Investment, Risks and Policy Innovation in the Electricity Supply Sector: A White Paper Prepared for the EIA Workshop on Consumer and Investor Decision-Making and the Use of Expectations

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Introduction

The National Energy Modeling System (NEMS) provides a basis for analyzing energy markets and policies in the United States. The Energy Information Administration is currently considering the role of expectations and risk in the model. This white paper was prepared to contribute to the review with a discussion of expectations and investment in the electricity supply sector.

In the past two decades, the electricity supply sector has moved from a relatively homogeneous industry characterized by state regulatory oversight or public ownership to a still-evolving, partially deregulated industry that varies significantly across states and regions. Investment decisions in the two regimes are fundamentally different. In the regulated states, where vertically integrated utilities are primary investors in generating capacity, the basic paradigm is for the utility and state regulators to negotiate over an investment program intended to produce generating capacity adequate to meet expected demand. The result is typically a portfolio of projects that addresses the cost, reliability and environmental goals of the regulatory authorities and additional profit-making needs of the utility.

Electricity suppliers in restructured states operate subject to environmental and reliability constraints imposed by state or federal regulators, but investments focus on maximizing profits. The calculation about profitability requires estimates about probable revenues in future years which depend on both demand for electricity and the investments of others – that is, whether the contemplated investment turns out to be competitive with alternative sources of power.

In principle, most of the dimensions of risk that affect decisions under each regime are similar: regulators, utilities, and merchant generators all strive to determine the least cost means of generation, the best technological opportunities, an accurate demand estimate, the likely construction obstacles (including public concerns that could affect licensing proceedings), and the impact of plausible future regulatory constraints. Cost-side risks exist in both regulated and restructured states, although they are typically muted for investors in regulated markets. But in restructured states, investors are faced with additional revenue-side uncertainty, as neither prices nor sales are guaranteed to anywhere near the degree that they are in regulated markets. This additional source of risk magnifies the impact of the risks associated with regulatory delays and policy changes. As a result, the extent and character of uncertainty is crucial to both the timing and choice of their investments.

These issues are developed below. Section two sketches out the principal ways uncertainty affects investment decisions in the electricity supply sector. The key concepts are net present value, risk premiums and real option values. Section three applies these concepts to investments in electricity supply, and reviews some evidence for the importance of option values to the timing and nature of investments in electricity generation. Section four returns to the question of how different risks have a differential impact on investment decisions in regulated and restructured states.

Real option value theory presents an analytical structure within which an actual option value – the value of delaying investment – is calculated as a function of the problem's parameters: the costs of investing at different times, alternative pay-offs and, most critically, the likelihood of different future outcomes. In even moderately complex situations, the calculations are difficult and require a great deal of information about the probability distributions over the range of outcomes. Efforts to calculate precise values are probably futile for the investment decisions of interest to NEMS, and may even be irrelevant, as the investors themselves are similarly constrained by a lack of information. Nevertheless, both empirical studies and interviews, reviewed in section 3, and the analyses in sections 2 and 4 suggest that investors in the electricity supply sector do take into account approximate or relative option values, if not a precise calculation. In the concluding section we discuss potential approaches for including relevant option value considerations in the NEMS model.

Section 2: Risk premiums and real options: uncertainty and investment in irreversible assets.

The reference point for decisions about a potential investment is its net present value (NPV). In a certain world, investment firms compare future revenue streams to expenses, including the initial investment, discount all future values to a present value-equivalent so as to allow valid comparisons for expenditures undertaken or revenues acquired at different points in time, and commence a project if the comparison is favorable – that is, when its NPV is positive.

Uncertainty over the profits or costs introduces two costly complications. First, the cost of capital for a risky endeavor is subject to a "risk premium" - an add-on to the interest rate charged by a lending bank - that reflects the possibility that the investor may not be able to meet subsequent obligations and will default on financing.

The risk premium varies not only with uncertainty over a project's outcome but also with the relationship between the project and other investments. Some projects can be bundled into a portfolio with a lower aggregate risk either because the individual portfolio elements have independent likelihoods of failure (e.g., outages at generating facilities that run on different fuels or have different technological characteristics) or because they are negatively correlated. An example of the latter is the price of natural gas and the price of electricity in much of the United States. An increase in gas prices is usually accompanied by an increase in wholesale electricity prices so that a package of both is less volatile than either alone: the profits from sales of high-priced gas prices can offset purchases of expensive electricity and vice versa.[1]

The portfolio may be assembled by parties other than the project manager. Contracts can shift the risk of a project to a third party through either a bilateral contract (e.g., a contract specifying sales of power in the future at a fixed price to an identified individual) or through a futures market. Instruments that allow risk to be shifted are often characterized as allowing the risk of a project to be borne by the individual or entity in the best position to do so. While risk preferences may enter such purchases, the key to the transaction is the range of other assets controlled by the purchaser, and hence the overall risk of his portfolio. The existence of markets for risk allows a much broader range of portfolio options, and hence reduces the risk premiums associated with individual projects.

A multitude of instruments exist for the risks associated with electricity projects. Derivatives, insurance, and pools provide hedging opportunities for uncertain fuel input prices, construction cost overruns, demand variability and (some) licensing delays.

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[1] EIA (2002) discusses a very wide range of risk-reducing opportunities, and the barriers to exapnding those opportunities in the electricity industry. See also IEA (2003).

While determining the appropriate premium for specific projects is complex, as a general proposition, greater volatility in either input prices or output prices confers a penalty on a project. In addition, when barriers exist to risk-shifting, the risk premium may be much higher due to limited portfolio, or diversification opportunities. Reasons for lack of markets, discussed further in section 4, include legal constraints on future contracts, lack of transparency in pricing or output decisions, or lack of sufficient uncorrelated investment opportunities. Earthquake and flood insurance, for example, carry high risk premiums relative to automobile insurance because if the disaster occurs, all of the insurees would file claims simultaneously.

A second modification to evaluating investments under uncertainty in electricity generating capacity is the real option value.[2] Drawing its name by analogy from financial options, the idea behind real option theory is that an investing firm effectively has an option to undertake some real investment (e.g., an electricity generating unit). If the investment is irreversible, it can be built at most once, just as an option can either be exercised (once) or allowed to expire. At each point in time, the investment's value might be measured by the risk-adjusted net present value, described above. Given uncertainty, the value changes over time, as some of the uncertain parameters are realized and expectations are updated. Thus, the investor faces the problem of choosing the best time to invest. Delaying investment will typically involve a penalty when the better potential outcomes are realized as revenues which will not materialize until further in the future. But the delay also allows information to accumulate which may lead to a more appropriate course of action.

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[2] There is a rich and well-developed economics literature on the relationship between the quantity and timing of investments and uncertainty. For an overview and discussion, see Pindyck (1991).

For example, investing in a coal-fired facility today may be a very good investment if there is strong economic growth and little concern with environmental pollution in the future. Alternatively, should a strict carbon emissions reduction policy be imposed, the plant might not be able to operate and would instead become a liability. Suppose that today the investment is acceptable, as the likelihood of a strict environmental control regime is small, the profits from sales of power are likely to be large, and the cost of the plant is manageable. But, it might be even better to wait a year, observe changes in the regulatory and policy regime, and then decide whether to undertake the investment or abandon it altogether in favor of a different type of plant. If, after a year, environmental controls remain lax and economic growth is strong, the investor can still build the plant, and foregoes only the lost year of revenues. But should the economy falter or emission controls look more likely so that the expected profits from the plant are no longer sufficient to justify its cost, the investor saves construction costs that would have been expended up to that time.

If there is no uncertainty about future costs or profits of an investment, its option value is zero: when a project passes an NPV test there is no benefit to delay. Similarly, if investment is fully reversible, then there are no benefits to delay as an incorrect investment can be costlessly corrected. But with uncertainty and some degree of irreversibility, the investor may be better off delaying investment until conditions become clear, retaining the option to invest in a different plant, place or business. A project's option value at each point in time is the value of delaying investment (keeping the option) rather than undertaking construction.

Uncertainty thus confers two costs on projects: the risk premium, which makes a project expensive relative to non-risky investments, and the option value, which gives investors an incentive to hold off on a project. The size of these costs depends only in part on the volatility associated with the investment, or the specific risk that pertains to the project. Additional considerations include whether the risk can be diversified, the ease at which contracts can be written or markets established so that risks can be assumed by third parties, and the extent to which investments are irreversible.

Section 3: Are real option values a consideration in real investment decisions?

Option values are extraordinarily difficult to calculate for electric generating plants. In a recent study, the International Energy Agency (2003) surveyed firms, and concluded that, "the real options approach has achieved little acceptance by power generation investors to date. Calculating the real options value of a power plant has proven to be a less reliable indicator of value than financial options are in the stock market for a variety of reasons. Unlike financial markets, forward markets for electricity and natural gas are not sufficiently liquid. The models must therefore rely on forecasts ... These forecasts, and the correlation between electricity and natural gas prices, are highly uncertain ..."[3] The IEA concluded that individual investment decisions in such plants are based instead on "market fundamentals": factors such as expected demand growth, rather than an explicit calculation of volatility. But this conclusion begs the question about whether option value considerations are included in the decision, even when an explicit calculation is not available. In fact, substantial evidence exists that the general principals of option pricing are integrated into investment decisions, so that ignoring its existence – equivalent to assuming its value is zero – may introduce more

[3] IEA (2003), p. 41.

errors into models of investment than the imprecise estimates that are the best the data allow. This section provides some examples.

Ishii and Yan (2006) provide direct evidence of real option values in the timing of investment decisions by merchant providers of electricity. They focus on the uncertainty introduced by state efforts to restructure electricity markets in the 1990s and introduce some degree of competition in generation. The regulatory policies themselves were then in flux, introducing policy uncertainty which varied across states in identifiable ways. The advantage of their approach (in addition to illuminating the impact of the public policy) is that the policy variation identifies measurable differences in the relative risk environments facing different investors. If the utilities incorporate uncertainty into investment decisions as described in the previous sections, then we should find well-defined differences in investments between high-uncertainty and low-uncertainty states.

Ishii and Yan observe a clear relationship between investment delay and policy uncertainty. They conclude that merchant generation companies held back on investments in states where the restructuring regimes were shaky and their ultimate fate unclear. This conclusion is reflected in a survey conducted by the General Accounting Office (2002) which queried developers of electricity generating capacities and found, in general, a relationship between risks (from any source) and the levels of investment, consistent with the predictions of an option analysis: "Higher risk levels can cause developers and commercial banks to delay investment until expected profits outweigh the increased risk, according to developers."[4]

Uncertainty is also predicted to affect the choice of generating units. Units subject to greater volatility over prices or inputs, and a higher degree of irreversibility

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[4] GAO (2002), p. 27.

have larger associated option values. Teisberg (1993) provides evidence for investment patterns consistent with an option value analysis in the choices of regulated utilities prior to industry restructuring. By the late 1970s, utilities' returns to investment, while stable by current industry standards, were subject to much greater risks than in the years prior to 1970. Inflation in construction costs, environmental-policy related construction delays, and the unsettling precedent of cost disallowances in some rate-making cases introduced substantial uncertainty over the ultimate returns to investments, particularly for capital intensive technologies with long construction periods. Teisberg shows that in response, utilities turned to projects that had lower capital costs and shorter construction periods, even though a traditional NPV calculation (including the relevant risk premiums) would have favored more capital-intensive technologies.

The IEA, in the same study quoted above, concedes that actual investments do respond to the volatility and risk associated with different alternatives, in particular, that uncertainty over future price levels favors "flexible short lead-time technologies" such as gas-fired power generation over large hydro and nuclear plants.[5] This preference is consistent with an options analysis on two counts. First, the estimates of price levels in the near future can be made with more confidence than those further off. The shorter construction schedule of the gas plants means that projected revenue streams are subject to less uncertainty than for the hydro and nuclear units. The option value of delay is thus lower, as a better estimate of actual NPV is available immediately. Second, the relative "flexibility" of the gas plants means that less investment falls in the irreversible category than for the "inflexible" technologies.

[5] IEA (2003), p. 90.

Including real option values can modify policy recommendations. A good illustration is given by Roques and Savva (2006) in their analysis of price caps.[6] Price caps limit the price charged when there is a shortage of electricity due to high demand, capacity outages, or transmission congestion. Implemented in most liberalised markets as a way of restraining market power abuse, the price caps are intended to discourage strategic withholding of capacity because the incentive to do so – very high prices associated with shortages – is removed. At the time of the California Energy Crisis, price caps were touted as a way to expand capacity.[7]

Irrespective of industry structure and the potential for market manipulation, sufficient volatility in demand means that the price caps may occasionally engage due to actual shortages rather than strategic withholding. The cap then produces two anti-investment effects. First, an appropriate price signal about the value of the shortage is not available, short-run profits are curtailed, and, irrespective of uncertainty, capacity expansion is inefficiently low.[8] Second, the price cap shifts the distribution of returns in a way that sharply increases the option value for capacity additions. As Roques and Savva demonstrate in a simulation, a typical price cap results in dramatically higher option value and in significant delays in the construction of new capacity – and hence higher prices. Their analysis concludes that in a Cournot oligopoly where there is opportunity for strategic withholding, an optimal price cap (one that minimizes prices) exists that balances the oligopoly problem of high price due to strategic withholding with high prices due to delayed investment from the implied option value. This cap is higher

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[6] see also Grobman and Carey (2001). A general treatment is provided in Earle et al., (2007).

[7] Borenstein (2002).

[8] A concise explanation and illustration of these arguments is presented in Joskow (2006).

than would be recommended through consideration of both strategic withholding and the direct disincentives from improper pricing during shortages.

Section 4. Risks, regulation and market structure

The studies discussed in the previous section suggest that changes in the risk environment can have important implications for investment decisions and policy conclusions. They thus pose a quandary for the NEMS model, which attempts to predict capacity additions on the basis of cost and technological conditions but, at present, does not incorporate assessments of the environment for risk or option values associated with different technologies under different conditions.

We expect that risk leads to (1) lower rates of investment (2) technological choices that favor reversible investments and (3) technological choices that allow rapid completion of generating units. Predictions from NEMS are likely to overstate investment and derive a biased mix of technologies if option values are ignored in the model. We consider here some systematic variations in policy that might help in determining when the bias is important.

Restructured electricity markets are based on the principle that prices are set in a market and that sellers and buyers bid for business. Numerous constraints modify this model, but in general some degree of competition exists in these states. Neither prices nor sales are guaranteed. Similarly the regulated model, where prices are set in rate hearings and capital projects assured a “fair” rate of return, overstates the security of the business. However, the two models are still sharply distinguished by the degree of uncertainty surrounding prices and profits over the life of an investment in electricity supply.

Electricity demand and supply are inherently volatile. Unique features of electricity markets that contribute to this volatility include the inability to store energy, the high value on reliable supply, and the lack of demand elasticity, which result in very high prices during periods of shortage. At the other end, the marginal cost of power from base load plants is very low so that prices are very low when capacity is ample. Finally, demand varies enormously over the year, in both predictable and unpredictable ways. In the regulated states, the risks are largely assumed by rate payers who support the construction and availability of reserve capacity and pay for fuel price variations through fuel cost adjustment clauses.

In restructured markets, alternatively, spot prices exhibit dramatic volatility. Between 1996 and 2001, the average annual volatility in the electricity spot market price was about 400% in the restructured markets, while none of the comparison commodities (oil, gas, metals, crops) was over 100% and most were under 30%.[9] Price caps of course moderate the high end of the range, but the risks remain impressive.

As is discussed in the Introduction, the key determinant of risk premiums is not variation in the price of an item per se, but the extent to which it can be diversified. Among restructured states, variation exists over diversification opportunities. In 2002, Pennsylvania and Texas had what was considered transparent rules and food opportunities to manage risks, while both legal rules and market conditions sharply limited forward contracting opportunities in California. According to a GAO survey, developers much prefered doing business in the former states.[10]

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[9] EIA, (2002), p. x.

[10] GAO (2002)

Considerable effort has been expended in restructured states to enhance the ability of investors to manage their risks, but overall, futures markets for electricity sales are considered to be poorly developed, and even forward contracts for capacity typically cover many fewer years than the planning period for investments. [11]

A range of problems contributes to the lack of futures markets in addition to the challenges posed by the need for electricity markets to clear instantaneously and associated price volatility. Market prices, especially in peak periods, do not reflect cost conditions due to price caps and, perhaps more importantly, the policies followed by dispatchers to manage reserve capacities and maintain reliability during periods of high demand.[12] Furthermore, the markets are not genuinely competitive, and concerns remain about the potential for suppliers to manipulate prices, as was observed during the California energy crisis. Legal restrictions against forward contracts remain in some states, and uncertainty persists as to the validity of some of the contracts that have been executed.[13] Absent reference prices and transparent markets, associated markets for diversifying future risks are unlikely to develop.

A second distinction between the regulated and restructured states is in the area of political risk. Regulated utilities are in theory subject to the whims of regulators, who could disallow expenditures or otherwise modify rate recovery. But a range of laws and

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[11] By contrast, the risks from fuel prices variability can be diversified. Natural gas is the most price-volatile fuel in the industry, but its price is highly correlated to electricity price so that come of the variability can be passed through to consumers or wholesale purchasers.

[12] A large literature addresses the inadequacies of risk management in restructured electricity markets. Important contributions include Bushnell (2005), Cramton and Stoft (2006), and Joskow (2006), who propose a variety of mechanisms that would facilitate forward contracts or capacity commitments. See also EIA (2002), Wolak (2004), Allaz and Vila (1993).

[13] In 2002 the GAO reported that, "investors are even more cautious about investments that rely on California's electricity markets. The lack of stable market rules presents uncertainty regarding the eventual market in the state. In addition, the perception that the state is seeking to abrogate the long-term contracts it signed last year has raised concerns about the finances of some projects." GAO (2002).

court decisions protect the utilities, and events like the disallowances examined by Teisberg are very unusual. Nearly all of the restructured states, by contrast, are still struggling to determine market rules and policies, which is plausibly another reason why the futures markets have yet to develop. Possible changes with implications for the profitability of investments run from relatively modest, such as changes in price caps, to potentially profound, such as changes in transmission policies or the advent of real-time pricing. Indeed, the standard markets risks – future variability in prices, market demand, and sales – are to a large extent endogenous to policy actions. More efficient transmission and the ability of prices to generate real-time demand responses may very substantially smooth demand loads and price volatility.[14]

Finally, the range of non-diversifiable future risks that face investors in restructured states means that even those risks that are common to them and to investors in regulated states are more costly. Licensing delays mean that a plant will commence operations further in the future – when the revenue stream is, for investors in restructured states, less certain. This distinction is recognized by the investors surveyed in the GAO's 2002 report:

> Developers told us that regulatory risks, such as lengthy and uncertain state approval processes and stringent environmental compliance requirements, were not, by themselves, obstacles to building a power plant in a state. Rather, they said, these factors can increase a project's risk because it is more costly to build and operate and because long-term projections about market conditions are less reliable. (p. 27)

[14] Policy risks – typically not diversifiable at all – and the endogeneity of the other risks to policy is probably the most important reason for the absence of adequate futures markets for electricity sales.

Section 5: Conclusions

Uncertainty is a critical component of the environment for investments in electricity supply. It affects both the level of investment and the mix of technologies. Ignoring either the existence of uncertainty of the differences in it across states may significantly distort predictions of investments and costs, as well as attempts to analyze the impact of public policies such as a carbon emissions control strategy.

The impact of uncertainty of specific investments is usefully summarized in the risk premium attached to capital costs of the project and the real option value of the investment. These numbers are not observable in the electricity supply industry, where a host of issues, many related to the reasons for why uncertainty is important to investment, have combined to limit the scope or existence of futures markets.[15]

Two sets parameters affect the relative size of these costs. The first might be termed environmental, and includes three key components. First, the ability to diversify relevant risks lowers risk premiums. Important parameters affecting diversification include (1) the flexibility allowed by state regulatory regimes; (2) the stability of state regulatory regimes and (3) the extent to which the markets in restructured states are competitive. Second, the existence of policy uncertainty, which is typically non-diversifiable, enhances the risk premium. Third, potential policy innovations may dampen the extent of market risks, particularly demand uncertainty.

The second set of parameters characterize technological choices. Variations in the cost of capital due to risk premiums impact investments proportionate to their capital requirements. Option values impact investment to the extent that (1) the investment is

[15] Nevertheless, some excellent studies have recently used the financial options framework to analyze policy issues within a simplified model of an electricity system (e.g., focusing on a subset of the risks) and produced useful and insightful results. See, e.g., Reinelt and Keith (2007); Roques et al (2006); Ishii and Yan (2004).

irreversible and (2) the timing of the returns to the investment coincide with uncertainty over revenues and costs. Project size, the length of the construction period, and the life of the facility each factor into the calculation.

Investment choices under uncertainty depend on both sets of parameters, as the technological parameters interact with the environmental conditions to generate both risk premium and an option value. Considering mechanisms to include even relatively crude rankings (e.g., categories of states based on regulated status or, for restructured states, the availability of diversification opportunities) may illuminate the impact of uncertainty on investment decisions.[16]

[16] Of course, we hope that regulatory policies improve over the time period that NEMS attempts to model. An interesting exercise would be to include a range of plausible values associated with risk premiums in different states and consider the investment consequences of successful policy innovations.

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