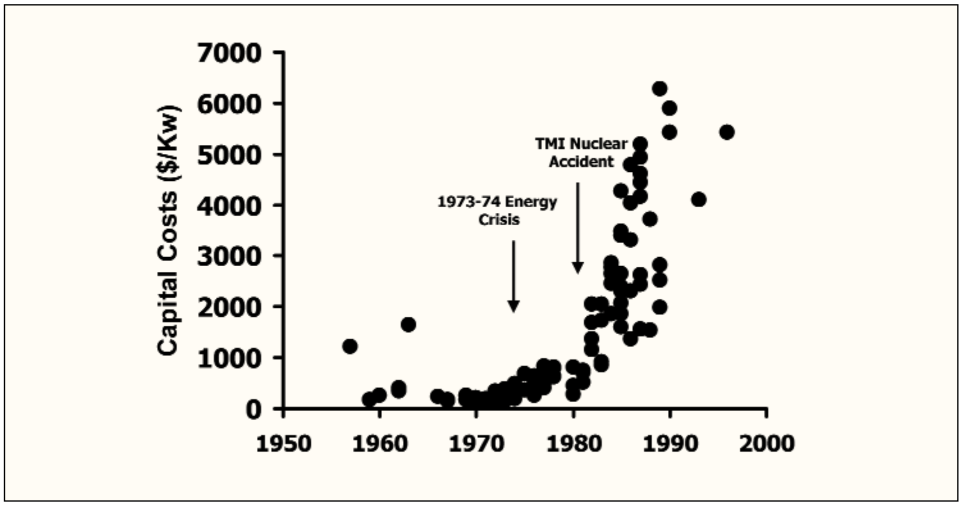

Figure 1 — Capital Cost History of US Nuclear Power Plants

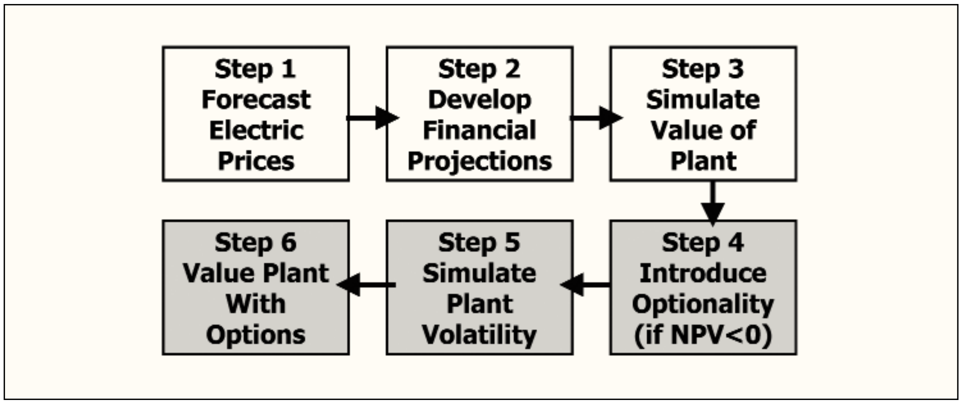

Figure 2 — The Steps Used to Value the Nuclear Plant

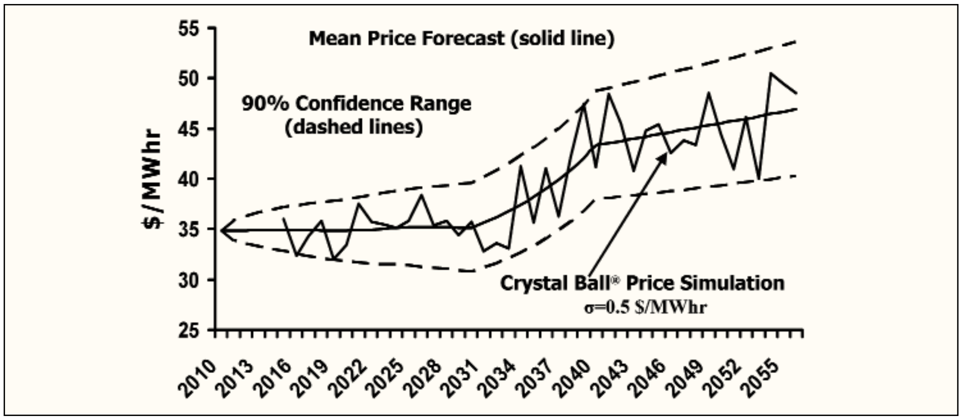

Figure 3 — Electricity Price Forecast

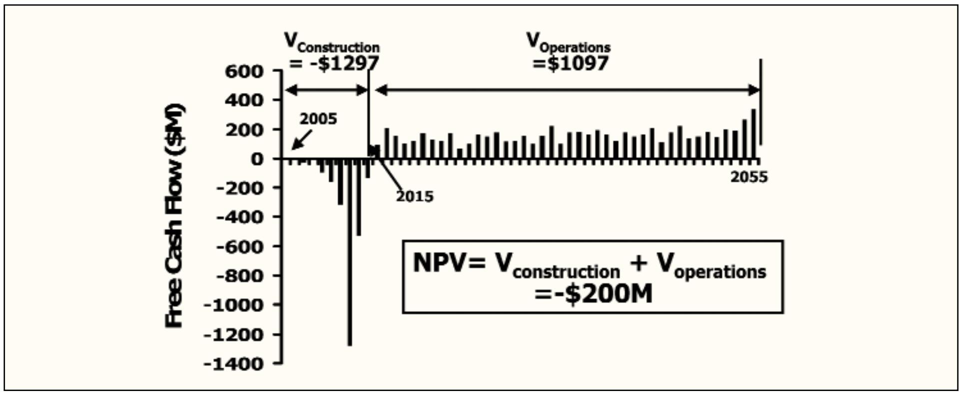

Figure 4 — Free Cash Flow Simulation

Microsoft® Excel in preparation for using Crystal Ball® to simulate plant value. Value Analyzer® financial software is a product of Value Analytix, LLC, located in London, UK.(www.valueanalytix.com).

In addition to price, the following uncertainties were modeled as random variables: plant production costs (including fuel), plant performance (capacity factor), plant capital costs and plant construction costs.

As mentioned above, the plant capital costs were of particular importance to the study and were modeled as a lognormal distribution with the supplier contingency representing one standard deviation [6]. Nuclear plant suppliers generally quote plant costs with a contingency. This contingency was specifically identified in the course of meeting with the suppliers. The average capital cost of the three most likely technologies to be constructed in Texas was $1535/Kw.

Figure 4 shows a single Crystal Ball® free cash flow simulation. In this simulation, over the life of the plant (2005-2055), the plant NPV was a negative $200 million—the negative value of free cash flow during construction (2005-2015) exceeded the positive cash flow value from operation (2015-2055).

Figure 5 summarizes the results of 1000 Crystal Ball simulations—the mean NPV is a negative $257 million and the standard deviation of the NPV is $160M. Without simulation, the "static" NPV is $240M, with a plant present value of $1160M, and an investment present value of $1400M.

On this basis, if a decision to build the plant had to be made today, it would be to not start the project. Either expected electric prices in Texas would need to be much higher or the plant's capital costs would need to be much lower, or both.

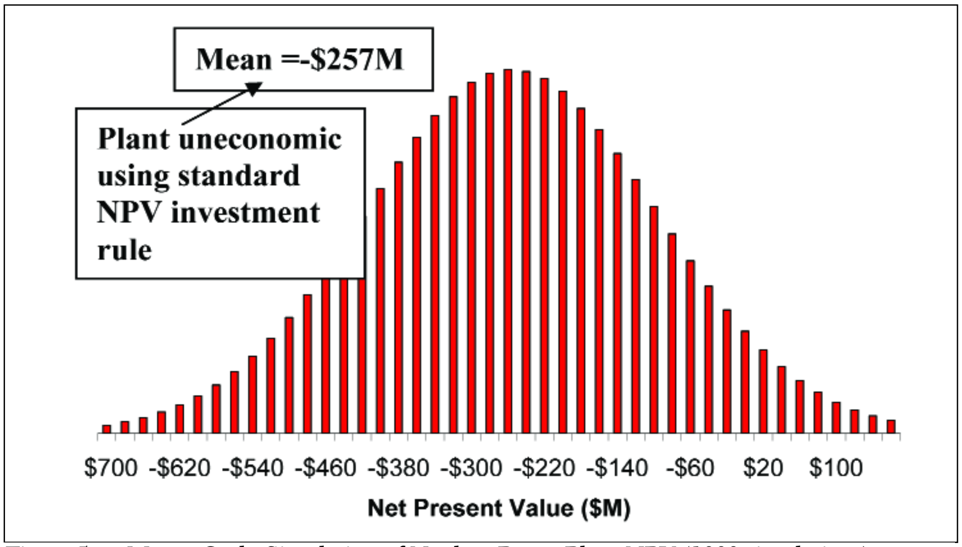

Figure 5 — Monte Carlo Simulation of Nuclear Power Plant NPV (1000 simulations)

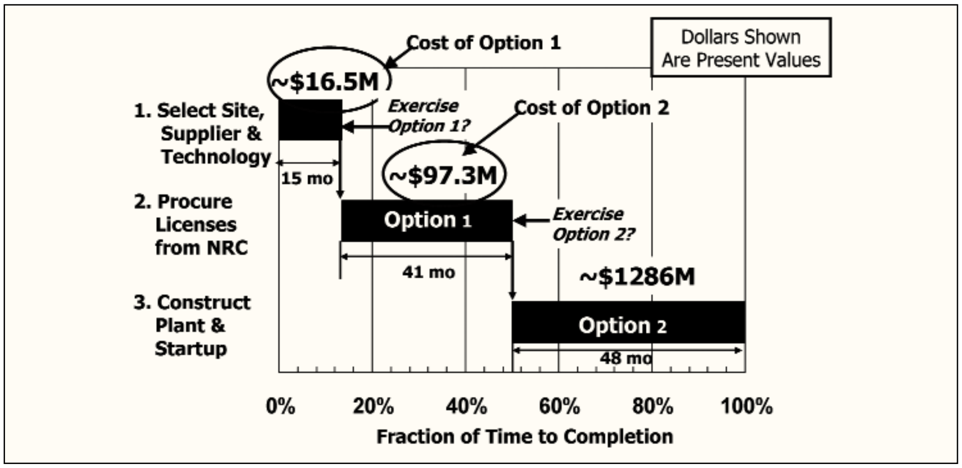

Figure 6 — Nuclear Plant Estimated Cost and Schedule

THE NUCLEAR PLANT'S EMBEDDED OPTIONS

New nuclear power plants are expected to take up to 10 years or more from inception to startup (approximately 48 months of this is actual construction). In the last round of nuclear plant construction, some nuclear plants took up to 12 years just to complete construction. However, to simplify, figure 6 shows there are three sequential phases that characterize the project and each of them is relatively independent of the others. They also must follow in order.

For instance, an applicant for a license to construct and operate a nuclear plant (phase 2) must already have chosen a technology, a supplier, and a site (phase 1). And, a license is required to initiate construction (phase 3).

If we look at the nuclear plant in this way, we can see that it more closely resembles that of a pharmaceutical project; the result of the previous phase dictates whether or not further expenditures on the project are justified.

If not, then the project is abandoned and the funds expended up to that time are lost. This in turn has the look of a financial call option where an option is exercised only if the underlying asset upon which the option is based is valued higher than the exercise price, before or when the option expires.

For instance, in figure 6, phase 1 represents the cost of acquiring an option to license the plant in 15 months. At the end of 15 months, a financial assessment is performed to determine whether to exercise the licensing option (which at the current time is believed to be $97.3M in present value terms.) If not, then the project is abandoned and the $16.5M is lost.

The same assessment is made at 56 months where the construction option must be exercised. Thus, the licensing option represents the cost of acquiring the construction option.

A typical nuclear plant analysis using the standard NPV analysis cannot reflect this flexibility; instead it assumes that once the project is started, there is no turning back. We have shown that the simulated NPV analysis results in a negative $257M; but this doesn't reflect the value of the flexibility inherent in the project.

THE APPROPRIATE METHODOLOGY REAL OPTIONS ANALYSIS

Why is there value in flexibility? And why can this not be identified by a standard NPV analysis?

Whenever an NPV analysis is undertaken, expected values are used (whether this is made explicit or not). An expected value weights the possible outcomes by the probability of their occurrence.

If one or more of the outcomes, by itself, would result in a negative NPV for the project, then this is reflected in the projects overall NPV; it lowers the expected project NPV. There is no way in an NPV analysis to simply throw out the negative contribution to the project NPV.

Does this accurately represent investor behavior? Do investors continue to make investments in projects when it becomes clear that the investment is a loser?

The real options methodology recognizes this possibility and accounts for it. An investment is seen as an option which gives the owner the right (but not the obligation) to purchase an asset (stream of cash flows).

If at the time the option is exercised, the investment has an expected positive NPV, then the asset is purchased. Otherwise it is abandoned and the cost of the option is lost.

In the case of the gulf coast nuclear plant, there are two embedded sequential options, giving two opportunities to evaluate whether or not the asset should be purchased (see figure 6).

This is particularly significant in the case of a nuclear plant because both the value of the nuclear plant and the total investment cannot be known with certainty at the start of the project given the lengthy project time, regulatory uncertainties (e.g., obtaining a construction and operating license), the potential for construction delays, and environmental policy.

In the case of the gulf coast nuclear plant, less than 10 percent of the project's investment occurs before the option to construct is exercised. As mentioned, this is a typical pattern in large energy industry investments (and many other investment intensive industries) where up-front costs are required to resolve the significant uncertainties prior to making a production decision.

Figure 7 is an intrinsic value graph for the gulf coast nuclear plant. The solid line ABC is the payoff in the case of an investment that is available only once (i.e., the standard NPV analysis).

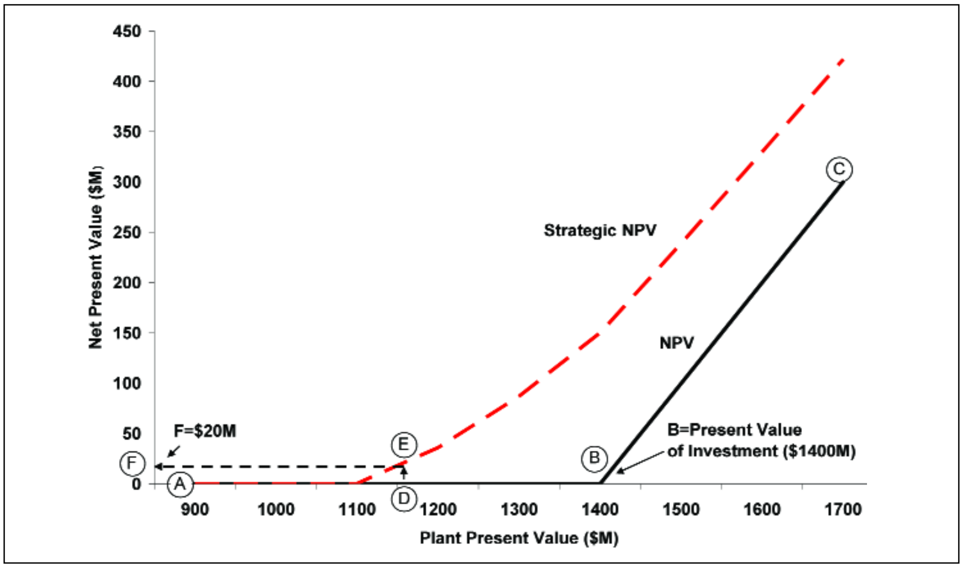

Figure 7 — Intrinsic Value of the Nuclear Plant

The solid line segment BC indicates that if the plant present value (V) exceeds the present value of investment (I) then there is a positive payoff to the investment. If V<I, as is shown in the solid line segment AB then the payoff is zero (since the investment will not be undertaken if the NPV<0). Another way to describe the solid line payoff is MAX (V-I,0).

The dotted line, on the other hand, takes into account the fact that the investment decision is available in the future (i.e., flexibility is present). The Appendix to this article discusses in more detail how the strategic NPV line is generated

This line is denoted the Strategic NPV, and the Strategic NPV line in figure 7 has a payoff greater than zero even though the NPV line payoff (segment AB) is zero. The difference between the two lines is the option value of the investment (sometimes called the "time value" or the "opportunity cost of immediate investment").

For the gulf coast nuclear plant the option value is the line DE located at the point on the horizontal axis where the present value of the plant is $1159M. $1159 is the expected present value of the nuclear plant using a "static" NPV analysis. Then line segment EF indicates that the strategic value of the plant is $28M. This is also the option value since the line AB is zero.

Since the option value is $28M, then the present value of the option cost cannot exceed $20M or the project should be abandoned. Figure 6 indicates the option should be purchased (i.e., phase 1 should be started) since the actual present value cost of the option is $16.5M.

The recommendation to initiate the project, when the expected NPV is less than zero, may strike traditional nuclear plant developers as contrary to common sense. But this has more to do with the past history of nuclear power than anything else.

Nuclear plants have always been built by regulated electric utilities, and the risks of these ventures have primarily been borne by the utilities' ratepayers, not shareholders. It is going to be difficult to build any nuclear plants outside of a rate base, or without a substantial risk-bearing partner (such as the US government) unless a real options framework is assumed.

This is already done quite regularly in other energy-intensive industries, such as pharmaceuticals, petroleum exploration and production, aircraft production, real estate and even non-nuclear power applications.

It is the object of this article to promote the real options framework in the US nuclear industry

The NPV analysis and the real options analysis leads to different and opposing decisions.

This situation arises because the NPV analysis fails to recognize that there is flexibility on the part of the project developers given the cost and timing pattern of the nuclear plant. This flexibility allows the developers to start the plant while resolving uncertainties, particularly the investment value and the Texas power market prices when the plant goes into operation.

One of the ways that developers can

resolve the market pricing uncertainties is to begin the sale of power purchase agreements prior to plant construction.

The plant investment uncertainty is resolved early (phase 1) as a supplier, a technology, and a site are all identified and contractual agreements entered into. It is essential for the plant developers to understand that the strategic NPV line does not indicate a positive NPV prior to the start of development.

Rather, it indicates that the NPV at some future time could be positive in spite of the fact that it may not be today; and that there is a justifiable cost today to keep the option open for the future. In the case of the gulf coast nuclear plant, the justifiable cost was greater than the actual cost, and the decision is to begin project development.

APPENDIX

Developing The Strategic NPV Line Using the Binomial Options Model

THE MODEL

This section will describe the basic framework for performing the real options analysis using the binomial options model.

Figure A1, is data taken from figure 6 in the report.

Starting to the right in figure A1 the last column describes the second option (the construction option-option 2). The underlying asset for option 2 is the present value of the nuclear plant which is a random variable determined primarily by the price of electricity, but also by operating costs and plant efficiency.

The second rightmost column describes the first option (whether or not to procure the license) where the underlying asset is the present value of the construction option.

Each column describes:

- the maturity (the time before a decision must be made to exercise the option or abandon the project;
- the exercise price (the investment required if the option is exercised);
- the option cost (the cost to acquire the option); and
- the type of option—European or American.

European options can only be exercised at the option's expiration date while American options can be exercised at any time. In this case, you cannot exercise the construction option until you have a license to do so so the construction option is a European option, as is the licensing option.

Since the real options analysis uses present values, the exercise prices and the option prices are given in both as-spent dollars and present-value dollars (in parenthesis). The cost of the licensing option shown in figure A1 is $16.5M in present value terms. This means that the value of the licensing option cannot exceed $16.5M.

The real options analysis for the gulf

Option	1. Licensing Option (Step 2)	2. Construction Option (step 3)
Maturity	15 months	56 months
Exercise Price	$128M (PV=$97.3M)	$2900M (PV=$1286M)
Option Cost	$18M (PV=$16.5M)	$128M (PV=$97.3M)
Type Option	European	European
Underlying	Construct Option	Plant Value

Figure A1 — Description of the Nuclear Plant Sequential Options

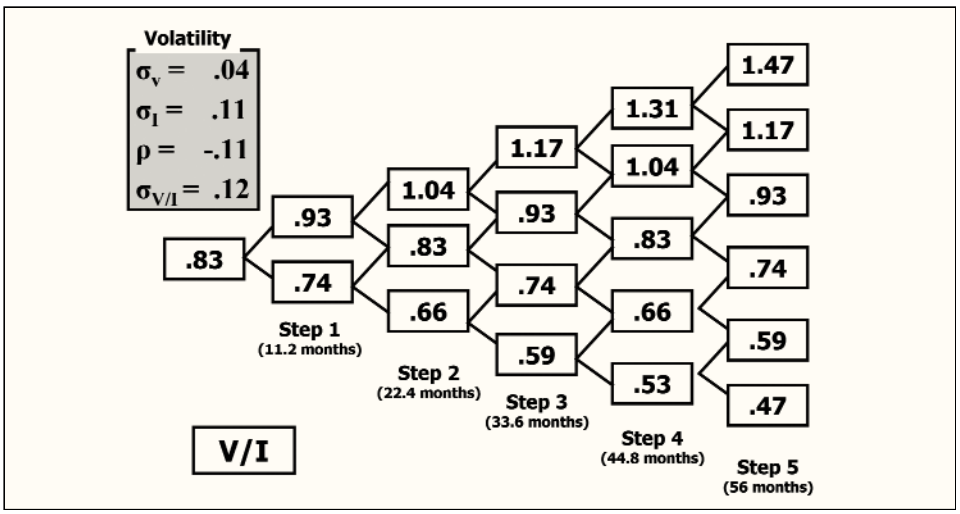

Figure A2 — Present Value Event Tree for V/I

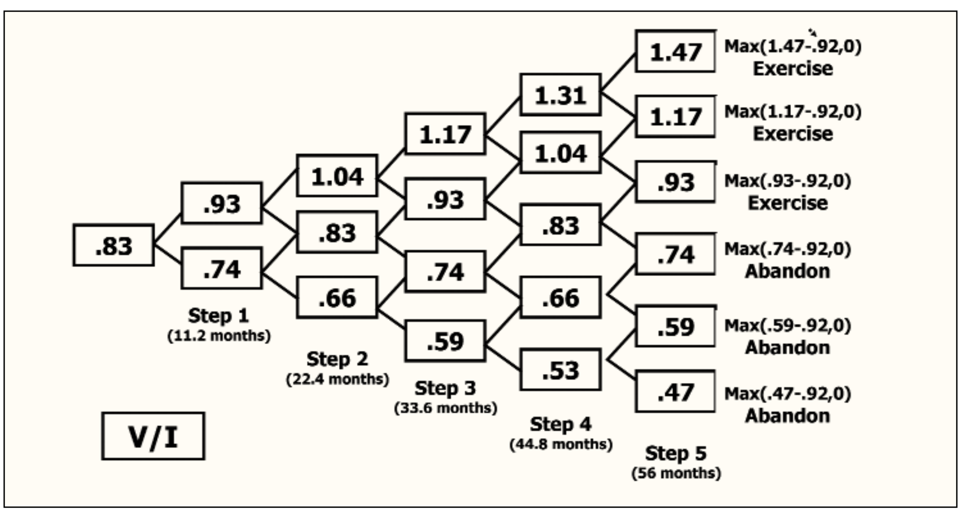

Figure A3 — Decision Tree for V/I

coast nuclear plant is complicated by the fact that both the plant present value (V) and the present value of investment (I) are both random variables.

Fortunately this problem has been addressed and requires the use of the ratio V/I to be used as the underlying asset where V is the present value of the nuclear plant and I is the present value of total investment in the plant [2]. "Total" is highlighted here because the following three costs make up the total investment:

- the cost of construction;
- the cost of acquiring the license; and
- the cost of identifying the site and supplier.

Since both V and I are random variables, then V/I is a random variable and the volatility of V/I can be simulated with Crystal Ball® [1]. This resulted in a volatility of 12 percent ($\sigma_{V/I}$ =.12).

THE NUCLEAR PLANT OPTION VALUE

In order to determine the option value of the nuclear plant Decisioneering's Real Options Analysis Toolkit® was employed using the custom sequential options model. There are two approaches for determining option value. Closed form solutions using either dynamic programming or contingent claims analysis are described by Dixit and Pindyck [2]. The other uses a binomial approximation and is most closely associated with T. Copeland and V. Antikarov [1,3]. The binomial approximation collapses to the closed form solutions as the number of time steps becomes infinite. The binomial approximation is used in this article.

The information shown in figure A1 was used as input to the model. Five time steps were chosen to span the period of 56 months from the start of the project until the decision to exercise the construction option (15 months + 41 months). The decision to exercise the licensing option occurs in 15 months.

The present value event tree for the underlying asset, V/I, is shown in figure A2. In the binomial options model, the random variable V/I can either increase or decrease its value from its previous node, and the amount of the increase or decrease is determined by $\sigma_{V/I}$. The up step (u) is related to the volatility by $u=e^{\sigma_{V/I}}$ and the down step (d) is a function of the up step by d=1/u.

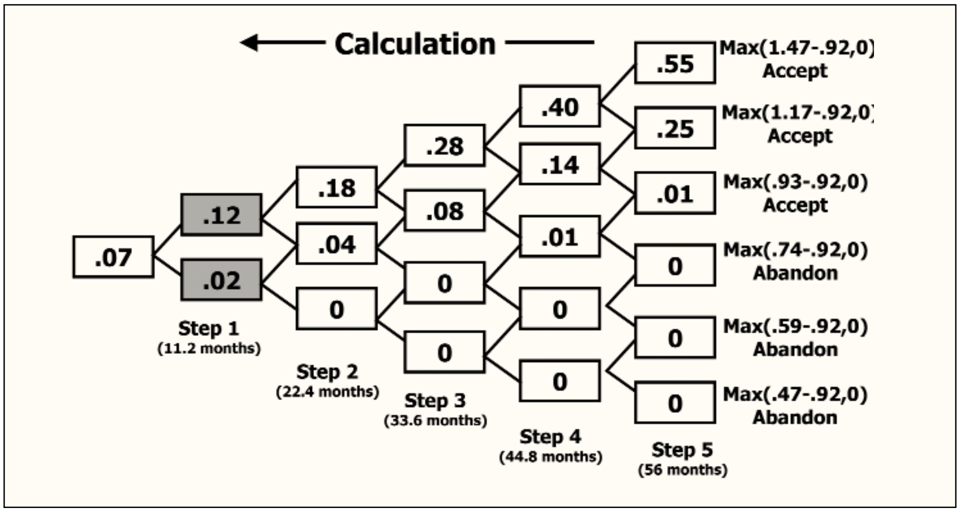

Figure A4 — Value Tree for Licensing Option

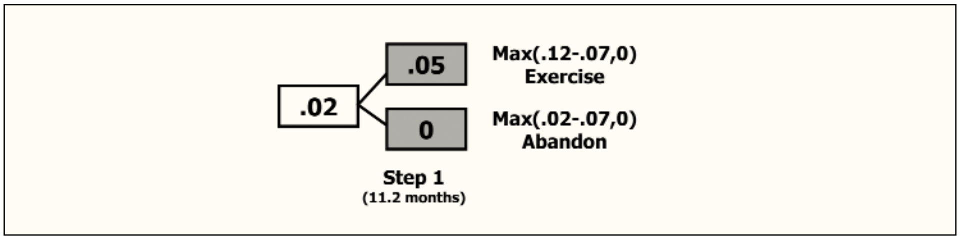

Figure A5 — Decision Tree for License Option

Thus, figure A2 shows the possible values of V/I at each time step through 56 months.

The decision tree for exercising the construction option is shown in figure A3. The construction option can only be exercised in step 5 since it is a European option (i.e., it cannot be exercised before the costs of site and supplier selection are known with certainty).

In figure A3, the construction phase exercise price (V/I) is 0.92 (For clarification on this important point, note that since V is divided by I, then all variables used in the analysis must also be divided by I.

The option will be exercised when the value of the option exceeds the option's exercise price. The exercise price is the cost of construction, $1286M divided by the total investment, $1400M, so that the exercise price is .92).

If the value of V/I at 56 months exceeds .92, then the option is exercised. If not, then the option is rejected and has zero value.

Figure A4 replicates the decision tree shown in figure A3, with the option values for each node. The calculations are performed recursively from right to left starting with the decision as to whether or not to exercise the construction option in step 5 (56 months).

The actual calculations for the recursive solution can be found in Copeland's Real Options book. [1]. It is noteworthy that these calculations are what give real options analyses a problem with actual application. They are not as intuitive as the NPV approach and it can be difficult to communicate the theory to corporate management; especially since real options is just now being taught in business schools. As time progresses, this limitation is likely to lessen, much as was the case with the incorporation of NPV analysis for corporate capital budgeting.

The two nodes at step onne represent the underlying asset for the licensing option. Since the present value licensing option investment is seven percent of the total plant present value investment, then the licensing option is exercised only when the nodal present value in step one exceeds .07, and this is shown in figure A5

Finally, the result we are seeking is shown in the first box in Figure A5. The option value for step 1 (site, supplier and technology selection) is equal to .02.

As we saw in figure A1, the expected present value cost of step one was $16.5M, and when divided by the expected present value investment ($1400M), the ratio is .01. This is less .02 and justifies initiating the site, supplier, and technology selection process. ◆

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