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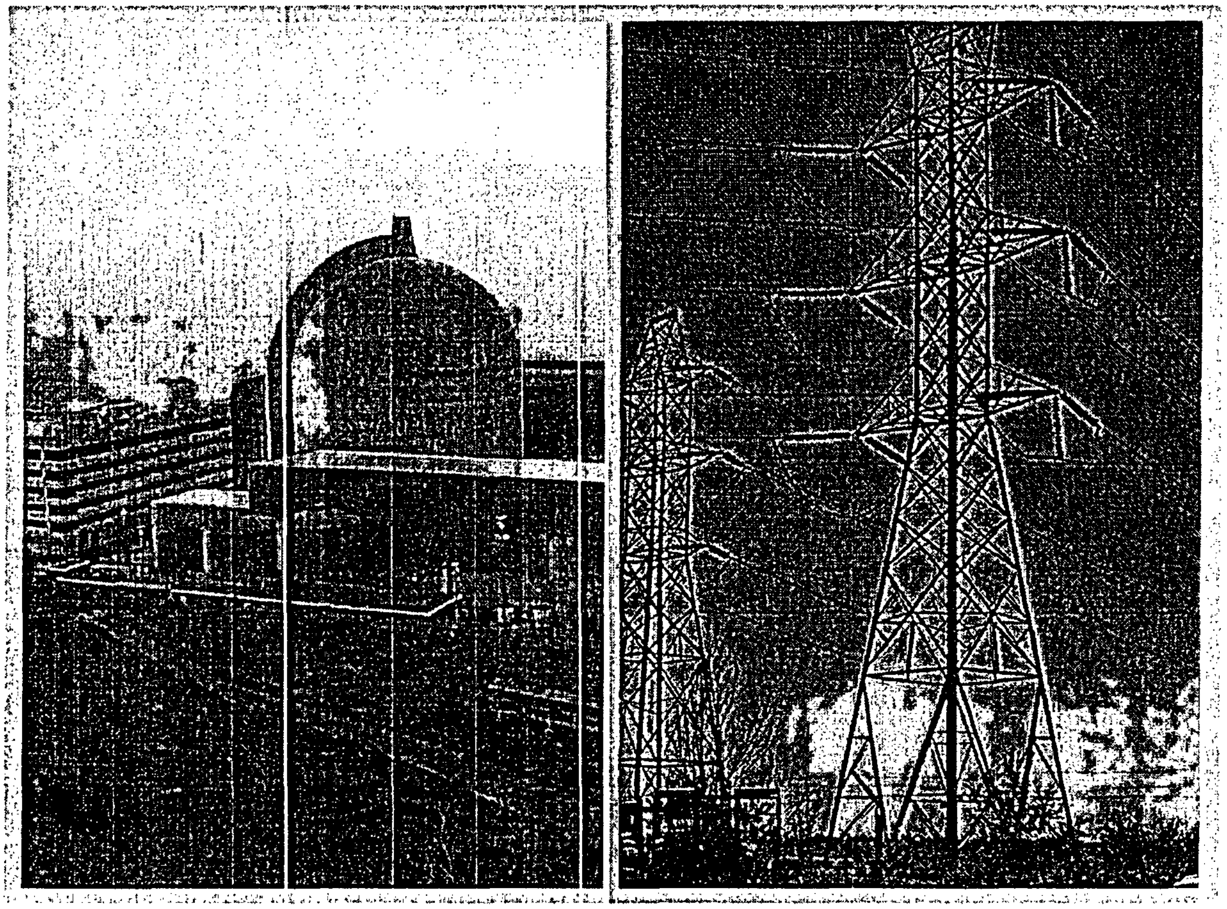
THE ECONOMIC FUTURE OF NUCLEAR POWER



A Study Conducted at The University of Chicago

August 2004

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U.S. NUCLEAR REGULATORY COMMISSION
In the Matter of Louisiana Energy Services, L.P.
Docket No. 70-3103-ML Official Exhibit No. NIRS/PC 239
OFFERED by: Applicant Intervenor NIRS/PC
NRC Staff Other
IDENTIFIED on 2/13/06 Witness/Panel Staff Panel
Action Taken: ADMITTED REJECTED WITHDRAWN
Reporter/Clerk Bethany Engel

Template=SECY-028

SECY-02

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THE ECONOMIC FUTURE OF NUCLEAR POWER

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Chapter 5. FINANCING ISSUES

Summary

As a prelude to considering energy scenarios for the future, which will be the capstone of the study in Chapters 9 and 10, this chapter develops the basic financial model used to analyze nuclear energy economic viability. Features of the U.S. tax system are introduced. Risk is considered in some depth. To provide a benchmark for the energy scenarios for the future that will contemplate alternative nuclear energy policies, the model is used to estimate the sensitivity of economic viability to uncertainties in the no-policy case.

Taxes

Recognition that nuclear energy plants will be owned and operated by utilities or other private providers requires introducing tax treatment of debt and equity, deduction of depreciation from taxable income with effects of different allowed depreciation schedules, effects of special tax provisions, and effects of inflation on taxes.

Risk

The perceived risk of investments in new nuclear facilities is widely appreciated to contribute to the risk premium on any new nuclear construction. Principal sources of risk are the possibilities that new plants will exceed original cost estimates and that construction delays will escalate costs. In this chapter guidelines from the corporate finance literature are used to specify likely relationships between project risk and risk premiums for corporate bonds and equity capital. Risk premiums have an important influence on the economic competitiveness of nuclear energy. A 3 percent risk premium is used for the first few plants.

No-Policy Scenarios

In using the financial model to study sensitivity to uncertainties, an overnight cost range for new nuclear plants of $1,200 to $1,800 per kW is used, based partly on the three technologies discussed as being realistic in Chapter 3. Given the capital cost range, the LCOE of new nuclear plants in the absence of policies is from $53 to $71 per MWh, with a 7-year construction time. The range is lower at $47 to $62 per MWh with a 5-year construction time. Costs remain outside the range of competitiveness with coal and gas, which have LCOEs of $33 to $41 per MWh and $35 to $45 per MWh, respectively.

The nuclear LCOE for the most favorable case, $47 per MWh, is close but still above the highest coal cost of $41 per MWh and gas cost of $45 per MWh. Longer debt terms and longer plant life span reduce nuclear LCOEs, but still do not bring them into the competitive range. The impact of construction delays is large, particularly if a 2-year delay occurs after all outlays have been made—capable of making the nuclear LCOE range from $61 to over $76 per MWh. These no-policy results provide benchmarks indicating the extent to which policies to be considered in Chapters 9 and 10 are needed to reduce nuclear LCOEs.

Outline

5.1. Introduction

To ascertain the conditions under which nuclear power will be competitive in the marketplace requires a financial model of private sector decisions. The required model is more elaborate than the LCOE model of Chapter 1 used to compare LCOEs in previous studies, because of tax considerations omitted there. Within the required financial model, careful attention is paid to rates of return on debt and equity that investors will demand in view of market perceptions of the riskiness of nuclear power investments. Introducing these considerations permits estimation of the cost of electricity that will have to be covered by revenues of operators of new nuclear facilities if these facilities are to be viewed by the private sector as warranted investments. These costs in the no-policy case are the starting point for considering policies that would make nuclear power competitive.

Section 5.2 develops the financial model that will be used for policy analysis in the present study. Section 5.3 reviews the finance literature for guides to risk premia and capital structure to be expected for new nuclear facilities. Section 5.4 lays out baseline assumptions in the absence of policies aimed at the nuclear power industry and applies the financial model to arrive at LCOEs in the no-policy case. Sensitivities to the baseline assumptions are explored.

5.2. The Financial LCOE Model

5.2.1. Basic Equation

The levelized cost of electricity, or LCOE, is defined as the constant real price of electricity over the life of the plant that compensates debt and equity investors at their required rates of return. Interest on debt accrues during the construction period and debt holders are repaid with equal annual payments over the debt term. Equity holders invest during the construction period and receive profits after tax and debt payment over the plant life. The LCOE is the electricity price that yields the internal rate of return required by equity holders on the returns accruing to them.

Equity is considered, with debt as an expense, rather than treating them symmetrically as in the pre-tax LCOE model, because of the different tax treatment of debt and equity returns. LCOE is the electricity price that solves the following equation:

PRESENT VALUE OF EQUITY INVESTMENT DURING THE CONSTRUCTION PERIOD

= PRESENT VALUE OF NET REVENUE EARNED BY EQUITY OVER THE LIFE OF THE PLANT

where

NET REVENUE = EARNINGS FROM LCOE REVENUE BEFORE INTEREST AND TAXES (EBIT)

– INTEREST EXPENSE – TAX EXPENSE + DEPRECIATION – REPAYMENT OF DEBT

Annual gross revenue equals the quantity of electricity generated multiplied by its price. Revenue in each year t is calculated as annual electricity production multiplied by the nominal electricity price in year t: $R_t = Q_t L_t$. Electricity production is calculated as plant capacity in megawatts (W) times the capacity factor (CF), times the number of hours in the year: $Q_t = W \cdot 8760 \cdot CF_t$. The nominal electricity price (L_t) in year t is the levelized cost of electricity (LCOE) in 2003 prices compounded at the rate of inflation from the year of the plant's opening, at time $t = 0$: $L_t = LCOE(1+\pi)^t$, where LCOE is the real price of electricity expressed in 2003 dollars, and π is the annual inflation rate.

The expenses consist of yearly fuel cycle costs described in Appendix A5, plus other yearly variable and fixed operating and maintenance costs and insurance as described in Section 1.4, plus decommissioning costs. The expenses are assumed to grow at the rate of inflation.

The spreadsheet model uses the GoalSeek function of Excel to solve the equation iteratively for LCOE.

5.2.2. Capital Investment

Overnight cost is the real dollar capital cost at the beginning of the construction period and is allocated equally to each year of the construction period. To accommodate the features of the tax system in this model, it is necessary to allow for inflation, so the real capital cost must be converted into nominal dollars over the life of the plant. Accordingly, the nominal outflow in each year of the construction period, recorded as negative revenue prior to the beginning of electricity sales, is:

$$I_t = C \cdot (1/n) \cdot (1 + \pi)^t,$$

where C is real overnight cost expressed in 2003 dollars, n is total construction time in years, I_t is the nominal investment in construction year t, where construction is from $t = -n$ to $t = -1$. Investment is assumed to occur at the beginning of a calendar year.

5.2.3. Interest

Interest costs are deductible against the corporate income tax. They are affected by risk considerations, which will be analyzed, and by loan guarantees, which is one of the financial policies that will be considered.

5.2.4. Taxes

Corporate income tax payments as well as state and local taxes are subtracted from revenues. As discussed more fully below, taxes give rise to depreciation allowances. Moreover, the policies aimed at the nuclear power industry to be considered in this study operate through affecting tax expense. These policies include investment tax credits, production tax credits, and accelerated depreciation.

5.2.5. Depreciation

Depreciation only becomes effective in an LCOE calculation when taxes are considered, because it is an allowance in the tax code that permits subtraction of an amount of capital expense from a year's taxable income. With no taxes, the only requirement is to recover the capital cost over the life of the plant. The life of the plant matters, but the time path at which the plant is assumed to depreciate is irrelevant.

A percent of the depreciable asset base can be deducted from gross income each year. Depreciation begins as the plant starts to operate. Two schedules are employed in the model, the Modified Accelerated Cost Recovery System (MACRS) and Straight Line, to examine the impact of different depreciation methods on LCOE. The Modified Accelerated Cost Recovery System (MACRS) schedule is a 1986 modification of the Accelerated Cost Recovery System (ACRS), which was established by the Economic Recovery Tax Act of 1981. Both ACRS and MACRS represent a departure from previous depreciation rules which were closely allied to financial depreciation concepts that attempt to depreciate an asset over its economic lifetime. The federal tax code assigns a 15-year depreciation period to electric utility plants under MACRS (IRS 2002, p. 93). MACRS allows declining balance or straight-line depreciation for classes of assets that include power plants. Declining balance is used here.

The depreciable asset base is measured in nominal dollars at the time of disbursement. Consequently a lengthier construction period, or a delay at the end of a construction period, would reduce the depreciable asset base relative to overnight costs because inflation has more time to raise other prices. This effect reduces the real value of the allowable deduction from revenues and hence would reduce the value of the depreciation allowance. While inflation has offsetting effects on revenues from electricity sales and prices of fuels and O&M outlays, the effect on the depreciation is not neutral.

During the construction period, part of the financing comes from debt investors and the other from equity holders. According to accounting rules, interest on debt outstanding is capitalized and added to the depreciable asset base, so the total asset base consists of nominal debt investment, equity investment, and interest expenses during the construction period. The depreciable asset base excludes equity appreciation.

5.3. Theory and Evidence of Risk Premiums and Capital Structure

This section is concerned with risk associated with new nuclear plants. The purpose is to develop guidelines for returns on equity, returns on debt and debt-equity ratios, to be used in the financial modeling of the present study. Section 5.3.1 characterizes the risks facing investments in new nuclear plants. Section 5.3.2 reviews studies of effects of uncertainty on decisions to build nuclear plants. Section 5.3.3 deals with required return on equity, 5.3.4 with required returns on debt, and 5.3.5 with debt-equity ratios. Section 5.3.6 addresses the choice of debt maturity.

5.3.1. The Nature of Financial Risks Facing New Nuclear Plants

New plants built in the United States in the next decade will have designs that have never been built in the United States, which increases the construction risks perceived especially on the first few units. Construction overseas of these designs, or closely related ones, will reduce only a part of the construction risk perceived for U.S. construction.

New nuclear power plants are large because the additional size improves the economics of a plant's thermal properties. The large size of the investment can add to the risk premium, particularly when the effect of the additional capacity coming on line in a particular market is considered. Some new coal plants are the same size or larger, which will tend to raise their risk premiums, but even the larger coal plants are expected to take only an average of 4 years to build. The length of the construction period (5 to 7 years) can further add to perceived financial risk (Lesceour and Penz 1999, p. 13).

The regulatory process was a source of construction delays and cost overruns during the 1970s and 1980s. The recent combining of construction and operating licenses into a single step gives hope that construction delays and uncertainties encountered in the last generation of nuclear plants can be avoided in new construction, but in the absence of actual experience, there is a perception that nuclear plants are riskier than others, as discussed by Scully Capital (2002a, 2002b).

5.3.2. Previous Studies of the Decision to Build Nuclear Plants

The influence of risks on an investor's willingness to undertake a nuclear power investment depends on the source of the risk as well as the level. Pindyck (1993) uses a model with two types of uncertainty to calculate critical values of expected capital cost in nuclear power plants, that is, costs above which an investor will not undertake a project, or if the project has begun, will cancel it. One type of uncertainty is technical uncertainty; the other input is cost uncertainty. Technical uncertainty involves uncertainties in completing the project. These uncertainties become resolved over the implementation period of the project—they either show themselves to be innocuous, and the project is completed, or they prove to be insuperable, and the project is abandoned. These risks are largely diversifiable. The input cost uncertainties are largely or totally outside the control of the investor. Wage rates and costs of materials are determined in larger markets, and in the case of nuclear power projects, these uncertainties include the possibility of regulatory changes. Input cost risk is partly nondiversifiable, because the input prices will be correlated with overall economic activity. The greater is the degree of input cost risk, the lower is the critical value of the expected capital cost that determines the go/no-go decision. The higher are perceived technical risks, the higher is the expected capital cost that the investor will tolerate.

A simple investment rule, using a risk-free interest rate, gives a critical value of capital cost per kW. Converting the 1982 prices from Pindyck's Table 3 (p. 70) to 2003 prices reveals a range on critical capital cost values from a high of $2,448 to a low of $1,649.

Investment is assumed to go forward as long as expected capital costs do not exceed these values.

Pindyck's study assumes a price of electricity and, using a risk-free interest rate, determines the threshold price of capital above which an investor would not buy a nuclear power plant. In contrast, the approach of the present study assumes a required price for capital, and using a weighted average cost of capital that includes an interest premium, determines the price of electricity.

Sommers (1980), using a logit regression analysis of 113 utilities, found that greater uncertainties about nuclear capital costs and construction times lowered the probability that a utility would invest in a nuclear plant rather than a coal plant. Capital cost uncertainty had a stronger dampening effect on the likelihood of a utility's investing in a nuclear plant than did the relative capital cost of nuclear and coal investments.

While the Sommers study corroborates the importance of risk factors this study has identified, it focuses on the probability that an investor would undertake construction of a nuclear plant. In contrast, the present study addresses the incentives that would be required to induce investors to undertake construction.

5.3.3. Required Rates of Return on Equity

5.3.3.1. Traditional CAPM and Its Irrelevance to the Present Study

The most widely used model of equilibrium equity asset pricing remains the capital asset pricing model (CAPM) of Sharpe (1964), Lintner (1965) and Black (1972) and Mossin (1966). The central implication of the CAPM is that expected returns for each asset (let this be r_i for asset i) should bear a linear relationship with the expected returns of the market as a whole. The CAPM equation is $r_i = r_f + \beta_i (r_m - r_f)$, where β_i is a measure of co-movement of each firm with the market. Expected stock returns are higher for firms with high correlations with the market return. Investors demand a premium for holding stocks which are highly correlated with the market, that is, for holding non-diversifiable or systematic risk. A model very similar to the CAPM is a consumption-based capital asset pricing model (CCAPM). This model suggests that expected asset returns have a linear relationship with overall marginal utility of consumption as determined by performance of the economy at large. Though there have been other theories of equilibrium asset pricing, CAPM and CCAPM are still most prevalently used. CAPM has become a central tool of financial analysis in the finance industry (see for example Graham and Harvey (2001) who find that firms rely heavily upon CAPM techniques).

CAPM and CCAPM do not include an effect of own variance of asset returns, a property often considered to be counter-intuitive. The reason for lack of effect of own variance is brought out in the Markowitz (1959) portfolio selection model (a building block of CAPM). Investors can completely rid themselves of any assets' idiosyncratic risk by diversifying, through the holding of a market basket containing essentially an infinite number

of securities. Since total market risk cannot be diversified away, only the correlation of securities returns with the market remain as a determinant of a security's value.

The evidence of the empirical validity of CAPM is mixed at best. Representative studies are Black, Jensen, and Scholes (1972), Fama and MacBeth (1973) who found limited success for CAPM over some years, and Fama and French (1992) who find no evidence at all for the CAPM. Banz (1981), Chan and Chen (1991), Stattman (1980) and Rosenberg et al. (1985) find that other factors besides CAPM beta help to explain equity returns, contrary to the central tenant of CAPM. The industry has continued to use the CAPM as a central tool in financial analysis, probably due to 1) its theoretical attractiveness, 2) its easy applicability using easily accessed data 3) lack of a better alternative and 4) its widespread base of understanding among forty years of MBA graduates.

A fundamental point for the present study is that new nuclear plant risk is idiosyncratic and not market risk. The risks involve events that are specific to a nuclear plant and have no expected correlation with overall market events. Thus, according to strict CAPM theory nuclear plant risk should have no effect on investors' valuation of the firm, and thus no effect on the required rate of return on equity for a firm building a nuclear plant.

5.3.3.2. Idiosyncratic Risk

Notwithstanding CAPM theory, own variance (the variance of a stock's returns) and idiosyncratic risk (the standard deviation of the error term from a regression of firm returns on the market over time) are also sometimes tested used as determinants of expected stock returns, such as in Douglas (1969). These measures fell out of favor in the face of the rapid acceptance of the CAPM and in light of alternative explanations for why own-variance effects may falsely appear to explain asset returns, such as is described by Miller and Scholes (1972) and tested by Fama and MacBeth (1973) and Roll and Ross (1980). However, idiosyncratic measures of risk have recently become a focus of renewed attention.

More recent papers, Tolley and Nielson (1992) and Nielson (1993), have reexamined this effect and have found support for own variance, both theoretically and empirically. Using techniques similar to Fama and French (1992), Nielson (1993) finds that own variance indeed explains some of the cross-variation in expected stock returns. Nielson also supports the size and the book to market (B/M) effects discussed above, but finds evidence that these may be proxies for the own variance effect. For a further contribution and references to other recent studies where own variance affects returns, see Tolley and Nielson (2003).

5.3.3.3. Previous Studies of Nuclear Power Equity Returns

Some papers have addressed the financing of nuclear plants specifically. However, these studies are for facilities built in the 1970s and 1980s in an environment which may not be similar to plants in the future. Most importantly these studies were done when the plants were fully operational, after they had been completed. Therefore they have little if any bearing on uncertainty about prospective construction costs for a plant with new technology

not yet built or for regulatory uncertainty surrounding the decision to build a plant, which are risks of concern the present study. Farber (1991) studied the effect of adopting nuclear technology on equity costs of electric utilities prior to the Three Mile Island (TMI) accident. Farber studied the effects on equity returns of thirty-six nuclear power adopters and twenty-five non-nuclear firms. He concluded that adoption of a nuclear plant increases a firm's CAPM equity beta. In addition, he concluded that the leniency of regulators may moderate the risk-increasing effect of nuclear power. Brooks and D'Souza (1982), Bowen et al. (1983), and Fraser and Kolari (1983) found that the TMI accident appeared to increase the expected beta risks of four utilities owning nuclear capacity, although Uselton et al. (1986) subsequently found the effect to be transitory.

Hearth et al. (1990) examine the effect on stock prices of cancellations of nuclear power plants. The authors found that decisions to cancel nuclear power plants under construction appeared to result in significant negative excess stock returns. This loss was found to be bigger with the ratio of the sunk costs relative to the utility's market value. Kalra et al. (1993) measure the U.S. stock market reaction to the April 1986 nuclear Chernobyl power plant accident. The authors found that after the Chernobyl event the betas for all power utilities (conventional, mixed and nuclear) rose.

Fuller et al. (1990) studied the reaction of financing environment of three special events: Three Mile Island accident, the Chernobyl catastrophe and the Washington Public Power Supply System bond default. Based upon the authors' cross-sectional analysis it was estimated that a 3 percent increase in the allowed rate of return for nuclear utilities would have been required to offset the discount associated with nuclear power.

Hill and Schneeweis (1983) use stock price data to study the effect on the stock returns of public utility firms of the TMI nuclear accident. The authors find that impact of the Three Mile Island accident on non-nuclear electrical utility firms was less than that on nuclear based utilities. Hewlett (1984) found that investors in nuclear firms required a 1 to 2 percent risk premium.

As noted, since these studies refer to utilities that already had nuclear plants, refer to a past regulatory environment, and in some cases rely on estimates of beta no longer accepted in the literature, they are at best suggestive and in any case give little if any help in choosing a required rate of return applicable to a firm that will build a new nuclear plant in the future.

5.3.4. Required Rates of Returns on Corporate Bonds

The academic literature generally assumes (see Elton et al., 2001) corporate debt carries the same rate of return as U.S. Treasury Bonds plus a premium. The premium is comprised of three parts 1) a premium for expected default risk, 2) a state tax premium (as income from corporate bonds is taxed and Treasuries are not), and 3) a premium for attracting risk-averse investors.

Theoretical reduced-form models explaining risky bond prices (and therefore expected returns) include Duffie and Singleton (1997), Jarrow et al. (1997), Lando (1997), Das and Tufano (1996) and Madan and Unal (1998). Option-based models stemming from the Black-Scholes (1973) option pricing formula are found in Merton (1997), Longstaff and Schwartz (1995), Galai and Masulis (1976), and Jones and Rosenfeld (1984).

The academic studies attempting to empirically explain corporate bond rates are sparser than for equities. Elton et al. (2001) find that most of the third part (risk aversion factor) is responsible for most of the bond premium, and that expected default premium is responsible for the least. Barrett et al. (1986) find a decrease in utility bond prices as a reaction to the 1979 Three Mile Island nuclear power plant accident.

Bond rating firms, most notably Standard and Poor's and Moody, appear essentially to evaluate default probability. Recent corporate bond yields were (from Moody, November 2003, twenty-year maturities) 5.54 percent for the AAA rated bond, 5.88 percent for the AA grade bonds, 6.03 for the A rated bonds and 6.59 percent for the Baa grade bonds. For comparison, the yields on twenty-year U.S. Treasury bonds during the same period were about 5.1 percent.

Altman and Kishore (1998) find the following percentages of par recovery rates one month after firms declare bankruptcy by grades of debt : AAA have about 68 percent rates of recovery, AA and A have about sixty percent, BBB bonds have about 49 percent, BB 39 percent, B and CCC 38 percent, and default have zero percent recovery rates.

5.3.5. Debt-to-Equity Ratios

The finance literature on the determinants of the debt-equity ratio is mixed. A starting point is the Modigliani and Miller (1958) study showing that under certain assumptions the debt-equity ratio is irrelevant. Current opinion is split between two main competing theories, neither of which is completely convincing in light of empirical tests. First, the static trade-off model proposes that firms have a target debt-equity ratio. In this model, debt has certain advantages: debt possibly lowers taxes, increases monitoring of management and motivates management. These advantages are weighed against debt's drawbacks, as noted in Jensen and Meckling (1976) and Myers (1977): possibly higher expected bankruptcy costs and higher costs due to agency problems.

The main competing theory is the Myers (1984) and Myers and Majluf (1984) pecking order theory. Here, asymmetric information and transactions costs drive firms to finance operations in the following order 1) retained earnings, 2) safe debt, 3) somewhat riskier debt and finally 4) riskier debt and equity. Once again, equity is more expensive due to asymmetric information: management knows more about firm outcomes than outside financiers who will, sometimes, be induced to buy over-priced equity. That is, equity will be over-priced due to asymmetric information, management knows that current shares are over-priced, reducing debt.

Much of the empirical work of an academic nature related to debt-equity ratios does not focus on risk. Work which does speak to risk generally finds a small role for risk in capital structure. See for example, Marsh (1982), Ghosh et al. (2000), Kale et al. (1991) and Fama and French (2003).

There is an on-going debate on whether industry-specific effects on debt-equity ratios exist. Schwartz and Aronson (1967), Scott (1972), Scott and Martin (1975), Bowen et al. (1982), Martin and Henderson (1984) and Bradley et al. (1984), Hull (1999), and Sibley (1999) find inter-industry differences in debt equity ratios. Remmers et al. (1974), Belkaoui (1975), and Sekely and Collins (1988) all fail to find evidence of differences in debt-equity across industries. Graham and Harvey (2001) surveyed 392 CFOs regarding their use of financial tools and targets. The responses indicated that if firms do have leverage targets, those targets are quite soft.

5.3.6. Debt Maturity

Multiple factors influence corporate borrowers' and lenders' choice of debt maturities. Moreover, debt maturity, debt-equity ratio and risk premium are interrelated. A number of models relate risk and capital structure to maturity choice, but no comprehensive model of all three choices has been found. The first sub-section (5.3.6.1) places maturity choice within the general context of the term structure of interest rates. The second sub-section (5.3.6.2) addresses informational asymmetry problems that may pose important risks in financing new nuclear power plants. The third sub-section (5.3.6.3) deals with the influence of other risks on maturity choice, and the fourth (5.3.6.4) discusses the influences of transaction costs and taxes. The fifth sub-section (5.3.6.5) addresses interactions between choices of debt maturity and capital structure. The sixth sub-section (5.3.6.6) reviews empirical evidence on risk and debt maturity. The final sub-section (5.3.6.7) summarizes.

5.3.6.1. Term Structure

The term structure of interest rates underlies debt maturity choices. An important consideration is the slope of the term structure, i.e., rate of rise of interest rates that must be paid as maturity length increases. Empirical evidence has shown that firms take into account the relative cost of short- and long-maturity bonds when issuing debt (Barclay and Smith 1995, Guedes and Opler 1996, Stohs and Mauer 1996, Graham and Harvey 2001). Other things being equal, firms gravitate to shorter maturity instruments when term structure slopes are steep, and toward long term instruments when slopes are shallow or negative. However, the slope of the term structure is clearly not the only determinant of maturity choice as the following sub-sections bring out.

5.3.6.2. Influences of Asymmetric Information on Debt Maturity Choice

When a lender either cannot assess the accuracy of a borrower's information regarding a project, or when a lender cannot easily monitor the actions that a borrower agrees to undertake as part of a loan contract, asymmetric information problems exist. One problem

is signaling. Another is the principal-agent, or agency, problem. Both problems are amenable to sorting solutions. Lenders devise a menu of debt maturities and interest rates that would leave them equally well off and let borrowers reveal their private information by selecting a particular combination that best serves their own interests.

In the signaling problem with private information, lenders cannot easily assess the accuracy of information borrowers provide. This situation occurs for construction cost estimates for new nuclear power plants. As the Scully report (2001a) brought out, one concern of investors is that vendors' cost estimates may not be borne out. Modeling of this problem suggests that borrowers with prospects that are unobservable to lenders choose short-term debt due to bond holders' fears that the firm may have poor prospects and consequently would be willing to give low rates only for short term bonds (Flannery 1986; Kale and Noe 1990; Rousseau 1999; Diamond 1991, 1993; Diamond and Rajan 2001; Berger et al. 2003). Firms with good prospects that are observable only to management sell short-term bonds because management knows that after its prospects are recognized as good by lenders, the firm can then re-finance at lower rates. Barclay and Smith (1995) find evidence that firms use debt maturity to signal information and firms with larger information asymmetries issue shorter term debt, and Benmelech (2003) finds evidence that firms with more salable, or redeployable, assets have longer debt maturities, implying a possible signaling with maturity. Antoniou et al. (2002) find no association of debt maturity with firm quality among French and German firms, which they suspect is due to those countries' legal structures, and modest support for signaling with maturity among U.K. firms. Bali and Skinner (2003) find evidence that higher project risk leads to shorter maturity.

In a well-known financial agency problem (Jensen and Meckling 1976; Myers 1977), firms that are recognized as having opportunities to transfer wealth from bondholders to equity holders by increasing the riskiness of their operations during the term of the contract, can signal their willingness to forego such opportunities by selling debt at the shorter end of the maturity spectrum. In the case of a loan on a nuclear power plant, where agency costs could exist is in ensuring construction quality. As part of the regulatory process, the utility must specify the characteristics of the plant in considerable detail. The U.S. Nuclear Regulatory Commission (NRC) reviews the plans, and under the revised 10 CFR 52, will issue a combined construction and operating license. Permission to operate is subject to confirmation that the actual construction conforms to plans. This supervisory function of NRC serves at least partially to assure the lender that the borrowing utility is performing according to contract. From the lender's perspective, if the construction is not performed in accordance with the contract, which would be determined by NRC inspections, the borrower would incur additional construction costs, possibly jeopardizing the repayment of the loan. A utility could signal its belief that its construction quality will meet NRC's standards by taking a shorter maturity loan.

5.3.6.3. Effects of Non-Informational Risks on Debt Maturity Choice

Liquidity risks tend to push debt maturities to the long end of the spectrum. A temporary problem could force issuers to refinance at unattractive rates. If bad news about a borrower arrives near the refinancing date, investors would raise the default premium on new debt. Firms with projects that could experience temporary problems will be motivated to hold longer-term debt, so as to face the debt renewal less frequently (Johnson 1967, Flannery 1986, Diamond 1991).

Some firms will want to match maturities of their liabilities and their assets. This motivation would be stronger when transactions costs and liquidity risks are higher (Mitchell 1991, Sarkar 1999). A bond would mature at the date an asset is to be sold or begin generating positive cash flow, avoiding both the need to roll over shorter maturity bonds and the higher cost of longer term bonds. Morris (1976) finds that financing long-lived assets with short-maturity debt could decrease the uncertainty of net income if interest rates are positively correlated with net operating income.

5.3.6.4. Transactions Costs and Taxes

Small debt issues have proportionally higher transactions costs than large issues. Large firms, such as those likely to build new nuclear power plants, would tend to choose shorter term debt to take advantage of lower market rates at the shorter end of the term structure (Fisher et al. 1989). In general, long-term debt allows its holders greater flexibility in timing of capital gain and loss declarations, and this flexibility is an option having value. Firms can sell long-term bonds for relatively more than short term bonds if this tax-timing option is highly valued (Brick and Palmon 1992).

Interest rate volatility reduces the present value of debt tax shields from short-term financing, making long-term debt attractive when interest rates are volatile (Guedes and Opler 1996, Brick and Ravid 1985, 1991; Kim et al. 1995). If new nuclear plants reached financing stages during a period of volatile interest rates, borrowers could be expected to want longer debt maturities. Kane et al. (1985) model the tax advantage to debt, net of a market premium for added bankruptcy risk, adjusting maturity and the debt-equity ratio to maximize firm value including the tax shield, with the result that optimal maturity is negatively associated with the tax advantage of debt. As the value of a tax shield falls, the debt-equity ratio falls and maturity lengthens. Policies that reduced tax obligations on new nuclear plants could increase the value of longer maturities.

5.3.6.5. Interactions between Choices of Debt Maturity and Capital Structure

To the extent that risks are affected by both debt-equity ratios and debt maturity, the two choices will be made simultaneously. For example, in a world of agency problems, should the debt-equity ratio be so low that bankruptcy is almost impossible, the incentive to lower debt maturity as a signal would disappear and the firm would move to a longer

maturity. In this way there is a trade-off between debt-equity ratio and debt maturity (Lee et al. 1983, Diamond 1991, Leland and Toft 1996, Elyasiani et al. 2002, Ju and Ou-Yang 2003).

5.3.6.6. Empirical Evidence on Relationships between Risk and Debt Maturity

Stohs and Mauer (1996) find that larger and less risky firms with longer-term asset maturities use longer-term debt, debt maturity varies inversely with earnings surprises and a firm's effective tax rate, and firms with high and very low bond ratings use short-term debt. Guedes and Opler (1996) find that large firms with high credit ratings tend to borrow at very short and very long terms, while low rated firms borrow at the middle of the spectrum, which they suggest is consistent with a trade-off between liquidity and agency effects.

5.3.6.7. Conclusions on Debt Maturity

Debt maturity is influenced by both project and firm characteristics. The choice of maturity involves a trade-off with interest rates and the debt-equity ratio. Informational uncertainties tend to encourage shorter-term debt. Firms financing assets that are either riskier or perceived to be riskier typically find some advantage to borrowing at shorter maturities, other influences being equal. Tax considerations and the correlation of a firm's income with economy-wide indicators such as interest rates or a stock market index also can influence maturity choice. The debt-equity ratio and maturity tend to move in opposite directions in the valuation of tax shields. A judgmental conclusion is that the various influences, on net, work against choice of highly lengthy maturities in the financing of new nuclear power plants.

5.3.7. Conclusions on Financial Effects of New Nuclear Plant Risk

Most of the finance literature on equity returns, bond returns and debt-equity ratios has dealt with a large number of considerations, with risk as such being considered if at all as only one consideration. The bottom line is that no readily identifiable - much less empirically verifiable - estimate of the effects of a new nuclear plant on a firm's finances is available from the literature. A strand running through the work reviewed is that with judicious relaxation of the stringent assumptions of traditional finance theory there could be an effect of own risk. It should be noted that, apart from academic investigation, received opinion of practitioners is that these effects exist both for equity and debt returns. The literature does, however, suggest relatively shorter debt terms for investments with the characteristics of new nuclear plants. The foregoing considerations inform the judgmental choices of financial effects of new nuclear plants to be used in the financial modeling of the present study.

5.4. No-Policy Scenario Analyses of LCOEs

Section 5.4.1 reviews the characteristics of nuclear and fossil plants that contribute to their relative economic advantages. Section 5.4.2 reports the values of cost and performance

and market variables used in the LCOE calculations in the benchmark no-policy case. Sections 5.4.3 and 5.4.4 discuss the use of these variables in sensitivity and scenario analysis.

5.4.1. Nuclear versus Fossil Plants: Economic Advantages and Disadvantages

Nuclear power has several advantageous economic characteristics, but also suffers from a number of disadvantageous characteristics as perceived by investors, as summarized by LaBar (2002). Advantageous economic characteristics are as follows:

- Low and predictable fuel and operation and maintenance (O&M) production costs. Nuclear production costs exhibit low volatility over both the short and long term because the primary energy source, uranium ore, represents a very small fraction of the total production cost. On the other hand, the cost of the primary energy source in fossil-fired plants is a large fraction of the production cost.

- High capacity factors. The operating nuclear plants in the United States now consistently achieve fleet-average capacity factors in the 90 percent range. The projected lifetime averaged capacity factors for competing baseload gas-fired combined cycle plants are in the range of 80 to 85 percent.

- Long Operating Lifetime. Operating lifetime licensing extensions have been obtained for several U.S. nuclear plants and more are expected in the future. New nuclear plants are being designed for a 60-year life. On the other hand, there is little experience in the long-term operation of competing baseload gas-fired combined cycle plants. Nominal gas-fired combined cycle plant lifetimes are not expected to exceed 25 years.

Disadvantageous economic characteristics of nuclear power are:

- Large plant size. Most new nuclear power plants are designed in the size range of 1,000 to 1,350 MW to gain economy of scale benefits and reduce the capital costs per kW. A drawback of this size range is high potential for exceeding demand growth. Widely used baseload gas-fired combined cycle plants are in the range of 500 to 600 MW.

- Large capital outlay. Total overnight capital costs of new nuclear plants are estimated to be in the $1,000 to $1,800 per kW cost range. For a 1,350 MW plant at $1,600 per kW, an investment of $2.16 billion can be required, excluding interest costs. The competing baseload gas-fired combined cycle plant capital cost is in the $450 to $650 per kW range. A 600 MW combined cycle plant at $650 per kW would require an investment of less than $0.4 billion.

- Long construction time. The construction time for new nuclear plants, even if optimized to achieve short construction times, is in the range of 3 to 4 years. The construction period for competing gas-fired combined cycle plant is about 2 years.

- Investment financing. The higher capital cost results in a higher total investment at risk and the longer construction time results in higher interest costs during construction as well as longer time-at-risk. These factors contribute to required returns on equity and debt.

The investment-financing hurdle may become easier to overcome as nuclear plant ownership has become increasingly concentrated. Twelve utilities, plus Tennessee Valley Authority (TVA), now own and operate nearly two-thirds of plants. The larger owners, now with 75 percent of U.S. capacity, are able to manage a portfolio of units. They can consider financing new units based on a larger balance sheet of total asset value. In addition, stock prices of nuclear utilities have recently outperformed non-nuclear utilities (Scully Capital 2002). Thirteen utilities account for 75 of the 103 nuclear plants and all of them are operating more than 2,000 MW of electrical capacity.

5.4.2. Parameter Values Used for the No-Policy Case

Table 5-1 identifies the parameter values used for the important parameters in calculations of LCOEs under the assumption that no policies are employed.

The three capital costs correspond to four nuclear plant designs, each with its own overnight cost, selected for analysis, as already discussed in Section 3.4. To review, one design is a mature plant, the FOAKE costs on which have already been paid. The ABWR and ACR-700 are such designs. Their overnight cost is assigned a value of $1,200 per kW. Another design is a plant that has not yet been built, the FOAKE costs on which are yet to be paid, such as the AP1000. On the assumption that the entire FOAKE cost is assigned to the first plant, this plant's cost is $1,500 per kW. The third capital cost is chosen to represent the Framatome reactor under consideration for construction in Finland. Its overnight cost is $1,800 per kW.

Table 5-1: Parameter Values for No-Policy Nuclear LCOE Calculations

Item	Parameter Value
Overnight Capital Cost	$1,200 per kW $1,500 per kW $1,800 per kW
Plant Life	40 years
Construction Time	7 years
Plant Size	1,000 MW
Capacity Factor	85 percent
Hours per Year	8,760 hours
Cost of Debt	10 percent
Cost of Equity	15 percent
Debt Term	15 years
Depreciation Term	15 years
Depreciation Schedule	MACRS[a]
Debt Finance	50 percent
Equity Finance	50 percent
Tax Rate	38 percent
Nuclear Fuel Cost	$4.35 per MWh
Nuclear Fixed O&M Cost	$60 per kW
Nuclear Variable O&M Cost	$2.10 per MWh
Nuclear Incremental Capital Expense	$210 per kW per year
Nuclear Decommissioning Cost	$350 million
Nuclear Waste Fee	$1 per MWh

[a]Modified Accelerated Cost Recovery System

5.4.2.1. Nuclear Construction Time

Nuclear construction projects are divided into several phases (DOE 2001a, pp. 13-16; DOE 2001b, pp.4-11 to 4-12). The start-up phase consists of early site permitting, design certification, plant licensing, site preparation, and procurement of long lead-time components such as pressure vessels and steam generators. Procurement continues during the construction phase. The final phase is start-up and testing. The stated DOE position of a 5-year construction schedule is based on the new streamlined regulatory policy. The base case in the present study is 7 years for anticipated construction time. This is the time period of major financial outlays prior to revenue generation from power sales. The business significance of this period is that it is a time of negative cash flow, during which interest costs accrue on expenditures. This duration is based on the assumption that the business community will form expectations taking account not only of the newer announced regulatory procedures but also of earlier experiences with construction times. The Scully interviews with financial and utility executives (Scully 2002a, p. 1-76), as well as anecdotal reports, reinforce the importance to the business community of expectations regarding construction time. Deutsche Bank's LCOE calculations for new nuclear power in the United States rely on a 7-year construction period (Smith and Hove 2003, Figure 66, p. 77).

Later policy scenarios in this study allow for revision of expectations from 7-year to 5-year construction times for later plants, based on more favorable than expected business outcomes with the first few plants. For simplicity, expenditures are assumed to occur equally in each year of construction. Experiments with more refined patterns of expenditures were found to be of little consequence.

It is important to recognize that the construction times used in the LCOE calculations are expected construction times, from which actual construction times may deviate. The profitability calculations that inform investment decisions are based on expected values of the variables in the LCOE formulation: sale prices of electricity, overnight cost, nuclear fuel costs, and O&M costs, as well as construction times. The influence of the expectation of the construction time on calculated LCOE is particularly important and has been of particular concern to the investment community. As noted above, the expectation of construction time for first plants will be heavily influenced by previous U.S. experience. However, new experience will give investors new data with which to update their expectations, and if construction times turn out to be the 5 years that DOE and vendors emphasize, investors will adjust their expectations accordingly.

5.4.2.2. Base Cost of Capital

The base cost of debt and equity to utilities was assessed from current Bloomberg's data (Bloomberg, Inc., 2004), adjusting for maturity and the currently abnormally low interest rates. The constituent firms of the Standard and Poor's 500 Utilities Index were used as the benchmark for the cost-of-debt and -equity calculations here because those data are widely used in gauging utility company performances. Individual data on weighted average costs (WAC) of debt and equity were taken for 37 of the largest utilities in the United States. Since Bloomberg reports the weighted average cost of debt post-tax, those numbers were converted to pre-tax with the formula WAC of Debt Before Tax = WAC of Debt After Tax / (1 – Effective Tax Rate). The effective tax rate for each utility is available from Bloomberg. The average WAC of debt for these utilities, adjusted to pre-tax basis, is 5.34 percent, and that for equity is 8 63 percent.

In its calculations of the costs of debt and equity for individual utilities, Bloomberg uses the 10-year U.S. Treasury bond as the risk-free rate, and adds its own debt and equity risk factors above that base rate. The 10-year generic government bond traded at 3.747 percent on the morning of March 15, 2004. The 30-year government bond traded at a spread of 1 percent above the 10-year rate, and the 15-year bond traded at 51 basis points above the 10-year bond. Thus, adjusting the Bloomberg capital cost estimates for a more appropriate maturity would add between .5 and 1 percentage point to the WACs of debt and equity reported in the previous paragraph.

The current bond yield is at a decadal low, as the Federal Reserve still holds the Federal Funds rate at 1 percent. These low rates are not expected to last long. It would be more appropriate to use an average of historical rates to smooth out the current aberration.

Using a 300-day moving average to smooth out the fluctuations in the yield on the generic 30-year government gives a return about 50 basis points above the current yield.

Thus the total adjustment to the base rates reported in Bloomberg, to account for term-structure and the currently low rates, is between 1 and 1.5 percentage points. These adjustments give a cost of equity between 9.64 and 10.13 percent and a cost of debt between 6.35 and 6.84 percent. For purposes of the present study, these capital cost estimates are rounded to 10 percent for equity and 7 percent for debt.

5.4.2.3. Risk Premium

While the finance literature has much to say about risk and bond and equity rates, it does not provide clear, quantitative guidance on the relationship between risk and interest rates, as the above review brings out. Many factors influence the relationship, and the subject is actively researched. Financial terms in recent nuclear construction overseas are not a satisfactory guide to a risk premium in the United States because of differences among countries in business practices, differences in business climate, varying degrees of involvement of governments in nuclear projects, and differences in regulatory regimes.

Themes in the above review are that nuclear plant risk is idiosyncratic (plant specific) rather than beta (market related) and that agreement is lacking on the effect of idiosyncratic risk on required returns. These considerations hinder estimation of the effect idiosyncratic risk as a variance concept. However, another and quite direct effect of nuclear plant risk is its effect on expected return. While risk leading to dispersion in possible future returns adds to variance, it also affects the expected returns if it is asymmetrical, as it is in the case of new nuclear plants. For the outcome where all goes according to plan, a normal projection of returns can be made. But the upside risk of favorable surprises is less than the downside risk from unforeseen delays and the like.

The investor maximizing expected returns will be indifferent between a security with normal market risk yielding a return of r and an investment with noticeable asymmetric downside risk yielding some higher return r_R, is needed to induce investors to hold the riskier security. The expected gross return for a security with normal market risk is $1+r$, which provides for paying back the original dollar invested. Through security pricing, investors will make $1+r$ equal to the expected return on a security with asymmetric downside risk. The expected gross return on the security with asymmetric downside risk is the gross return on a dollar invested $1+r_R$ times the probability that the investment will be successful, plus the probability that it will be unsuccessful times the fraction of the dollar that will be recovered if unsuccessful, or $[p_S + (1 - p_S)f_L](1 + r_R)$ where p_S is the probability of a normal or successful outcome and f_L is the fraction of the dollar that will be recovered in the event of an unsuccessful outcome. Setting $1+r$ equal to $[p_S + (1 - p_S)f_L](1 + r_R)$ and re-arranging gives

$$1+r_R = (1+r)/ [p_S + (1-p_S)f_L].$$

Letting the risk premium be ρ, so that $r_R = r + \rho$ and solving for ρ gives

$$\rho = (1 + r)\{-1 + 1/[p_S + (1 - p_S)f_L]\}$$

which in the special case where nothing is recovered ($f_L = 0$), gives $\rho = (1+r)[(1-p_S)/p_S]$.

Table 5-2 below shows risk premiums for different combinations of probabilities of experiencing an unsuccessful outcome and extent of loss in the event of such an outcome. Each scenario uses a normal rate of return of 10 percent.

Table 5-2: Risk Premiums for Alternative Investment Losses and Loss Probabilities, $1-p_s$

Probability of Unsuccessful Outcome ($1-p_S$)	Percent of Investment Value Recovered (f_L):				
	50	25	0	-25	-50
1.00%	0.6%	0.8%	1.1%	1.4%	1.7%
2.00%	1.1%	1.7%	2.2%	2.8%	3.4%
2.50%	1.4%	2.1%	2.8%	3.5%	4.3%
3.00%	1.7%	2.5%	3.4%	4.3%	5.2%
3.50%	2.0%	3.0%	4.0%	5.0%	6.1%
4.00%	2.2%	3.4%	4.6%	5.8%	7.0%
5.00%	2.8%	4.3%	5.8%	7.3%	8.9%
6.00%	3.4%	5.2%	7.0%	8.9%	10.9%

Loss of 50 percent of the value of the investment, in the first column of Table 5-2, would represent a case in which the investor considers it plausible that construction delays or higher-than-expected component costs could cause the new plant's LCOE to be considerably higher than the best case. Overruns of this magnitude can occur if cost overruns involve capital costs, which are the most important component of nuclear power costs, or if delays occur that increase the carrying or interest cost before plants begin operation, which again is an important cost component. A loss in asset value would be incurred. The cost overruns could cause the borrower to default on the loan, leaving the lender to sell the plant for a price consistent with an LCOE of competing coal or baseload gas plants which could be half that of the nuclear plant. A similar scenario could account for column 2, in which 25 cents on the dollar are obtained. The 100 percent loss in column 3 (0 cents on the dollar) would be associated with the prospect of not being allowed to open the plant after it is built, despite the structure of the new regulatory system. In columns 4 and 5, the lender also considers the prospect of getting its bond rating downgraded, in addition to its losses on the project. The project losses in these cases would decrease the asset value of the firm more extensively than through loss of the direct investment. Each of the alternatives is a set of possible outcomes expected to occur with probability less than one, a set of possible losses with associated

probabilities used by investors in assessing risks of equity and debt holding. These are possible losses, not actual losses.

Assuming that investors form consortia to spread their risks, the LCOE calculations in the present study use a risk premium of 3 percent. Such a risk premium is consistent with a 5.3 percent probability of the 50 percent loss (column 1 of Table 5-2), a 3.5 percent probability of the 75 percent loss (column 2), a 2.5 percent probability of the complete loss (column 3), and 2.1 and 1.8 percent probabilities of the losses to affiliated assets (columns 4 and 5). Informal conversations with a number of Wall Street analysts corroborated the reasonable magnitude of the 3 percent premium as a lower bound estimate.

5.4.2.4. Debt-to-Equity Ratio

Allowing for differences between market capitalization and book value, debt-equity ratios for the larger utilities in the United States currently average in the neighborhood of 50-50 (Bloomberg, Inc. 2004).

5.4.2.5. Utility Regulatory Status and Financial Risk

Regulation of electric utilities in the United States, which has included both rate-of-return and retail price regulation, has tended to shield utilities from market price risks, thus reducing their costs of capital (Joskow 1997; Hogan 2002). The Energy Policy Act of 1992, implemented with FERC Orders 888 and 889 in 1996, deregulated electricity wholesale markets. Presently 18 states and the District of Columbia are actively preparing to deregulate retail markets, and 10 other states have passed legislation to do so or are studying how to do so (PNNL 2004).

Evidence from both the United States and the U.K. suggests that the deregulation of the 1990s placed more of this risk on the firms, removing it from direct payment by consumers (Nwaeze 2000; Buckland and Fraser 2001). Whether the direct placement of risk on consumers or producers has a net negative or positive effect on retail prices appears to remain an open question. In the continued movement to further restructuring and retail deregulation, political and regulatory risks exist that tend to raise the hurdle rates for new generation investments in currently regulated states (Ishii and Yan 2004).

Under regulation, utilities occasionally faced the risk of having some portion of construction costs disallowed from their rate base. While rate-of-return regulation might prevent capital markets from charging risk premiums appropriate to such risks in new generation projects, both lenders and equity holders might decline to supply funds for projects with such risks without such compensation. It is not clear that the financial strength of a firm would have more influence than the characteristics of a project in the financial market's assessment of risk. While issuance of project bonds for a project perceived as risky by financial markets would incur a risk premium that senior debt for firm financing might avoid, the latter strategy could result in a general downgrading of the firm's debt, which could be more costly than the isolated project financing.

The full effects of deregulation and restructuring on capital costs for new generation capacity do not appear to be thoroughly understood.

5.4.2.6 Coal and Gas Construction Times and Overnight Costs

For its LCOE calculations, Deutsche Bank used an overnight cost of $1,119 per kW for pulverized coal baseload plants, with 4-year construction time, and $590 per kW overnight cost for gas turbine combined cycle (GTCC) baseload plants, with 3-year construction times (Smith and Hove 2003, Figure 65-66, pp. 76-77). MIT (2003, Table A-5.A.4, p. 135) used $1,300 per kW for pulverized coal plants and $500 per kW for GTCC generation, with 4- and 2-year construction periods respectively. Drennan et al. (2002) average EIA and Platt's data, deriving overnight costs of $1,182 per kW for coal generation and $588 for GTCC generation, with 3- and 2-year construction times respectively.

Investigation of recently planned pulverized coal plants and GTCC plants yielded ranges of overnight costs from $933 to $1,700 per kW for coal, with an average of $1,460, and $450 to $708 for GTCC, with an average of $567. Anticipated construction times for coal ranged from 2 to 5 years and for GTCC from 12 to 24 months (Alliant Energy 2004; Armistead and Barnes 2002; *Bristol Herald Courier* 2004; Calpine 2001; Dominion Energy 2001, 2004; Energy Info Source 2003; *Generation Markets Week* 2002; *Houston Business Journal* 2001; Lignite Energy Council 2004; Mazur 2003; *Merchant Power Monthly* 2004a, 2004b; Midwest Generation 2004; Minnesota Environmental Partnership 2004; Nebraska Public Power District 2003, 2004; NRG Energy 2004; Peabody Energy 2004; Reuters 2001, 2004; Sargent & Lundy 2004); The Shaw Group 2001; *Tyler Morning Telegram* 2004; Wisconsin Public Service Corporation 2002; Xcel Energy 2004).

5.4.3. Competitiveness of Nuclear Power in the No-Policy Case

Table 5-3 reports the first-plant LCOEs for the three reactor types, distinguished by their overnight costs, for 5- and 7-year construction periods. In each case, the plant life is 40 years, and the debt term is 15 years. The interest rate on debt is 10 percent and the return on equity is 15 percent. LCOEs in this and subsequent tables were derived using an iterative process that provides the appropriate return to equity based on free cash flow available to the utility.

The LCOEs reported in Table 5-3 are for first plants. Even though the ABWR and ACR-700 are of mature design, their construction experience has been outside the United States, so a first plant of one of these designs built in the United States should be considered a first-of-a-kind in this country, since only a portion of the overseas learning would be immediately transferable to the U.S. construction. The LCOE for the mature-design reactors ($1,200 per kW), with an optimistic 5-year construction period is $47 per MWh. The other two reactor designs have higher LCOEs, and a 7-year construction period would raise those costs. These LCOEs are calculated with a 15-year MACRS (Modified Accelerated Cost Recovery System) depreciation schedule. Using a 15-year straight-line depreciation schedule raises these LCOEs by about 4 percent.

Table 5-3: First-Plant LCOEs for Three Reactor Costs, 5- and 7-Year Construction Periods, $ per MWh, 2003 Prices

Construction Period	Mature Design, Foake Costs Paid, $1,200 per kW Overnight Cost	New Design, Foake Costs Not Yet Paid, $1,500 per kW Overnight Cost	Advanced New Design, Foake Costs Not Yet Paid, $1,800 per kW Overnight Cost
5 years	47	54	62
7 years	53	62	71

A question for the LCOEs of Table 5-3 is how close they are to the LCOEs of competing fossil generation. Tables 5-4 and 5-5 report the LCOEs for coal and gas generation, for alternative capital costs, fuel prices, and construction periods.

In Table 5-4, the coal plant's overnight cost ranges from $1,182 per kW to $1,430 per kW. The low overnight cost is an average of costs used in Drennan at al. (2002), originating from EIA and 2002 Platt's data. The mid-range of $1,300 per kW was used by Reis and Crozat (2002), and the high cost is an average of recently announced pulverized coal generation projects. See Section 6.2.4 for further discussion regarding new coal plants. Projected construction times for recently announced pulverized coal plants in the 1000 MW size range have varied from 2 to 4 years. The coal price of $1.02 per MMBtu is an average of prices used in Drennan at al. (2002), also originating from EIA and 2002 Platt's data; the price of $1.23 per MMBtu corresponds to 2003 delivered coal prices; and the price of $1.15 per MMBtu is EIA's 2004 forecast for 2015, with subsequently declining real prices. Coal plants are assumed to be financed at interest rates of 7 percent on debt and 12 percent on equity. Considering different capital costs, coal prices and construction times, the range from the scenarios is $33 to $41 per MWh.

Table 5-4: LCOEs for Pulverized Coal Plants, 85 Percent Capacity Factors, Alternative Overnight Costs, Coal Prices and Construction Periods, $ per MWh, 2003 Prices

	Overnight Cost								
	$1,182 per kW			$1,350 per kW			$1,460 per kW		
	Coal price, $ per MMBtu								
	1.02	1.23	1.15 & Varying over Forecast[a]	1.02	1.23	1.15 & Varying over Forecast[a]	1.02	1.23	1.15 & Varying over Forecast[a]
	Cost per MWh								
2-yr construction	33	35	35	36	38	37	37	39	38
3-yr construction	34	36	35	37	39	38	38	40	39
4-yr construction	35	37	36	37	39	39	39	41	40

[a]From a price of $1.15 per MMBtu in 2015, the forecast varies between $1.13 and $1.14 through 2020; rises to $1.15 through 2022; and reaches $1.16 in 2023, at which level it remains for the remainder of the plant life.

In Table 5-5, the gas plant's overnight cost ranges from $500 per kW to $700 per kW. The low and high overnight costs represent the range reported in recent GTCC plants, while the mid-range cost is an average of costs used in Drennan et al. (2002). Recent construction times have ranged from 12 to 24 months. The gas price of $3.39 per MMBtu is an average of prices used in Drennan at al. (2002), originating from EIA and 2002 Platt's data. It corresponds to an average of 2001 and 2002 gas price forecasts for the period 2010 to 2015. The price of $4.30 per MMBtu corresponds to the 2003 gas price forecast for the same period; the price of $4.25 is EIA's 2004 forecast for 2015, and that forecast has gas prices rise to $4.51 by 2020, which accounts for the slightly higher LCOEs under that price forecast than under the constant price of $4.30 per MMBtu. As with coal, the interest rates are 7 percent for debt and 12 percent for equity. The lowest LCOE is $35 per MWh, and the highest is $45 per MWh.

Table 5-5: LCOEs for Gas Turbine Combined Cycle Plants, 85 Percent Capacity Factors, Alternative Overnight Costs, Gas Prices and Construction Periods, $ per MWh, 2003 Prices

	Overnight Cost								
	$500 per kW			$588 per kW			$700 per kW		
	Gas price, $ per MMBtu								
	3.39	4.30	4.25 & Varying over Forecast[a]	3.39	4.30	4.25 & Varying over Forecast[a]	3.39	4.30	4.25 & Varying over Forecast[a]
	Cost per MWh								
1-yr construction	35	41	42	36	42	43	37	44	44
2-yr construction	35	41	42	36	43	43	38	44	45

[a]From a price forecast of $4.25 per MMBtu in 2015, a peak of $4.51 is reached in 2021, from which the forecast falls to $4.48 by 2025, at which level it remains for the remainder of the plant life.

Comparison of the $47 per MWh LCOE of the $1,200 per kW built in 5 years, in Table 5-3, with either of the fossil LCOEs in Tables 5-4 and 5-5, shows no surprise. No observers have expected the first new nuclear plants to be competitive with mature fossil power generation without some sort of temporary assistance during the new technology's shake-down period of the first several plants. However, the comparison of the LCOEs in these three tables shows the magnitude of the competitive gap that any policies would have to bridge.

5.4.4. Sensitivity Analysis for First Nuclear Plants

Before proceeding to the analysis of such policies in Chapter 9, sensitivities of the no-policy case to several parameters are considered. Table 5-6 reports the effects of a longer plant life than the 40 years used in the LCOEs reported in Table 5-3, as well as alternative capacity factors and construction periods. As Table 5-6 shows for the $1,200 per kW ABWR or ACR-700 reactor, a 60-year plant life has a minimal impact on the LCOE, because of the discounting of the additional 20 years of life span beginning 40 years from the present, regardless of capacity factor or length of construction period.

Table 5-6: Effects of Capacity Factor, Construction Period, and Plant Life on First-Plant Nuclear LCOE for Three Reactor Costs, $ per MWh, 2003 Prices

Capacity Factor, Percent	Overnight Cost					
	$1,200 per kW		$1,500 per kW		$1,800 per kW	
	5-year construction period					
	Plant Life		Plant Life		Plant Life	
	40 years	60 years	40 years	60 years	40 years	60 years
85	47	47	54	53	62	61
90	44	43	51	50	58	58
95	42	41	49	48	56	55
	7-year construction period					
	Plant Life		Plant Life		Plant Life	
	40 years	60 years	40 years	60 years	40 years	60 years
85	53	53	62	61	71	70
90	50	49	58	58	67	66
95	47	47	56	55	64	63

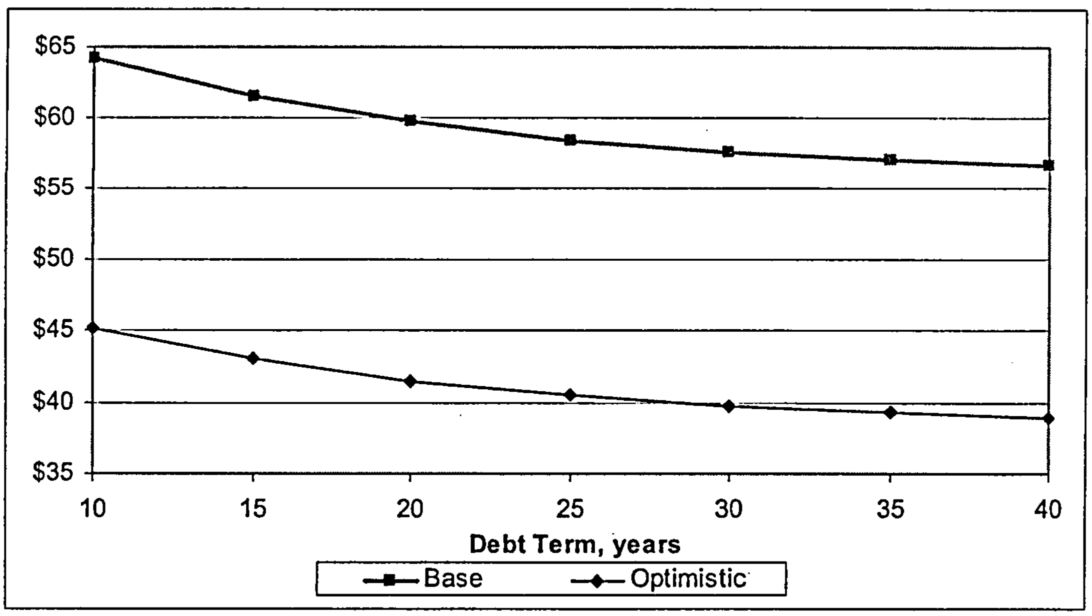
With an 85 percent capacity factor, the additional 20 years of plant life reduces the LCOE of the $1,200 per kW plant by $0.72 per MWh if it can be built in 5 years, or by $0.79 per MWh if construction takes 7 years. The $1,500 and $1,800 per kW plants experience similar impacts.

Capacity factor adds directly to the ability to produce revenue. The base capacity factor of 85 percent may appear low relative to recently achieved availability levels in U.S. nuclear plants, in the range of 90 to 92 percent. Some questions have been raised whether those high levels are sustainable, and it is worth considering that capacity factor in a newly opened plant may be something below its long-term operating level, which would have a large effect on discounted revenues and correspondingly raise LCOE. Table 5-6 also reports the sensitivity of the LCOEs of Table 5-3 to variations in capacity factor, from 85 percent through 95 percent, for 5- and 7-year construction periods. The $1,200 per kW plant could achieve an LCOE as low as $42 per MWh with a 95 percent capacity factor, if the plant could be built in 5 years.

Lengthening the debt term reduces the LCOE. The upper line in Figure 5-1 shows the LCOE of a first $1,500 per kW plant, built in 7 years, with debt terms ranging from 10 years to 40 years. Varying the debt term by 30 years from a short term of 10 years to a long term of 40 can reduce the LCOE by a little more than 10 percent. While addressing such financing structure can help keep the LCOE down, by itself it is not a panacea.

The lower line of Figure 5-1 supposes that each cost and performance parameter is at its most optimistic value and examines the effect of changing the debt term. This calculation is for a plant built in 5 years, at $1,200 per kW overnight cost, with 60 percent debt and 40 percent equity, and expecting a 60-year operating life. Debt and equity interest rates remain at 10 and 15 percent. The LCOE with a 25-year debt term is $40 per MWh, and extending the debt term to 40 years by only another $1.50 per MWh, to $39 per MWh. This is close to the range of gas-fired power, but the combination of cost and performance assumptions is probably too optimistic for a first plant. Nonetheless, the ability of shifting the basic cost and performance parameters within a range of values that may be realistic for a later plant offers promise for the commercial viability of some n^{th} plant in the future.

Figure 5-1: The Effect of Debt Term: First-Plant LCOEs for a $1,500 per kW, AP1000, and $1,200 per kW Plant with Reduced Construction Time and Higher Debt Ratio, $ per MWh, 2003 Prices



The impact of construction delays is addressed in Table 5-7. The $1,500 per kW reactor design is chosen for illustration. Two cases are considered in a 7-year construction period. The first row of the table reports the LCOE with no construction delays. The second row reports the impact of a 2-year hiatus in construction coming in the middle of the construction period, and the bottom row places the delay after 7 years, when all construction outlays have been expended but power sales from the plant have not been allowed to begin.

A 2-year delay in the middle of the construction would increase the interest component of total capital costs enough to raise the LCOE 12 percent above what it would be in the absence of delays—from $62 to $69 per MWh. A comparable period of delay after all

expenditures have been put out at interest would raise the LCOE by 24 percent. The seriousness of construction delays for economic viability cannot be underestimated.

Table 5-7: The Impact of Construction Delays on the First-Plant LCOE of a $1,500 per kW Plant, $ per MWh, 2003 Prices

No delay	62
Delay in middle of construction period	69
Delay after end of construction period	76

An inflation rate of 3 percent is used in all LCOE calculations. Experimentation indicates some sensitivity of the real LCOE to the inflation rate. To keep the real interest rate constant, when varying the inflation rate, a corresponding adjustment is made in the interest rates. For example, to experiment with a 2 percent inflation rate from a base rate of 3 percent, 1 percentage point is subtracted from the debt and equity interest rates. Reducing the inflation rate from 3 percent to 2 percent in this manner reduces LCOE by a little less than 4.5 percent.

5.5. Conclusion

The analysis here indicates that reasonable variations in the cost and performance parameters of new reactor designs do not appear able to bring these new plants fully into the competitive range of generation costs, although the variations do help materially. Reducing the construction period of a plant with $1,500 per kW overnight cost from 7 years to 5, extending plant life, and rearranging the debt term of the financing all reduce the nuclear LCOE, the lowest-cost nuclear cases remain just above the highest-cost coal and gas cases. Increasing capacity factor, for any given capital cost and construction time, from 85 to 95 percent would decrease LCOE by a little less than 10 percent. The results here are for first new plants coming on line in 2015. The effects of learning by doing and favorable construction and operating outcomes on LCOEs of subsequent plants will be considered in Chapter 9.

References

Alliant Energy. (2004) "Power Iowa – Emery Generating Station." Newsroom, Current Issues. Retrieved May 2004, from the World Wide Web: http://www.alliantenergy.com/stellent/groups/public/documents/pub/news_ci_pi_011130.hcsp.

Altman, Edward I., and Vellore M. Kishore. (1998) "Defaults and Returns on High Yield Bonds: Analysis Through 1997." Working Paper. New York: NYU Salomon Center.

Antoniou, Antonios, Yilmaz Guney, and Krishna Paudyal. (2002) "The Determinants of Corporate Debt Maturity Structure." Working paper, Centre for Empirical Research in Finance, Department of Economics and Finance, University of Durham, version 1.4, December 12.

Armistead, Thomas F., and Jonathan Barnes. (2002) "Coal Gets New Respect," November 18. Retrieved May 2004 from the World Wide Web: http://enr.construction.com.

Bali, Geetanjali, and Frank S. Skinner. (2003) "The At-Issue Maturity of Corporate Bonds: The Influence of Credit Rating, Security Level, Duration and Macroeconomic Conditions." ISMA Discussion Papers in Finance 2003-01, International Securities Market Association, University of Reading.

Banz, Rolf W. (1981) "The Relationship Between Return and Market Value of Common Stocks," *Journal of Financial Economics* 9: 3-18.

Barclay, M.J., and Clifford W. Smith, Jr. (1995) "The Maturity Structure of Corporate Debt," *Journal of Finance* 50: 609-631.

Barrett, W. Brian, Andrea J. Heuson, and Robert W. Kolb. (1986) "The Effect of Three Mile Island on Utility Bond Risk Premia: A Note," *Journal of Finance* 41: 255-261.

Belkaoui, Ahmed. (1975) "A Canadian Survey of Financial Structure," *Financial Management* 4: 74-79.

Benmelech, Efraim. (2003) "Asset Salability and Debt Maturity: Evidence from 19th Century American Railroads." Working paper, Graduate School of Business, University of Chicago, October.

Berger, Allen N., Marco Espinosa-Vega, W. Scott Frame, Nathan H. Miller. (2003) "Debt Maturity, Risk, and Asymmetric Information." Mimeo, preliminary draft, Federal Reserve Board and International Monetary Fund, January.

Black, Fischer and Myron S. Scholes. (1973) "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 81: 637-654.

Black, Fischer, Michael C. Jensen, and Myron S. Scholes. (1972) "The Capital Asset Pricing Model: Some Empirical Tests," in Michael C Jensen, ed., *Studies in the Theory of Capital Markets*. New York: Praeger, pp. 79-121.

Black, Fischer. (1972) "Capital Market Equilibrium with Restricted Borrowing," *Journal of Business* 45: 444-455.

Bloomberg, Inc. (2004). Bloomberg Financial Data. March. Retrieved from World Wide Web March 2004: http://www.bloomberg.com/index.html.

Bowen, Robert M., Lane A. Daley, and Charles C. Huber, Jr. (1982) "Evidence on the Existence and Determinants of Inter-Industry Differences in Leverage," *Financial Management* 11: 10-20.

Bowen, Robert M., R. Castanias, and Lane A. Daley. (1983) "Intra-Industry Effects of the Accident at Three Mile Island," *Journal of Financial and Quantitative Analysis* 18: 87-110.

Bradley, Michael, Gregg A. Jarrell, and E. Han Kim. (1984) "On the Existence of an Optimal Capital Structure: Theory and Evidence," *Journal of Finance* 39: 857-880.

Brick, Ivan E., and Oded Palmon. (1992) "Interest Rate Fluctuations and the Advantage of Long-Term Debt Financing : A Note on the Effect of the Tax Timing Option," *Financial Review* 27: 467-474.

Brick, Ivan E., and S. Abraham Ravid. (1985) "On the Relevance of Debt Maturity Structure," *Journal of Finance* 40: 1423-1437.

Brick, Ivan E., and S. Abraham Ravid. (1991) "Interest Rate Uncertainty and the Optimal Debt Maturity Structure," *Journal of Financial and Quantitative Analysis* 26: 63-81.

Bristol (Va.) Herald Courier. (2004) "Governor Signs Meth Bill," April 16. Retrieved May 2004, from the World Wide Web: http://www.mapinc.org/drugnews/v04/n594/a04.html?66704.

Brooks, L., and R. D'Souza. (1982) "Electric Utility Returns and Risk in the Light of Three Mile Island," *Public Utilities Fortnightly*, November 11, 26-32.

Buckland, Roger, and Patricia Fraser. (2001) "Political and Regulatory Risk: Beta Sensitivity in U.K. Electricity Distribution," *Journal of Regulatory Economics* 19: 5-25.

Calpine Corporation. (2001) "New Power Plant in Bastrop Begins Operations in Time for Summer Demands." Press release, June 4. Retrieved May 2004 from the World Wide Web: http://www.corporate-ir.net/ireye/ir_site.zhtml?ticker=CPN&script=411&layout=-6&item_id=180275.

Chen, Chao, Philp Fanara, Jr., and Raymond F. Gorman. (1987) "Abandonment Decisions and the Market Value of the Firm: The Case of Nuclear Power Project Abandonment," *Journal of Accounting and Public Policy* 6: 285-297.

Das, S. and P. Tufano. (1996) "Pricing Credit Sensitive Debt when Interest Rates and Credit Spreads are Stochastic," *Journal of Financial Engineering* 5: 161-198.

Diamond, Douglas W. (1991) "Debt Maturity Structure and Liquidity Risk," *Quarterly Journal of Economics* 106: 709-738.

Diamond, Douglas W. (1993) "Seniority and Maturity of Debt Contracts," *Journal of Financial Economics* 33: 341-368.

Diamond, Douglas W., and Raghuram G. Rajan. (2001) "Banks, Short-term Debt and Financial Crises: Theory, Policy Implications and Applications," *Carnegie-Rochester Conference Series on Policy* 54: 37-71.

Dominion Energy. (2001) "Dominion Plans $600 Million Power Station in Person County." News release, September 28. Retrieved May 2004, from the World Wide Web: http://www.dom.com/news/dom2001/pr0928.jsp.

Dominion Energy. (2004) Personal communication. Corporate Communications Department, Richmond, Va., May 26.

Douglas, George W. (1969) "Risk in the Equity Markets: An Empirical Appraisal of Market Efficiency," *Yale Economic Essays* 9: 2-45.

Drennan, Thomas E., Arnold B. Baker, and William Kamery. (2002) *Electricity Generation Cost Simulation Model (GenSim)*. SAND2002-3376. Albuquerque, N.M.: Sandia National Laboratories, November.

Duffie, D., and K. Singleton. (1997) "Modeling Term Structures of Defaultable Bonds," *Review of Financial Studies* 12: 687-720.

Duffee, G. (1998) "The Relation Between Treasury Yields and Corporate Bond Yield Spreads," *Journal of Finance* 53: 2225-2241.

Elyasiani, Elyas, Lin Guo, and Liang Tang. (2002) "The Determinants of Debt Maturity at Issuance: A System-Based Model," *Review of Quantitative Finance and Accounting* 19: 351-377.

Elton, Edwin J., Martin J. Gruber, Deepak Agrawal, and Christopher Mann. (2001) "Explaining the Rate Spread on Corporate Bonds," *Journal of Finance* 56: 247-277.

Energy Info Source. (2003) "MidAmerican Energy Begins Work on High-Tech Generation Plant," September 9. Retrieved May 2004, from the World Wide Web: http://www.energyinfosource.com/aoi/news-details.cfm?id=19974&FLink=&tf=1.

Fama, Eugene F. (1965) "Portfolio Analysis in a Stable Paretian Market," *Management Science* 11: 404-419.

Fama, Eugene, and Kenneth French. (1992) "The Cross Section of Expected Stock Returns," *Journal of Finance* 47: 427-465.

Fama, Eugene F., and Kenneth R. French. (2002) "Testing Trade-off and Pecking Order Predictions," *Review of Financial Studies* 15: 1-33.

Fama, Eugene F., and Kenneth R. French. (2003) "Financing Decisions: Who Issues Stock ?" Mimeo. Chicago, IL.: University of Chicago Graduate School of Business, October.

Fama, Eugene, and James MacBeth. (1973) "Risk, Return, and Equilibrium," *Journal of Political Economy* 81: 607-636.

Farber, Stephen. (1991) "Nuclear Power, Systematic Risk, and the Cost of Capital," *Contemporary Policy Issues* 9: 73-82.

Fisher, Edwin O., Robert Heinkel, and Josef Zechner. (1989) "Dynamic Capital Structure Choice: Theory and Test," *Journal of Finance* 44: 19-40.

Fisher, Larry. (1966) "Some New Stock Market Indexes," *Journal of Business* 39: 191-225.

Flannery, M. (1986) "Asymmetric Information and Risky Debt Maturity Choice," *Journal of Finance* 41: 18-38.

Fons, Jerome S., Kimball, Andrew E. (1991) "Corporate Bond Defaults and Default Rates, 1970-90," *Journal of Fixed Income* 1, No. 1: 36-47.

Fraser, Donald R., and James W. Kolari. (1983) "Effects of Three Mile Island on Nuclear and Non-Nuclear Dependent Utilities," *Journal of the Midwest Finance Association* 12: 1285-1292.

Fuller, Russell J., George W. Hinman, and Thomas C. Lowinger. (1990) "The Impact of Nuclear Power on the Systematic Risk and Market Value of Electric Utility Common Stock," *The Energy Journal* 11, No. 2: 117-133.

Galai, D., and R. Masulis. (1976) "The Option Pricing Model and the Risk Factor of Stock," *Journal of Financial Economics* 3: 53-81.

Generation Markets Week. (2002) "Mississippi Merchant Plant Generation," Power Daily, September 3. Retrieved May 2004, from the World Wide Web: www.aengblom.com/docs/GMW02-09-03Miss.pdf.

Ghosh, Arvin, Francis Cai, and Wenhui Li. (2000) "The Determinants of Capital Structure," *American Business Review* 29: 129-132.

Graham, John R., and Campbell R. Harvey. (2001) "The Theory and Practice of Corporate Finance: Evidence from the Field," *Journal of Financial Economics* 60: 187-243.

Guedes, Jose, and Tim Opler. (1996) "The Determinants of the Maturity of Corporate Debt Issues," *Journal of Finance* 51: 1809-1833.

Hamilton, David T. (1999) "August Default Report," *Moody's Risk Management Services* September, p. 3.

Hearth, Douglas, Ronald W. Melichor, and Darryl E. J. Gurley. (1990) "Nuclear Power Plant Cancellations: Sunk Costs and Utility Stock Returns," *Quarterly Journal of Business and Economics* 29, no. 1: 102-116

Hewlett, J. (1984) "Investor Perceptions of Nuclear Power." Washington, D.C.: DOE/EIA-0446. Energy Information Agency, U.S. Department of Energy, May.

Hill, Joanne, and Thomas Schneeweis. (1983) "The Effect of Three Mile Island on Electric Utility Stock Prices: A Note," *Journal of Finance* 38: 1285-1292.

Hogan, William W. (2002) "Electricity Market Restructuring: Reform of Reforms," *Journal of Regulatory Economics* 21: 103-132.

Houston Business Journal. (2001) "Reliant Starts Miss. Power Plant Construction," October 8. Retrieved May 2004, from the World Wide Web: http://www.bizjournals.com/houston/stories/2001/10/08/daily4.html.

Hull, Robert M. (1999) "Leverage Ratios, Industry Norms, and Stock Price Reaction: An Empirical Investigation of Stock-for-Debt Transactions," *Financial Management* 28: 32-45.

Ishii, Jun, and Jingming Yan. (2004) "Investment under Regulatory Uncertainty: U.S. Electricity Generation Investment since 1996." Working Paper, Center for the Study of Energy Markets. Berkeley: University of California Energy Institute, March.

Jarrow, R., D. Lando, and S. Turnbull (1997) "A Markov Model for the Term Structure of Credit Spreads," *Review of Financial Studies* 10: 481-523.

Jensen, Michael, and William Meckling. (1976) "Theory of the Firm: Managerial Behavior, Agency Costs, and Capital Structure," *Journal of Financial Economics* 3: 305-360.

Johnson, Ramon E. (1967) "Term Structures of Corporate Bond Yields as a Function of Risk of Default," *Journal of Finance* 22: 313-345.

Jones, E. Philip, Scott P. Mason, and Eric E. Rosenfeld, and Lawrence Fisher. (1984) "Contingent Claims of Analysis of Corporate Capital Structures: An Empirical Investigation," *Journal of Finance* 39: 611-625.

Joskow, Paul L. (1997) "Restructuring, Competition and Regulatory Reform in the U.S. Electricity Sector," *Journal of Economic Perspectives* 11: 119-138.

Ju, Nengjiu, and Hui Ou-Yang. (2003) "A Dynamic Model of Optimal Capital Structure and Debt Maturity with Stochastic Interest Rates." Working paper, December 15.

Kale, J. R., and T. Noe. (1990) "Risky Debt Maturity Choice in a Sequential Game Equilibrium," *Journal of Financial Research* 13: 155-165.

Kale, Jayant R., Thomas H. Noe, and Gabriel G. Ramirez. (1991) "The Effect of Business Risk on Corporate Capital Structure: Theory and Evidence," *Journal of Finance* 46: 1693.

Kalra, Rajiv, Glenn V. Henderson, Jr., and Gary A. Raines, (1993) "Effects of the Chernobyl Nuclear Accident on Utility Share Prices," *Quarterly Journal of Business and Economics* 32: 52-77.

Kane, A., A. J. Marcus, and R. L. McDonald. (1985) "Debt policy and the rate of return premium to leverage," *Journal of Financial and Quantitative Analysis* 20: 479-499.

Kim, C.S., D.C. Mauer, and M. H. Stohs. (1995) "Corporate Debt Maturity Policy and Investor Tax-timing Options: Theory and Evidence," *Financial Management* 24: 33-45.

LaBar, Malcolm (2002) "The Gas Turbine-Modular Helium Reactor: A Promising Option for Near Term Deployment." San Diego, Ca.: General Atomics. Retrieved December 13, 2003 from the World Wide Web: http://www.ga.com/gtmhr/images/ANS.pdf.

Lando, D. (1997) "Some Elements of Rating-Based Credit Risk Modeling," in N. Jegadeesh and B. Tuckman, eds., *Advanced Tools for the Fixed Income Professional*. New York: Wiley, pp. 193-215.

Lee, W. Y., A. V. Thakor, and G. Vora. (1983) "Screening, Market Signaling and Capital Structure Theory," *Journal of Finance* 38: 1507-1518.

Leland, H. E., and K. B. Toft. (1996) "Optimal Capital Structure, Endogenous Bankruptcy, and the Term Structure of Credit Spreads," *Journal of Finance* 51: 987-1019.

Lescoeur, Bruno, and Philippe Penz. (1999) La problématique du financement du investissements électronucléaires," *Revue de économie financière* 51: 167-182.

Lignite Energy Council. (2004). "Energy Success Story, King Plant Readies for New Emissions Control Technology," February. Retrieved May 2004, from the World Wide Web: http://www.lignite.com/ess/feb_04.html.

Lintner, John. (1965) "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets," *Review of Economics and Statistics* 47: 13-37.

Longstaff, Francis, and E. Schwartz. (1995) "A Simple Approach to Valuing Risky Fixed and Floating Rate Debt," *Journal of Finance* 50: 789-819.

Madan, D. B., and H. Unal (1998) "Pricing the Risks of Default," *Review of Derivatives Research* 2: 121-160.

Markowitz, Harry M. (1959) *Portfolio Selection: Efficient Diversification of Investments.* New York: Wiley.

Marsh, Paul. (1982) "The Choice Between Equity and Debt: An Empirical Study," *Journal of Finance* 37: 121-144 .

Martin, Linda J., and Glenn V. Henderson. (1984) "Industry Influence on Financial Structure: A Matter of Interpretation," *Review of Business and Economic Research* 19: 57-67.

Mazur, Frank. (2003), commentary, "Nature's Power: Blowing in the Wind," Representative Frank Mazur's (Vermont) Home Page. Retrieved May 2004, from the World Wide Web: http://home.adelphia.net/~frankmazur/windmills_10_03.htm.

Merchant Power Monthly. (2004a) "As Natural Gas Surges, Illinois Utilities Turn to Coal to Fuel Power Plants," Vol. 19, no. 4 (April), pp. 2-3.

Merchant Power Monthly. (2004b) "Boston-Based Firm Delays Building Natural-Gas-Fired Plant in North Carolina," Vol. 19, no. 4 (April), p. 9.

Merton, Robert. (1997) "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance* 29: 449-470.

Midwest Generation. (2004) Personal communication. Government Affairs Department, Chicago, May 26.

Miller, Merton, and Myron Scholes. (1972) "Rates of Return in Relation to Risk: A Re-Examination of Some Recent Findings," in Michael Jensen, editor, *Studies in the Theory of Capital Markets*. New York: Praeger, pp. 47-78.

Minnesota Environmental Partnership. (2004) "Once-King Coal Returns to the Midwest." Environmental News, May 5. Retrieved from World Wide Web May 2004: http://www.mepartnership.org/mep_whatsnew.sap?new_id=651.

Mitchell, Karlyn. (1991) "The Call, Sinking Fund, and Term to Maturity Features of Corporate Bonds: An Empirical Investigation," *Journal of Financial and Quantitative Analysis* 26: 201-222.

Modigliani, Franco, and Merton H. Miller. (1958) "The Cost of Capital, Corporation Finance, and the Theory of Investment," *American Economic Review* 48: 261-297.

Morris, J. R. (1975) "On Corporate Debt Maturity Policies," *Journal of Finance* 31: 29-37.

Morris, J. R. (1992) "Factors Affecting the Maturity Structure of Corporate Debt." Working paper, University of Colorado at Denver.

Mossin, Jan. (1966) "Equilibrium in Capital Markets," *Econometrica* 34: 768-783.

Myers, Stewart. (1977) "Determinants of Corporate Borrowing," *Journal of Financial Economics* 9: 147-176.

Myers, Stewart C. (1984) "The Capital Structure Puzzle," *Journal of Finance* 39: 575-592.

Myers, Stewart C., and Nicholas S. Majluf. (1984) "Corporate Financing and Investment Decisions when Firms have Information that Investors Do Not Have," *Journal of Financial Economics* 13: 187-221.

Nebraska Public Power District. (2003) "Power Plant Construction Begins" News release, June 26. Retrieved May 2004, from the World Wide Web: http://www.nppd.com/News/News_Releases/2003/Additional_Files/construction.asp

Nebraska Public Power District. (2004) Personal communication. Corporate Communications Department, Columbus, Nebr., May 26.

Nielson, Mark. (1993) *Investigation Costs and the Effects of Own Variance on Security Prices*. Ph.D. dissertation, University of Chicago, Department of Economics.

NRG Energy. (2004) Personal communication. Media Relations Department, Minneapolis, May 27.

Nwaeze, Emeka T. (2000) "Deregulation of the Electric Power Industry: The Earnings, Risk, and Return Effects," *Journal of Regulatory Economics* 17: 49-67.

Pacific Northwest National Laboratory (PNNL). (2004) State Electricity Restructuring Status. Retrieved March 2004 from the World Wide Web: http://pnnl-utilityrestructuring.pnl.gov/Electric/electric.htm.

Pindyck, Robert S. (1993) "Investments of Uncertain Cost," *Journal of Financial Economics* 34: 53-76.

Peabody Energy. (2004) Personal communication. Public Relations Department, St. Louis, May 25.

Ravid, Abraham. (1996) "Debt Maturity: A Survey," *Financial Markets, Institutions and Instruments* 5: 1-68.

Realdon, Marco. (2003) "About Debt and the Option to Extend Debt Maturity." Discussion Papers in Economics, No. 2003/20, Department of Economics and Related Studies, University of York.

Remmers, Lee, Arthur Stonehill, Richard Wright, and Theo Beekhuisen. (1974) "Industry and Size as Debt Ratio Determinants in Manufacturing Internationally," *Financial Management* 3: 24-32.

Reuters. (2001) "Record Gas Prices Breathe Life Into Nuclear Power," January 25. Retrieved May 2004 from the World Wide Web: https://www.pbmr.co.za/press_archive/record_gas_prices.htm.

Reuters (2004) "Reliant to Mothball Miss. Power Plant," News for RRI.N., May 4. Retrieved May 2004 from the World Wide Web: http://biz.yahoo.com/prnews/040504/datu041_1.html.

Roll, Richard, and Stephen A. Ross. (1980) "An Empirical Investigation of the Arbitrage Pricing Theory," *Journal of Finance* 35: 1073-1103.

Rosenberg, B., K. Reid, and R. Lanstein. (1985) "Persuasive Evidence of Market Inefficiency," *Journal of Portfolio Management* 11: 9-17.

Rousseau, Fabrice. (1999) "Signaling with Debt Maturity Choice." Working paper, National University of Ireland, Maynooth, November.

Sargent & Lundy. (2004) Personal communication. Fossil Power Department, Chicago, May 24.

Sarkar, Sudipto. (1999) "Illiquidity Risk, Project Characteristics, and the Optimal Maturity of Corporate Debt," *Journal of Financial Research* 22: 353-370.

Schwartz, Eli, and J. Richard Aronson. (1967) "Some Surrogate Evidence in Support of the Concept of Optimal Financial Structure," *Journal of Finance* 22: 10-18.

Scott, David F. (1972) "Evidence on the Importance of Financial Structure," *Financial Management* 1: 45-50.

Scott, David F., and John D. Martin. (1975) "Industry Influence on Financial Structure," *Financial Management* 4: 67-73.

Scully Capital. (2002a) *Business Case for New Nuclear Power Plants.* Final Draft. Washington, D.C.: Scully Capital, July. Retrieved December 2003 from the World Wide Web: http://www.scullycapital.com.

Scully Capital. (2002b) "BCNPP: Business Case for New Nuclear Power Plants; Briefing for NERAC." Retrieved December 13, 2003 from the World Wide Web: http://nuclear.gov/home/bc/ExecOverviewNERAC100102.pdf.

Sekely, William S., and J. Markham Collins. (1988) "Cultural Influences on International Capital Structure," *Journal of International Business Studies* 19: 87-100.

Sharpe, Steven. (1991) "Credit Rationing, Concessionary Lending, and Debt Maturity," *Journal of Banking and Finance* 15: 581-604.

Sharpe, William F. (1964) "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk," *Journal of Finance* 19: 425-442.

The Shaw Group. (2001) "Shaw Signs Agreement with NRG Energy for Power Plant Construction." Press release, September 27. Retrieved May 2004 from the World Wide Web: http://www.shawgrp.com/press_Releases/2001/092701.cfm.

Sibley, Mike. (1991) "The Search for Industry Financing Patterns," *American Business Review*, January: 85-91.

Smith, Richard, and Anders Hove. (2003) "The Old Reliables: Coal, Nuclear and Gas in 2003." New York: Deutsche Bank AG.

Sommers, Paul. (1980) "The Adoption of Nuclear Power Generation," *Bell Journal of Economics and Management* 11: 283-291.

Stattman, D. (1980) "Book Values and Stock Returns," *The Chicago MBA: A Journal of Selected Papers* 4: 25-45.

Stohs, Mark Hoven, and David C. Mauer. (1996) "The Determinants of Corporate Debt Maturity," *Journal of Business* 69: 279-312.

Titman, Sheridan. (1992) "Interest Rate Swaps and Corporate Financing Choices," *Journal of Finance* 47: 1503-1516.

Titman, Sheridan, and R. Wessels. (1988) "The Determinants of Capital Structure Choice," *Journal of Finance* 43: 1-19.

Tolley, George, and Mark Nielson. (1992) "Asset Pricing with Investigation Costs." Mimeo. University of Chicago, March.

Tolley, George, and Mark Nielson. (2003) "Asset Pricing with Information Costs." Mimeo, University of Chicago and MacroEcon Global Advisors, working paper, July.

Tyler Morning Telegram. (2004) "Clean-Air Efforts Threatened, Environmentalists Say," March 2. From Typerpaper.com. Retrieved May 2004, from the World Wide Web: http://www.zwire.com/site/news.cfm?newsid=11055212&BRD=1994&PAG=461&dept.

U.S. Department of Energy (DOE). (2001a) "A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010, Volume I." Summary Report. Washington, D.C.: Office of Nuclear Energy, Science and Technology, October.

U.S. Department of Energy (DOE). (2001b) "A Roadmap to Deploy New Nuclear Power Plants in the United States by 2010, Volume II." Main Report. Washington, D.C.: Office of Nuclear Energy, Science and Technology, October.

U.S. Department of the Treasury, Internal Revenue Service (IRS). (2002) "How to Depreciate Property." Publication 946. Washington, D.C.: IRS.

Uselton, Gene C., James W. Kolari, and Donald R. Fraser. (1986) "Long-Term Trends in the Riskiness of Electric Utility Shares," *Journal of Business Finance and Accounting* 13: 453-459.

Wiggins, James B. (1990) "The Relation Between Risk and Optimal Debt Maturity and the Value of Leverage," *Journal of Financial and Quantitative Analysis* 25: 377-386.

Wisconsin Public Service Corporation. (2002) "WPS Resources Corporation Discusses Financial Details of Wisconsin Public Service Corporation Building a 500-Megawatt Coal-Fired Electric Generator." WPS Resources Corporation, September 25. Retrieved May 2004 from the World Wide Web: http://www.wpsr.com/cfm/smwpsr.gif.

Xcel Energy. (2004) Personal communication. Capital Projects, Engineering and Construction Department, Minneapolis. May 24.