Applying Financial Option Theory to Utility Resource Planning

Jonathan B. Lowell, New England Electric

Options have become an important risk management tool in the financial markets. Short and long term resource options will become equally important elements in utility efforts to plan for future environmental requirements and more competitive electricity markets, and all the uncertainty they encompass. Techniques developed by financial researchers to quantify the value of options can be applied to utility resource planning to quantify the value of the flexibility (or its lack) in available resource choices. The approach can also be used to calculate the value of delaying a decision to commit. This paper discusses methods developed and applied by New England Electric to evaluate a number of different options, including purchased power contract buyouts, baseload facility contract extension, construction of a combustion turbine peaking facility, and DSM retrofit programs. It also provides more general insights into the value of flexibility attributable to the fixed versus variable cost characteristics of resources. Lastly, the likely impacts of option theory on utility planning are examined from the different risk perspectives of customers and shareholders.

Introduction

Uncertainty plays an important part in investment decisions for all businesses. This is certainly more evident than ever before in the utility industry, as talk of competition pervades discussions of the industry's future. The widely taught and commonly applied Net Present Value (NPV) decision rule fails to recognize the impact of uncertainty and can lead to potentially costly decisions. In its simplest form, the NPV rule suggests that if the discounted value of an investment's future cash inflows (benefits) exceeds the discounted value of its outflows (costs), the investment makes sense and should be pursued. The basic rule, with benefits and costs extended and modified as desired to include societal costs, free riders, and so forth, forms the foundation of the cost benefit analysis at the heart of most integrated resource planning processes. This approach implicitly assumes that the discount rate adequately addresses all components of risk.

Most utility resource decisions share three characteristics. Their benefits are subject to significant *uncertainty,* caused by the difficulties in estimating future demands, fuel prices, measure lives, and a host of other factors. Most resources have flexibility in their *timing.* The resource investment can be accelerated, delayed, or cancelled within certain limits. Once dollars are spent, however, they become at least partially or completely *sunk.* For investments that possess these attributes, the flexibility to wait for better information has an important and measurable value not captured by the NPV rule.[1]

Financial options represent the *right,* but not the *obligation*, to buy or sell an asset at some future time. This flexibility parallels closely the rights contained within many utility resource investment choices. In fact, a single capacity investment may incorporate any or all of the "real" options listed in Table 1.[2]

Table 1. Real Options Embedded in Resource Investments

1. Delay in-service date
2. Accelerate in-service date
3. Abandon prior to operation
4. Expand project size
5. Reduce project size
6. Mothball
7. Retire and salvage
8. Sell future output under contract

A number of different approaches have been used to address the NPV rule's inability to capture the impact of uncertainty. These include risk adjusted discount rates[3], scenario and sensitivity analysis, Monte Carlo simulation and decision analysis. While the first three provide additional guidance to the decision maker, they do not measure the value of flexibility represented by real options. The latter two techniques, if used appropriately, provide ways to incorporate option value in the decision process. In fact, as the reader will likely observe, the numerical techniques used to evaluate real options can be seen as a subset of decision analysis.

Methodology

Black-Scholes and the Binomial Approximation

In 1972 Fisher Black and Myron Scholes published an option pricing model that used the concepts of arbitrage and hedge portfolios to derive a closed form solution to the option valuation problem that did not depend on knowledge of the probabilities of future price movements of the underlying asset. Arbitrage is the practice of buying an asset at a low price in one market and selling it immediately for a higher price in a different market for an instantaneous profit. In efficient competitive markets, opportunities for arbitrage should not exist. The approach can be illustrated using a simple one-period option model, of which the Black-Scholes model is a multi-period continuous-time extension.

Begin by constructing two different portfolios. Let the first consist of a call option providing the right to buy one share of stock one period in the future at an exercise price X. The second portfolio consists of N of shares of the same stock priced at P per share, plus B dollars of risk-free debt borrowed at a rate of $1 + r$ per period. Further suppose that at the end of the period, the "market" will either move up or down according to a "random walk"[5] process. Let u be the volatility factor by which the price moves up in an "up" market, and let d represent the same for a "down" market. If the market moves up, the value of each share will be worth uP. In a down market, shares will be worth dP.

It is possible to determine the number of shares N and the amount of risk-free borrowing B such that both portfolios have identical returns under either up or down markets. Applying the assumption that no arbitrage opportunities exist, the value of the option V today must equal the value of the shares plus borrowings. If they did not, there would be an opportunity for arbitrage. Investors could buy the lower cost portfolio and receive the identical return. These relationships allow a system of two equations in two unknowns to be solved for the value of the option, as illustrated in Figure 1 using hypothetical parameters.[6]

Note that nothing has been said in the derivation about the probabilities of the respective up and down market movements. The u and d factors reflect the level of volatility and the long term trend in the market price.

The one period model can be easily extended into a multiperiod model. At each period, the market price can move either up or down, generating a tree of future outcomes. This representation, known as the Binomial model, forms the basis for most numerical solutions to option value problems and is illustrated in Figure 2. The value of the call option at expiration is determined at each node on the right side of the tree. The value of the ancestor node to the left is determined by the process outlined above, forming a portfolio of the underlying asset plus risk-free debt that duplicates the performance of the option and solving for its value. At each step, the tree can be "back-solved" to determine the value of the option at the beginning of the first period.

In practice at New England Electric, we have evaluated the binomial expansion of resource choices incorporating real options using a decision analysis framework. Probabilities are assigned to each branch - generally 50% for up movements and 50% for down movements. Asymmetric probabilities can be used when the "market's" underlying random walk process exhibits mean reversion, a tendency to return to an equilibrium value. The value at each terminal node is the expected value of benefits attributable to the resource under the future market conditions represented by the node. The expected value of each ancestor node is then back-calculated as shown in Figure 3.7 This procedure provides an adjusted NPV for a specific resource. The value of the real option is found by evaluating a similar tree for the same resource without the embedded real option, and taking the difference.

Case Studies

To date option theory has been applied to a number of resource decisions at New England Electric. These include the decision to commit or delay an investment in improvements at an existing hydro facility, the decision to retire an existing fossil-fueled generating station, the choice between two different contract extension options on a baseload NUG (non-utility generator) project, a buyout decision on a NUG peaker project, and estimation of the option value of DSM retrofit programs. Several of these are described below to illustrate some of the practical problems encountered, how they were resolved, and the types of conclusions reached.[8]

	Stock plus Borrowing	Call Option
Value at start of period	$NP\text{-}B$	V
Value at end of period: Up Market	$NuP\text{-}B(1+r)$	$uP\text{-}X$ if $uP>X$ 0 otherwise
Value at end of period: Down Market	$NdP\text{-}B(1+r)$	$dP\text{-}X$ if $dP>X$ 0 otherwise

Assume:	Value of Call Option	V
	Exercise Price	$X = 100$
	Up Market Volatility Factor	$u = 1.1$
	Down Market Volatility Factor	$d = 0.95$
	Share Price	$P = 102$
	Risk-free return	$r = 5\%$
	Shares of stock	N
	Amount Borrowed	B

This provides:

$$NuP\text{-}B(1+r) = uP\text{-}X \qquad N\times 1.1\times 102 - B\times 1.05 = 1.1\times 102\text{-}100$$
$$NdP\text{-}B(1+r) = 0 \qquad N\times 0.95\times 102 - B\times 1.05 = 0$$

Solving for N and B: $N = 0.80$

$B = 73.59$

By the assumption of arbitrage, the portfolio costs are equal:

$V = NP\text{-}B$ or

$V = \mathbf{8.01}$

Figure 1. Derivation of the Value of a Cell Option

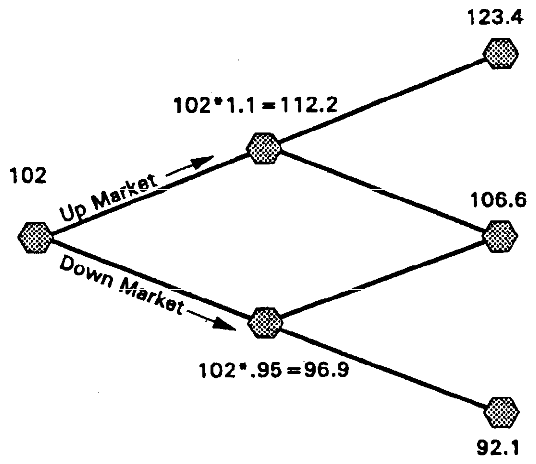

Figure 2. Binomial Tree

Combined Cycle Contract Extension

During negotiations with a successful bidder in the Company's recent supply-side RFP, the bidder offered a contract extension option for a gas-fired combined cycle plant. The option allowed a 15 year firm commitment to be extended at the utility's discretion according to a specified price formula for an additional 5 year period. The formula price/KWH for the 5 year option was above projected avoided costs. Option theory was applied to value the contract extension option.

Baseload generating plants provide two types of benefits - capacity and energy. Each of these has a separate market value. The two market values will be only partially correlated, at best, because capacity prices within the New England Power Pool (NEPOOL) are determined primarily by the supply of generation relative to the Pool's peak load, while energy prices are driven mostly by fuel prices.

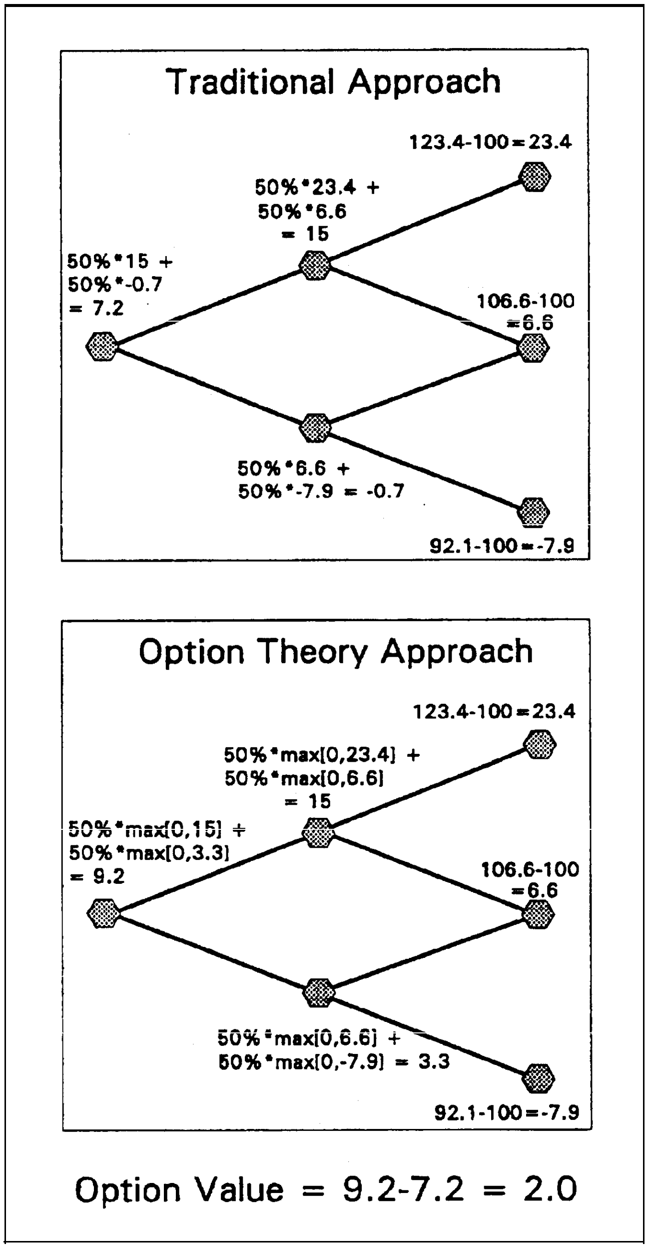

Figure 5. Binomial Model Example

During periods of tight supply, average capacity factor will rise and expensive units will run more frequently, driving up energy costs, but this effect is minor compared to fuel price impacts. The binomial models adopted from financial option theory allow for only one source of uncertainty - the market price - and are not readily adapted to options on underlying assets whose value depends on two separate and partially independent sources of uncertainty.

To surmount this problem, capacity and energy benefits were combined into a single quantity, net benefits.[9] Net benefits represent the difference between the unit's contract price/KWH, and the Company's avoided cost/ KWH (including both capacity and energy avoided costs). The volatility of net revenues will be a function of the volatility of both the capacity and energy components. For a baseload plant, energy benefit volatility should be low because both the plant's fuel cost and the fuel costs avoided by the plant will be strongly correlated. The plant's capacity costs should be relatively fixed, but avoided capacity cost (i.e., the market value of capacity) is quite volatile. We therefore expect the combined volatility of net revenues to be less than 100% of the volatility of avoided costs. Lacking historical information on capacity market values, 10% annual volatility[10] was assumed for avoided costs, and net revenue volatility was assumed to be half of that, or 5%. The approach is illustrated in Figure 4. Sensitivity analysis was conducted on these parameters to test the robustness of the final decision.

The findings of this analysis were, at first glance, somewhat counterintuitive. Traditional methods would have shown the 5 year option to be a $-2.3m "bad deal", because it was priced above avoided cost. The value of the option was estimated to be $7m. Sensitivity analysis on the impact of net benefit volatility indicated a range on the value of the option of from $2m to $20m. It is uncertainty, or volatility, that causes options to have value, and it is, in this case, clearly an important factor. The option allows the utility, for a price, to prune the binomial "tree" of all the nodes representing undesired outcomes, adding significant value. For this project, most of the nodes were undesired, but the option still had positive value. Depending on the price charged by the project's developer, the option could become a very attractive "good deal".

Some important caveats arise from this example that must be considered before routinely applying option theory to utility resource real options. First the sensitivity of the result makes it important to develop reliable estimates of avoided cost volatility. As already noted, this is not a trivial task. Second, fifteen years into the future is a long time and many things can change. We need look back only half that time to find the Soviet Union was still the evil empire and the Berlin Wall still divided East from West. For a 5 year option 15 years from now to have the value today calculated above, both parties must still be in business and capable of performing under the contract. An option contract with a bankrupt firm may be a worthless piece of paper.

Combustion Turbine Buyout

The second case study looks at a contract with an independent power producer to develop a new gas-fired combustion turbine peaking facility with a projected on-line date of 1997. The project contained several real options that needed to be valued as part of the negotiation process with the developer. The first option was a

Energy Benefit = **Avoided Energy Cost - Fuel Cost** **(low volatility)**

Capacity Benefit = **Market Value of Capacity - Fixed Costs** **(high volatility)**

Net Benefit = **Energy Benefit + Capacity Benefit** **(moderate volatility)**

Figure 4. Calculation of Net Benefits

straightforward buyout, allowing the utility the right to terminate the contract in exchange for a fixed fee. The buyout option expires two years prior to the contracted in-service date of the project. The second embedded real option was the flexibility to delay the in-service date, also in exchange for payment of a fee.

Combustion turbines generally have very little energy value because of their high fuel cost per KWH produced. The option value analysis was conducted using the simplifying assumption that the project would provide only capacity benefits. The value of those capacity benefits will depend on the future market value of capacity within the New England region. Despite the lack of a market for capacity that meets the classical macroeconomic definition of an efficient market (many buyers, many sellers, each with perfect information), and little historical data to analyze, planners at New England Electric have developed some strongly held opinions about the likely future behavior of the imperfect market that exists. It was important to “tune” the binomial option valuation model to reflect this behavior if we were to produce results that decision makers would find useful.

Briefly, New England Electric planners believe capacity value fluctuates around a long run equilibrium value tied to the cost of production. The cost of production is taken to be the “real-levelized” revenue requirements of a new combustion turbine. During times of regional capacity surplus, the forces of supply and demand will drive market values below the long run equilibrium value. That is where the New England capacity market is today. As the surplus capacity is absorbed, either through load growth, unit retirements, or both, capacity values will slowly climb, reaching the equilibrium value at the time of the projected regional need date around 2000.

If demand overshoots supply, capacity values would climb above the real-levelized equilibrium value. For planning purposes, we do not make the assumption that will happen. In theory, there is no upper bound on capacity market value, but we believe it to be very unlikely (1 chance in 20) that values would exceed 115% of the equilibrium value. 115% is roughly the ratio of the first year revenue requirement of a combustion turbine to the real-levelized revenue requirement. Such a market would provide strong incentives to developers to build new resources.

A mean reverting random walk process provided the means to modify the binomial tree to reflect this behavior. Whenever capacity value exceeded the projected market equilibrium value, the probability of a downward price movement in the next period was assumed to increase to some number q_{above}, where $q_{above} > 50\%$. The probability of an upward movement becomes $(1-q_{above})$. For capacity values less than or equal to the equilibrium, the probability of a downward move, q_{below} was assumed to equal 50%. A value of $q_{above} = 60\%$ was empirically found to exhibit the 1 chance in 20 behavior judged to be reasonable. The revised binomial tree is illustrated in Figure 5. The different capacity value distributions that result from adopting the mean reverting assumptions of $q_{below} = 50\%$ and $q_{above} = 60\%$, and the standard binomial distribution assumptions of $q_{above} = q_{below} = 50\%$ after 25 years of market evolution are shown in Figure 6.

Because negotiations on this project have not yet concluded, it is not possible to provide specific results of the analysis. The results did, however, provide clear guidance to the Companies’ negotiations and changed our original strategy regarding the role of the peaker in our resource plan. The options to buyout and delay each contributed in a different and measurable way to the project’s overall resource value.

Calculating the value of delay is one important application of option theory to utility resource planning. It is the opportunity cost of making a commitment to invest. When included in the decision process, option theory will tend to defer investments, especially for long lead-time resources. When would option theory tell you to proceed and not delay? Suppose New England faced opposite capacity market conditions - tight capacity and high demand. Option theory would calculate a very low or negative value of delay, signaling that the investment should be made as soon as possible. Market-driven DSM opportunities are another example of investments that option theory would promote. The *cost* of delay is so large if DSM opportunities are not captured at the time of new building construction and are pushed into the retrofit category, that

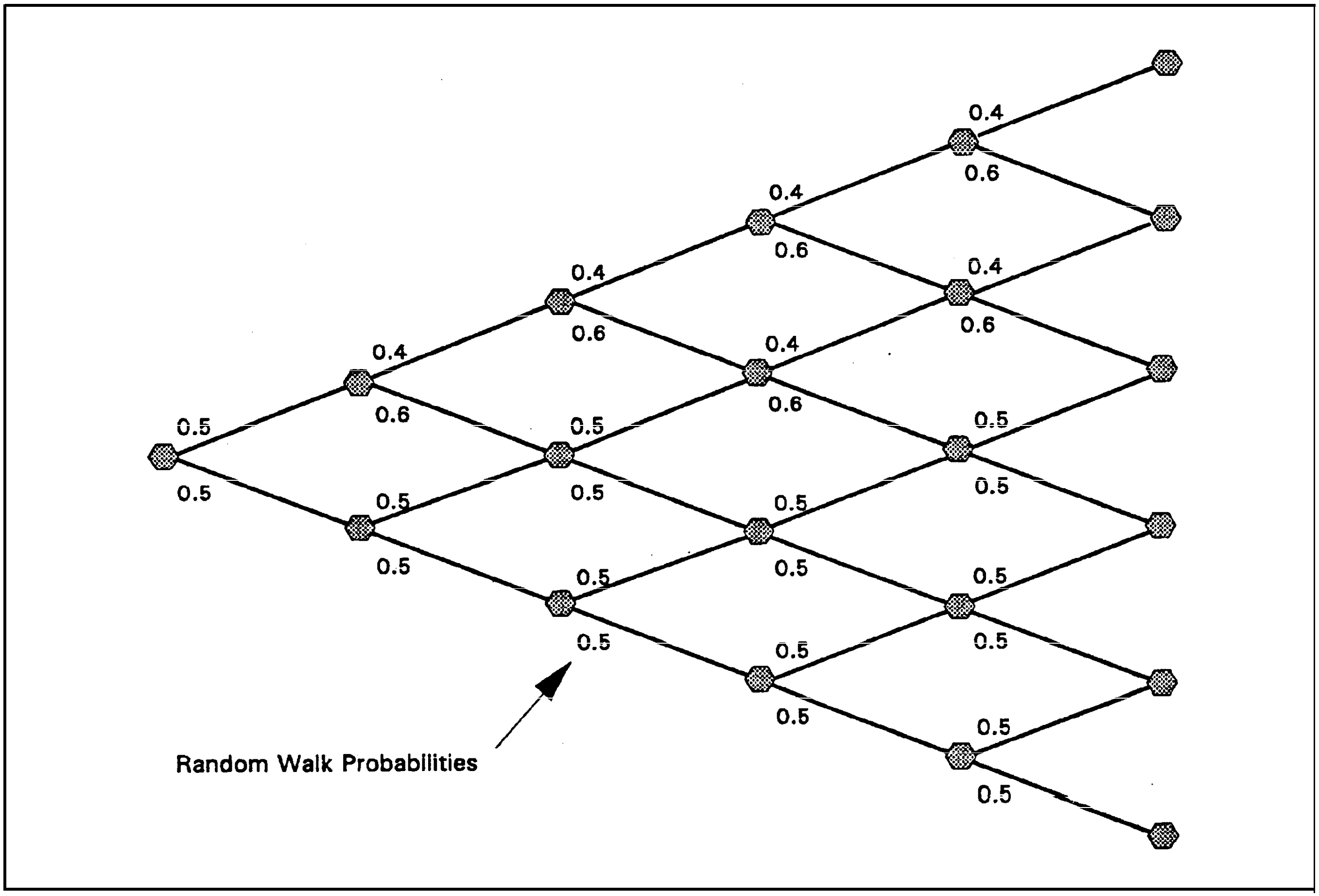

Figure 5. Mean Reverting Model

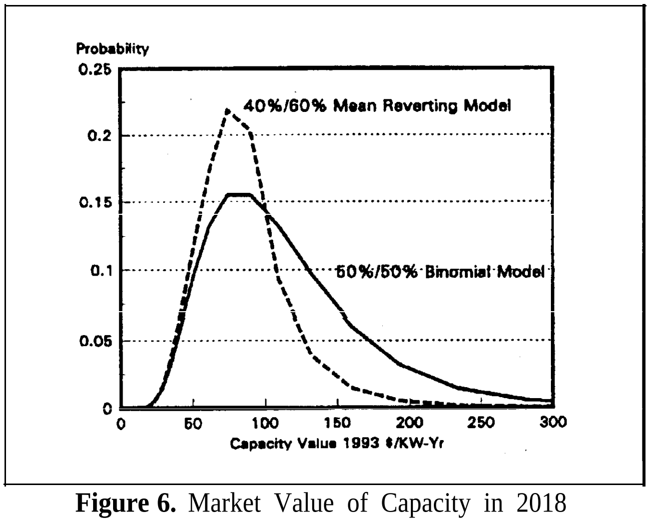

Figure 6. Market Value of Capacity in 2018

it will seldom make sense to delay. Furthermore, because of short lead-times, DSM retrofit opportunities that look good under a traditional NPV decision rule are less likely to be "delayed" by option theory than long lead-time supply-side alternatives. The longer the lead-time, the greater the uncertainty, and the higher the value of delay will be.

Implications of Option Theory for Integrated Resource Planning

Option theory provides a way to quantify the loss of flexibility represented by resource commitments that create sunk costs. Incorporating this value into the planning process will clearly impact the types of resources likely to be included in integrated resource plans.

Resources with a high ratio of fixed to variable costs have relatively little flexibility and will have high value of delay. Leading the list of investments likely to be disadvantaged are long lead-time, high capital cost projects such as nuclear power plants or major hydro developments. To be economic after factoring in the option value of delaying, projects of this nature will have to be "sure winners" under the traditional NPV approach. Large coal plants, while possessing more flexibility than nuclear facilities, fall into a similar category. Resources that can be added in small increments and with low capital requirements will suffer less of an option value penalty and will be more likely to be included. The value of flexibility that comes with small resources may well be sufficient to overcome economies of scale often associated with the larger baseload technologies.[11]

Emission control strategies are another area of utility resource planning that may be strongly influenced by option theory principles. Switching to lower sulfur fuel and allowance purchases represent low capital cost approaches to meeting Clean Air Act SO_2 requirements. The installation of scrubbers is at the opposite end of the spectrum, a high capital cost strategy that will prove more difficult to justify when the option value of the commitment decision is accounted for.

Option theory also provides a justification for research and development investments in renewable technologies. These investments are essentially the purchase price of an option on future resources. If the R&D does not succeed in commercializing the technology, the option may expire worthless. But even a small chance that the technology will become viable gives the option value. That value establishes an upper bound on the size of the research program that can be justified.

Implications for Ratepayers and Shareholders

How will increased competition in the utility industry impact resource planning? Clearly, risks of surplus capacity will be borne more and more by shareholders and less by ratepayers. Option theory, by setting a higher cost justification hurdle and thereby delaying commitments, and by judging investment opportunities against a competitive market standard, will work to protect shareholders from the more brutal impacts seen in another industry with overcapacity, the airlines. Customers will be protected by those same competitive forces and will pay the market price.

What if competition remains a mirage on the horizon, and the obligation to serve coupled with cost of service regulation rules the day? By a similar line of reasoning, option theory will work to protect ratepayers from having to support unnecessary or premature investments. Will it lead to a less reliable system? Not if utilities manage their resource portfolio appropriately, by including more than enough options to cover anticipated requirements. The savings gained through greater flexibility will more than offset the “insurance” cost of acquiring the options.

Future Research

A number of issues need to be resolved to “operationalize” option theory techniques into the utility resource planning process. First, a solid theoretical foundation for incorporating multiple sources of uncertainty into the option value calculation must be developed. This problem was alluded to in the combined cycle case study presented above. Most resource options have at least two partially independent sources of uncertainty, capacity value and energy value. If fuel choice distinctions are important, energy value may have to be represented as a function of three or four different fuel price uncertainties. Second, sensitivity analysis has demonstrated the importance of volatility assumptions in determining option values. More research into historical capacity and energy market value volatility will help to ensure that reasonable assumptions are used and reasonable results obtained. Lastly, this paper has discussed only one side of the story, the calculation of what a given element of flexibility is worth is worth to the utility. There is very little information illuminating what the market wants to charge for providing that flexibility. Future RFPs will eventually provide this market data.

Acknowledgments

The author is indebted to a number of individuals whose suggestions and prior efforts formed the jumping off point for the work in this paper, including Dr. Robert Pindyck of the Massachusetts Institute of Technology, Mr. Tom Kaslow of New England Electric, and Mr. Tom Parkinson of Northbridge Associates.

Endnotes

1. Dixit and Pindyck provide a complete discussion of these principles in *Investment Under Uncertainty,* Princeton University Press, 1994.

2. A summary of the range of applications of real options theory to business decisions and a review of work done to date is provided by Lenos Trigeorgis in “Real Options and Interactions With Financial Flexibility”, *Financial Management,* Autumn 1993.

3. Shimon Awerbuch provides a thorough discussion of risk-adjusted discount rates and how they may influence resource selections in the April 1993 issue of *Electricity Journal.*

4. This approach has been used by the Northwest Power Planning Council to develop an optimal resource acquisition timing strategy that implicitly incorporates the option value of long term resource choices. While similar to the Council’s approach in its desired outcome, the methodology reviewed in this paper allows the option value of specific resource choices to be identified and quantified.

5. The term *random walk* describes a process, such as a market price, that evolves randomly over time. Given today's price, tomorrow's price will move up or down in an unpredictable or random manner.

6. This example is adapted from information in Chapter 3 of "Financial Options", edited by Figlewski, Silber, and Subrahmanyam, 1990, which presents a full development of the Black-Scholes model and the Binomial model of option valuation.

7. Note that to simplify the illustration, a discount rate of 0% has been assumed.

8. The cases presented are drawn from analyses actually conducted by New England Electric. Some assumptions and facts have been altered to preserve the Company's negotiating position in present and future dealings in competitive power markets. The alterations have been designed to retain the important features of each case study.

9. This approach was first suggested to New England Electric by Tom Parkinson of Northbridge Associates.

10. Volatility, as used in the remainder of this paper, is defined as the percentage by which the net benefit may increase or decrease during each period. In the cases presented, the period is equal to one year.

11. An interesting example illustrating this point using coal and oil-fired resources is presented in *Investment Under Uncertainty*, Dixit and Pindyck, 1994, on pages 51-54.