# Effects of the Chernobyl Nuclear Accident on Utility Share Prices

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## Abstract

Market reaction in the U.S. to the Chernobyl nuclear accident can be attributed only to a change in market expectations for the future of the nuclear power industry, given that there was no direct link between Chernobyl and any U.S. power utility. This study measures stock market reaction to Chernobyl using the event parameter approach, which uses dummy variables. Results indicate negative price reactions to the accident. For both nuclear utilities and nonnuclear utilities the effects were small and transitory. The most pronounced effects observed were for the mixed utilities—firms with between zero and 20 percent nuclear capacity. Many of these firms at that time were committed to large, and often troubled, new nuclear generating capacities.

## Introduction

Chernobyl was the largest nuclear accident ever. It caused at least 35 deaths, injuries to at least 1,000, and the forced evacuation of thousands of persons. The accident led, predictably, to a global renewal of protest against the use of nuclear power.

The Three Mile Island (TMI) accident in this country in 1979 is our closest analogy to Chernobyl. Three studies have examined electric utility share price reaction to TMI: Bowen *et al.* (1983); Fraser and Kolari (1983); and Hill and Schneeweis (1983). Hill and Schneeweis use monthly stock price data, while the other studies use daily data. All find statistically significant negative price reactions for nuclear-dependent utility stocks. A study by Barrett *et al.* (1986) of the effect of the TMI accident on utility bond risk and premium finds a decrease in utility bond prices. The authors conclude that there was an increase in the utility risk premium as a consequence of the TMI accident.

In the case of TMI, U.S. electric utilities were involved directly or indirectly, so it is not possible to separate the overall market reaction to the TMI accident by reaction due to direct financial consequences of TMI for U.S. utilities


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or general reassessment of prospects for the nuclear power industry. The 1986 Chernobyl incident, however, provides an opportunity to replicate studies on the effects of a nuclear accident on utility share prices.

Chernobyl differs from TMI in several important respects. The plant was built with different technology, was operating in a different political and social environment, and was subject to a different set of operating standards and regulations. An important difference is that the accident had no direct financial impact on any U.S. utility, so any share price reaction in this country can be attributed only to general reassessment of the future of nuclear power.

News of the Chernobyl accident initially was suppressed—again a difference from TMI. It was only after Sweden detected unusually large amounts of radioactivity in the atmosphere on April 28, 1986 that the Soviets acknowledged an explosion had occurred in one of the reactors at the generating facility. This announcement played down the magnitude of the accident. News media were not allowed access to the accident site, nor were they allowed to interview persons fleeing from the area. Western media representatives, accustomed to investigating and obtaining information on their own, were forced to rely on official and unofficial Soviet reports, leaks, and rumors to inform the public about the details. Even so, during the month following Chernobyl more than 250 news, editorial, and other items related to the accident appeared in the *New York Times* alone. *The Los Angeles Times* carried another 150. Appendix A enumerates some key news items related to Chernobyl that appeared in these papers.

## Research Problem

U.S. capital markets are considered to be informationally efficient. That is, electric utility common stock prices should reflect fully the risks of their investments. Chernobyl generated information that was likely to affect stock prices. An accident of such dimensions would be expected to produce negative market price reactions in a related industry.

No U.S. electric utility, however, was associated directly with or affected by the Chernobyl accident. Furthermore, cancellation of previously ordered nuclear generating capacity after Three Mile Island already had reduced reliance of the U.S. electric industry on nuclear energy. Between 1972 and 1982 utilities cancelled plans for over 100 nuclear plants, about 50 percent of the previously committed new nuclear generating capacity. (See *Nuclear Plant Cancellations: Causes, Costs and Consequences,* 1983.) Chen *et al.* (1987) find nuclear power plant cancellations after the TMI accident to be associated with positive share price reaction, suggesting that nuclear power plants post-TMI were not perceived as positive NPV projects. Reduced nuclear exposure of utilities that had cancelled plant projects should have reduced negative price effects of the Chernobyl accident for such utilities.

## Data Collection

To estimate the effect of the Chernobyl accident on the shareholder wealth of electric utilities, a list of public power utilities (SIC code 4911) was assembled. This list includes firms traded on the New York or the American Stock Exchange that claim generation and/or distribution of electric power as their main business activity. Eleven firms whose stock did not trade during the study period were eliminated, leaving 71 firms in the sample.

Energy Information Administration financial statistics and Moody's *Utility and Industrial Manuals* for the year 1986 are used to determine total installed capacity (in megawatt hours) and installed capacity fueled by nuclear power for each firm. Details of installed capacity of two holding companies, DPL, Inc. and Brascan Ltd., are not available from these sources, reducing the sample to 69 firms.

The sample is split into three groups: nuclear, mixed, and conventional utilities, depending on the percentage of generating capacity that is provided by nuclear fuel.[1] A utility with nuclear capacity of 20 percent or more (rounded) is classified as a nuclear utility; 20 firms fall into this category. Utilities with under 20 percent but more than zero percent nuclear capacity are classified as mixed utilities; 16 firms fit this category. Firms with no nuclear capacity are classified as conventional utilities; 33 firms fit this category. The sample firms are listed in Appendix B.

## Methodology

The Chernobyl accident was unanticipated. Electric utility share prices could not have incorporated and discounted the effects of the accident prior to April 28, 1986. United Press International, the *New York Times*, and the *Los Angeles Times* covered the news of Chernobyl on April 29, 1986, which is defined as the news or event day (ND, or t = 0).

The study uses daily common stock returns from the Center for Research in Security Prices (CRSP) tapes. Stock market reaction to Chernobyl is measured using the event study methodology proposed by Fama, Fisher, Jensen, and Roll

[1] Classification of utilities according to nuclear capacity is imprecise because of prior cancellations of nuclear construction and/or capacity under construction. The current classifications reflect the best information available.

(1969). The event parameter model (EPM) suggested by Binder (1985), Malatesta (1986), and Karafiath (1988) is used.

There are several reasons for choosing the event parameter model for this study. The Fama, Fisher, Jensen, and Roll approach assumes that abnormal returns, residuals, are independent and identically distributed for the various sample firms. As Binder points out (1985, p. 371), however, there are three problems with these assumptions:

- Abnormal returns can be expected to differ across firms;
- Residual variances may differ across firms; and
- There may be cross correlation between residuals of the sample firms.

The problem of correlation between residuals, or contemporaneous covariance, is exacerbated when the event occurs at the same time for all firms (calendar clustering) and/or when the sample firms are in the same or related industries (industry clustering). The current study by its nature involves both calendar and industry clustering: The event day is April 29, 1986 for all sample firms, and all the firms are electric utilities.

The EPM handles the contemporaneous covariance problem; the estimated variance for the t test is based on the variance of the portfolio returns. This variance estimate reflects the highly intercorrelated nature of firms' returns.

Before running the EPM regression, the Gujarati (1970) technique was used to test for alpha and beta shifts. This technique provides insight on whether Chernobyl disturbed the normal relationship between utilities and the market during the observation window. Algebraically, the model fitted is as follows:

$$(1)\ R_{it} = \alpha_i + \alpha_{i0}D_{0t} + \beta_i R_{mt} + \beta_{i0}R_{mt}D_{0t} + \varepsilon_{it}$$

where:

$R_{it}$ = Realized return on portfolio i on day t, from the CRSP daily return tape;
$\alpha_i$ = Intercept term for portfolio i;
$\alpha_{i0}$ = Shift in the intercept term for portfolio i during the event period;
$D_{0t}$ = A dummy variable that is equal to 1 during the event interval and zero otherwise;
$\beta_i$ = Systematic risk of portfolio i;
$R_{mt}$ = Return on the market on day t, the value-weighted CRSP index;
$\beta_{i0}$ = Shift in the systematic risk of portfolio i during the event period; and
$\varepsilon_{it}$ = A random disturbance term.

Returns for individual securities are calculated as follows:

$$(2)\ R_{jt} = \frac{p(t) + d(t)}{p(t - 1)} - 1$$

where:

$R_{jt}$ = Return on security j for day t;
$p(t)$ = Closing price at time t;
$d(t)$ = Cash dividend during t ($t - 1 <$ ex dividend date $\leq t$); and
$p(t - 1)$ = Closing price at time t - 1.

The portfolio return is an equally weighted[2] average of the returns of the stocks included in that portfolio (as listed in Appendix B). To run equation (1), the portfolio return, $R_{it}$, is regressed on $R_{mt}$, the value-weighted CRSP index. The regression includes all observations from t = -250 through t = +28. The influence of the event window observations (t = -1, +28) on $\alpha_i$ and $\beta_i$ is eliminated by setting the dummy variable, $D_{0t}$, equal to one on every day from t = -1 to t = +28. In this application the coefficients on the dummy variables are the shifts in the regression parameters during the event window. That is, $\alpha_{i0}$ is the change in the portfolio alpha and $\beta_{i0}$ is the change in the portfolio beta during the 30 day event window.

Next, the effect of Chernobyl on daily utility returns is estimated. The EPM uses dummy variables to capture daily return effects during the event period.[3] This model algebraically is:

$$(3)\ R_{it} = \alpha_i + \beta_i R_{mt} + \sum_{n=ND-1}^{ND+28} \tau_{in} D_{nt} + \varepsilon_{it}$$

where:

$\tau_{in}$ = Estimated coefficient on dummy variable $D_{nt}$, or abnormal return on portfolio i on observation n;

[2]The analysis also was run using portfolio returns weighted by the market value (MV) of the firms' equity. Compustat values were used for equity market values (supplemented in two cases with data from Moody's where data were missing on the tapes).

[3]As is traditional, a 30 day postevent sample of returns, starting on news day minus one was examined. Examination of portfolio returns on days 29 and 30 revealed no significant excess returns for any portfolio. Two SAS multivariate regression procedures (PROC GLM and PROC SYSREG) were used; the two procedures produce identical outputs.

$D_{nt}$ = Dummy variable, which is equal to 1 on observation n and zero otherwise;

The other variables are as defined before.

Equation (3) uses 30 different daily dummies, each set at one for a single day t and zero otherwise; t = -1, +28. Equation (1) measures the impact of the event on the regression parameter estimates during the event window. Equation (3) measures the impact as daily effects—prediction errors—the difference between the observed portfolio return and what would have been predicted from a regression relationship estimated over the prior 250 day period. The alphas and betas estimated by fitting either equation (1) or (3) are the same as would be produced by a simple OLS regression using estimation period data only.

The event parameter procedure is analogous to the prediction error methodology, as used by Dodd and Warner (1983). Use of a dummy variable for each day in the event interval (ND -1 to ND +28) eliminates the computations for the prediction errors. The prediction errors are found directly as the coefficients of the dummy variables, $D_{nt}$. Thus,

(4) $PE_{it} = \tau_{in}$

Under the null hypothesis of no abnormal returns, the prediction errors are assumed to be normally distributed with zero mean, so the standardized prediction errors, $SPE_{it}$, are distributed as student t. $SPE_{it}$ are obtained by standardizing the prediction errors, $PE_{it}$ or $\tau_{in}$, by the regression forecast error. In the EPM model, $SPE_{it}$ is simply the t value for $\tau_{in}$ for portfolio i on event day n. The cumulative prediction error, CPE, is the sum of the PEs between any two specified event days.

The test statistic, F, is found by testing the restriction that the sum of $\tau_{in}$ equals zero for the portfolios for various subperiods:

(5) $$\sum_{n=T_{1i}}^{T_{2i}} \tau_{in} = 0.$$

This test, suggested by Karafiath (1988), is available as an option in SAS and adjusts for potential correlation between the various $\tau_{in}$.

Because the study uses three portfolios of utilities, there is still a possibility of residual cross correlation. To guard against false inferences, the regressions also were run for the three portfolios using seemingly unrelated regressions (SUR). This proved unnecessary. For all three portfolios the standardized prediction errors from the SUR were the same, on all days for all intents and purposes, as would have resulted from fitting an OLS model for the three portfolios. The test in equation (5) was based on an OLS procedure (PROC REG) because it is not available as part of the SAS general linear (PROC GLM or PROC SYSREG) procedures.

## Empirical Results

Table 1 provides results of estimating equation (1) for the three portfolios of utilities—nuclear, mixed, and conventional (Panel A)—and three difference portfolios (Panel B). Panel B's results are used to test for differences between the parameters of the three portfolios and for differences in the shifts of these parameters across portfolios.

The alphas of the three portfolios are small, The conventional and mixed portfolios earned about one-tenth of a percent a day, apart from market-related fluctuations in returns. The nuclear portfolio alpha was not significantly different from zero. The betas suggest that nuclear utilities were riskier than conventional utilities in this post-TMI period. There was a reduction in the market sensitivity of the conventional and nuclear portfolios immediately after Chernobyl. There was a marked increase in the beta of the mixed portfolio. None of these changes in beta is, however, statistically significant at the 5 percent level.

The most noticeable result in Panel A is the alpha shift for the mixed utility portfolio, which is a statistically significant -0.00337—slightly more than three-tenths of a percent per day. This constitutes a loss of more than 10 percent over the 30 trading day event window.

Panel B is similar to Panel A. The only change is the dependent variable, which in this case is the difference in the returns on the three portfolios. This test is suggested in Karafiath (1988, p. 356) as an extension of methods in Thompson (1985). The purpose of this regression is to test whether the reaction to Chernobyl was statistically different for the different portfolios.

Tests for whether the alphas of nuclear (and mixed) and conventional utilities were different cannot be rejected at normal research thresholds. The evidence does suggest that the alphas of the mixed and nuclear utilities were different: the mixed utilities had a higher alpha before Chernobyl.

Before Chernobyl, nuclear utilities were the most risky; they had the highest betas. The nuclear utility portfolio beta was 0.185 higher than the beta of the conventional utility portfolio and 0.118 higher than the beta of the mixed utility portfolio. Both of these differences are statistically significant. The beta of the mixed utilities was not significantly different from that of the conventional utilities before Chernobyl.

During the thirty day Chernobyl event window, the alphas of nuclear and mixed utility portfolios declined; the decline for the mixed utility portfolio was statistically significant (Table 1, Panel A). This decline is also significantly greater than it was for the nuclear portfolio (Table 1, Panel B).

During the event period the relationship between the portfolio betas also changed. Both the conventional and nuclear utility portfolio betas declined (Table 1, Panel A). The conventional utility beta declined more, but that difference is not statistically significant (Table 1, Panel B). The mixed utility portfolio beta increased (Table 1, Panel A). The difference between the change in this portfolio and the changes in either of the other two is statistically significant (Table 1, Panel B). The increase of the mixed portfolio beta was coincident with a significant decline in this portfolio's alpha.

Table 2 summarizes the results of estimating the EPM model parameters for the three utility portfolios. Figure 1 plots the CPEs for the nuclear, mixed, and conventional utility portfolios for the period ND - 1 to ND + 28. Neither the table nor the figure show any measurable impact on the conventional utilities. There are no significant daily SPEs, and the CPE graph hovers around the zero line.[4]

The nuclear portfolio lost a significant 1 percent plus on day zero. There are no significant one day SPEs after that. The mixed utility portfolio provides the most noticeable results (consistent with the results in Table 1). There are statistically significant one day SPEs on eight days: t = -1, 0, 1, 2, 3 (positive), 8, 15, and 20. The mixed portfolio experienced negative abnormal returns on 19 of the 30 trading days in the event window. Further, the positive PEs are usually small and the negative PEs are often large. The CPE for the mixed portfolio was -0.111 on day 28—an 11 percent loss in 30 trading days.[5]

Table 3 presents CPEs and related test statistics for a number of subperiods. These results serve to amplify those reported in Table 2. There was little effect on the conventional utilities during this period. This portfolio lost 1.2 percent over the two day (-1, 0) event period, which is statistically significant at the 10 percent level. That small loss was more than recouped over the next five trading days (1 through 5). There are no significant interval F values other than for the first two day period.

[4]The results for MV-weighted portfolios are essentially the same as those reported in the paper. The R-square values were higher using MV weights, but the pattern of results was the same: the mixed utilities were the big losers (CPE = -8.2 percent, t = -1, +28), nuclear utilities had a relatively small loss (CPE = -2.2 percent, t = -1, +28; with one significant SPE at t = 0), and conventional utilities were not affected materially (CPE = -0.9 percent, t = -1, +28; with no significant SPEs on any day in the event window).

[5]This is the same loss recorded as an alpha shift in Panel A, Table 1. Table 1 reports the average per day abnormal return—the alpha shift—a permanent effect. Table 2 reports results estimated without considering parameter shifts. Table 2 reports each day's individual abnormal return for each portfolio.

The results for the nuclear portfolio are similar—it lost a statistically significant 1.6 percent over the first two days (-1, 0). Other than that, there are no significant interval F values.

The mixed portfolio is the one that shows the greatest impact. This portfolio lost 2.7 percent in the first two days. It lost another 1.7 percent in days 1 through 5 (although this interval F value is not statistically significant) and another 3 percent during days 6 through 10. None of the reported intervals has a positive CPE. Several have significant negative CPEs.

The results for the conventional and nuclear utilities suggest that conditions returned to normal soon after the Chernobyl crisis subsided, although there may have been more subtle changes. Betas not only reflect correlations with the market and standard deviations of returns, but also are influenced by the variability of market returns. Beta may seem higher for utilities during calm markets because the denominator in the beta calculation (market variance or standard variation) is lower than average.

Total and relative risks of the three portfolios are examined in Table 4, which reports: [6]

- Correlation coefficients of portfolio returns with those of the market;
- Standard deviations of portfolio daily returns; and
- Betas for the three portfolios during the 500 trading days around Chernobyl.

The correlations of all three utility portfolio returns with market returns were higher after Chernobyl.

Before Chernobyl the beta for the conventional utility portfolio was lower than the beta for the mixed utility portfolio, which in turn was lower than the beta for the nuclear portfolio.[7] The beta for the mixed utility portfolio was, however, lower than the beta for the nuclear portfolio because of less correlation with the market. The standard deviation of the mixed utility portfolio returns was the highest of the three portfolios, but its correlation coefficient was the lowest.

Chernobyl seems to have had a small effect on the riskiness of the conventional utilities. The correlation with the market and the standard deviation of returns both increased, but the post-Chernobyl beta (0.570 for t + 1 to t + 250) is much the same as before (0.560 for t - 250 to t - 1).

[6]This framework for examining the riskiness of utility shares follows Uselton et al. (1986).

[7]The differences in the parameter estimates in Tables 1 and 2 are due to slight differences in fitting of the regression equations. The beta estimates reported in Table 4 for the period t - 250 to t - 1 should be the same as reported in Tables 1 and 2. In Table 4 the betas are output from a correlation analysis rather than a regression analysis, again producing rounding differences in some cases.

The impact on the nuclear portfolio also seems small. The post-Chernobyl beta (0.641 for t + 1 to t + 250) is much the same as it was for the period t - 125 to t - 1.

A more noticeable effect is on the riskiness of the mixed utilities portfolio. This portfolio had the largest standard deviation of returns, as it did before Chernobyl. After Chernobyl its correlation with the market increased. Consequently, in post-Chernobyl periods the mixed portfolio had a higher beta than the nuclear portfolio.

## Interpretation of Results

As would be expected, U.S. electric utilities displayed a statistically significant negative reaction to the Chernobyl accident. Chernobyl destabilized the industry. The share price reaction for the conventional and the nuclear utilities, however, was relatively small and transitory. Moreover, the magnitude of the response was much the same for nuclear and conventional power producers. The reaction to the accident is characterized as transitory because it did not produce statistically significant alpha shifts in these two portfolios. The t-values for the alpha shifts for the conventional and the nuclear portfolios are 0.12 and -0.76, respectively.

It is fair to characterize the reaction to Chernobyl as relatively small for these two portfolios. The CPEs for these portfolios for the month and a half (30 trading days) starting at t = -1 all indicate less than 1.5 percent negative abnormal return for the period. For the conventional portfolio the abnormal return was a positive 0.9 percent (Table 2). For the nuclear firms it was a negative 1.3 percent.

For these two portfolios the t-values for the beta shifts are greater than those for the alpha shifts. The betas of the conventional and nuclear portfolios declined during the event period. This can be interpreted to mean that utilities did not follow the market as normally because of the impact of Chernobyl, but reacted to industry-related rather than market-related factors. These portfolios' returns declined upon the news of Chernobyl. As the crisis subsided, returns rebounded. It appears that things returned to normal for the firms included in these two portfolios.

There were some subtle changes in the riskiness of the portfolios of utilities in this study. All three portfolio returns were correlated more highly with the market after Chernobyl. Although the beta changes were not large for the conventional and nuclear utilities, they were significant for the mixed portfolio. The mixed portfolio had less systematic risk than the nuclear portfolio before Chernobyl. After Chernobyl it became riskier than the nuclear portfolio—primarily because of a higher correlation with the market.

## Mixed Utilities: A Closer Look

The results for the mixed utilities are the most interesting, warranting a closer look. There are 16 firms in this portfolio. Ten had two or more significant (10 percent level) negative daily PEs during the 30 trading days in the study. Ten of the firms had negative individual CPEs in excess of 1 percent, five in excess of 10 percent, two in excess of 20 percent, and one was a negative 33.1 percent (in a 30 day trading period). Most of these firms, particularly all of the big losers, shared a common attribute. Each was committed to a sizeable new nuclear power capacity that was not yet approved. Many of the firms were part owners of the troubled Seabrook project.

The largest negative abnormal reaction was experienced by Gulf States Utilities Company (GSU). Its -33.1 percent CPE can be traced to a number of circumstances, all related to its River Bend nuclear plant, which at $4.4 billion is the third most costly nuclear generating station. During this period GSU lost several rate cases in Louisiana and Texas, had its debt and preferred stock downrated by Standard & Poor and Moody's, and was threatened with the disallowance of $1.6 billion in River Bend's construction costs. It cut its dividends and retained bankruptcy and reorganization counsel.

Four of the other big losers were Public Service of New Hampshire (PSNH; CPE = -22.9 percent), United Illuminating Co. (UI; CPE = -19.1 percent), Eastern Utilities Association (EUA; CPE = -14.2 percent), and Central Maine Power Co. (CMP; CPE = -11.3 percent). All these firms are part owners of the Seabrook nuclear plant. Their shares of Seabrook were 35.6 percent for PSNH, 17.5 percent for UI, 2.9 percent for EUA, and 6.0 percent for CMP. Eastern's commitment was larger than 2.9 percent because at the time of the accident Eastern was negotiating to buy from other utilities (including Bangor Hydro-Electric Co., Central Vermont Public Service Corp., and Fitchburg Gas & Electric Light Co.) additional shares that would raise its ownership to 15.1 percent.

Seabrook's testing was delayed because of the Chernobyl accident. The negotiation range for the sales price of Seabrook plummeted more than 35 percent. PSNH charged off $300 million (about 25 percent of its equity) because it did not expect to recover its investment in Seabrook 2 or Pilgrim 2 nuclear power plants.

Southern California Edison (SCEd), which owned 15.8 percent of the Palo Verde nuclear plant, had a CPE of -5.6 percent for the period. Unit one of Palo Verde had gone on line February 1, 1986. At the time of the Chernobyl accident units two and three were yet to be activated. Rate-making hearings were in progress on amount and treatment of Palo Verde allowable costs. SCEd contended it was unfair to abandon traditional cost-based rate-making after the company was committed to participate in this project. Chernobyl made the outcome of this dispute more uncertain.

SCEd was also 75 percent owner of the San Onofre nuclear generating station. At that time SCEd was involved in a rate-making dispute with the California PUC over disallowance of a substantial amount of San Onofre construction costs. It became doubtful that SCEd would win this dispute.

American Electric Power Inc. (AEP) was the next largest loser (CPE = -4.7 percent). AEP is an integrated public utility system—a holding company—composed of eight operating companies in seven states (Michigan, Indiana, Ohio, West Virginia, Virginia, Kentucky, and Tennessee).

One of the firms owned by AEP is Columbus & Southern Ohio Electric Co. (C&SOE). C&SOE is one of the owners of the Zimmer plant, originally planned as a nuclear plant but eventually converted, at great cost, to a coal facility . With disallowance of many costs related to Zimmer, C&SOE and AEP experienced financial losses. The plant's ultimate cost and the outcome of related legal and regulatory matters were all unknown when the Chernobyl accident occurred. It appears the accident further unsettled AEP investors.

New England Electric System (NEES; CPE = -3.2 percent) is another owner (10.0 percent) of Seabrook . Through New England Power, NEES also owns about 12 percent of Millstone No. 3, a nuclear plant in Waterford, Connecticut. Although an operating license had not been obtained at the date of the 1985 statements (Moody's, 1986, Vol. 2, p. 4430), the plant had a May 1986 commercial operation date.

Ohio Edison (CPE = -2.3 percent) was another firm with nuclear construction in progress. Although the company had cut its nuclear commitment (terminating plans in January of 1980 for four nuclear facilities), Ohio Edison still had a large commitment to nuclear construction. The largest construction projects in progress were Perry No. 1 and Perry No. 2. Ohio Edison would own 35.24 percent of them, and then-current (1985) work in progress cost was almost $2 billion. Termination of Perry No. 2 was being considered in 1985 (Moody's, 1986, Vol. 2, p. 3046).

At the very least, Chernobyl fueled investor fear about licensing delays for nuclear plants. All nine of the firms discussed here, those with 30 day losses of 2 percent or more, were involved with troubled nuclear construction publicized by both the popular and the financial press. Chernobyl exacerbated their already existing regulatory problems.

## Summary and Conclusion

Utility investors recognized that Chernobyl marked the start of a new era for nuclear power in the U.S. Even though the Chernobyl facility was different from

U.S. plants in both design and management, the accident dramatized the consequences of a nuclear accident.

The market was quick to recognize the consequences for utilities with nuclear plants that were not yet licensed or for which the rate base or rate-making treatment was yet to be established. Subsequent developments have proven investor fears to be well founded.

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**Table 1**
**Market Model Parameters and Parameter Shifts for Utility Portfolios and Difference Portfolios**

Panel A

| | (I) Conventional Utilities (33) | (II) Mixed Utilities (16) | (III) Nuclear Utilities (20) |
|---|---|---|---|
| Alpha | 0.001 | 0.001 | 0.000 |
| t value | 2.57 | 3.07 | 1.34 |
| p value | 0.011 | 0.002 | 0.182 |
| Beta | 0.561 | 0.628 | 0.746 |
| t value | 12.08 | 10.71 | 14.91 |
| p value | 0.001 | 0.001 | 0.001 |
| Alpha shift | 0.000 | -0.003 | -0.001 |
| t value | 0.12 | -3.01 | -0.76 |
| p value | 0.903 | 0.003 | 0.447 |
| Beta shift | -0.193 | 0.159 | -0.122 |
| t value | -1.73 | 1.13 | -1.01 |
| p value | 0.085 | 0.261 | 0.312 |
| R-squared | 0.365 | 0.375 | 0.482 |
| Adjusted R-squared | 0.358 | 0.368 | 0.476 |
| F value | 53.12 | 55.31 | 85.91 |
| p value | 0.001 | 0.001 | 0.001 |

Panel B

| | (II-I) Nuclear-Conventional | (II-1) Mixed-Conventional | (II-III) Mixed-Nuclear |
|---|---|---|---|
| Alpha | 0.000 | 0.000 | 0.001 |
| t value | -1.31 | 1.26 | 2.11 |
| p value | 0.193 | 0.208 | 0.036 |
| Beta | 0.185 | 0.067 | -0.118 |
| t value | 4.63 | 1.39 | -2.20 |
| p value | 0.001 | 0.165 | 0.029 |
| Alpha shift | -0.001 | -0.003 | -0.003 |
| t value | -1.10 | -3.78 | -2.59 |
| p value | 0.275 | 0.001 | 0.010 |
| Beta shift | 0.071 | 0.353 | 0.282 |
| t value | 0.74 | 3.04 | 2.18 |
| p value | 0.461 | 0.003 | 0.030 |
| R-squared | 0.103 | 0.105 | 0.044 |
| Adjusted R-squared | 0.094 | 0.096 | 0.034 |
| F value | 10.63 | 10.87 | 4.23 |
| p value | 0.001 | 0.001 | 0.006 |

**Table 2**
**Prediction Errors and Cumulative Prediction Errors**

Conventionals
(33)

| | |
|---|---|
| Alpha | 0.0008 |
| Beta | 0.562 |
| R-squared | 0.395 |
| Adjusted R-squared | 0.319 |
| F value | 5.238 |
| p value | 0.0001 |

| Event Day | PE | SPE (t) | p value | CPE |
|---|---|---|---|---|
| -1 | -0.005 | -1.07 | 0.285 | -0.005 |
| 0 | -0.007 | -1.37 | 0.171 | -0.012 |
| 1 | 0.006 | 1.14 | 0.254 | -0.006 |
| 2 | 0.003 | 0.52 | 0.606 | -0.004 |
| 3 | 0.003 | 0.70 | 0.486 | 0.000 |
| 4 | -0.003 | -0.68 | 0.497 | -0.004 |
| 5 | 0.004 | 0.89 | 0.377 | 0.001 |
| 6 | -0.002 | -0.33 | 0.739 | -0.001 |
| 7 | 0.001 | 0.16 | 0.874 | 0.000 |
| 8 | -0.006 | -1.29 | 0.198 | -0.006 |
| 9 | 0.003 | 0.68 | 0.498 | -0.003 |
| 10 | 0.001 | 0.11 | 0.914 | -0.003 |
| 11 | 0.001 | 0.18 | 0.860 | -0.002 |
| 12 | 0.003 | 0.67 | 0.502 | 0.002 |
| 13 | 0.002 | 0.32 | 0.748 | 0.003 |
| 14 | -0.001 | -0.24 | 0.807 | 0.002 |
| 15 | -0.006 | -1.28 | 0.203 | -0.004 |
| 16 | 0.004 | 0.83 | 0.410 | 0.000 |
| 17 | -0.006 | -1.26 | 0.209 | -0.007 |
| 18 | 0.001 | 0.19 | 0.852 | -0.006 |
| 19 | 0.002 | 0.36 | 0.722 | -0.004 |
| 20 | 0.001 | 0.17 | 0.862 | -0.003 |
| 21 | 0.003 | 0.59 | 0.556 | 0.000 |
| 22 | -0.001 | -0.19 | 0.849 | -0.001 |
| 23 | 0.005 | 1.00 | 0.320 | 0.004 |
| 24 | 0.000 | -0.03 | 0.973 | 0.004 |
| 25 | 0.001 | 0.16 | 0.877 | 0.004 |
| 26 | 0.001 | 0.11 | 0.910 | 0.005 |
| 27 | 0.001 | 0.17 | 0.869 | 0.006 |
| 28 | 0.004 | 0.74 | 0.462 | 0.009 |

**Table 2 (cont.)**
**Prediction Errors and Cumulative Prediction Errors**

Mixed Utilities
(16)

| | |
|---|---|
| Alpha | 0.0012 |
| Beta | 0.627 |
| R-squared | 0.456 |
| Adjusted R-squared | 0.389 |
| F value | 6.738 |
| p value | 0.0001 |

| Event Day | PE | SPE (t) | p value | CPE |
|---|---|---|---|---|
| -1 | -0.011 | -1.943 | 0.053 | -0.011 |
| 0 | -0.015 | -2.559 | 0.011 | -0.027 |
| 1 | -0.016 | -2.692 | 0.008 | -0.043 |
| 2 | -0.011 | -1.924 | 0.056 | -0.054 |
| 3 | 0.014 | 2.344 | 0.020 | -0.040 |
| 4 | -0.003 | -0.496 | 0.621 | -0.043 |
| 5 | -0.001 | -0.098 | 0.922 | -0.044 |
| 6 | -0.007 | -1.253 | 0.212 | -0.051 |
| 7 | -0.001 | -0.137 | 0.891 | -0.052 |
| 8 | -0.014 | -2.306 | 0.022 | -0.065 |
| 9 | -0.006 | -1.055 | 0.293 | -0.072 |
| 10 | -0.002 | -0.384 | 0.701 | -0.074 |
| 11 | -0.004 | -0.673 | 0.502 | -0.078 |
| 12 | 0.001 | 0.217 | 0.828 | -0.076 |
| 13 | 0.002 | 0.271 | 0.787 | -0.075 |
| 14 | 0.001 | 0.102 | 0.919 | -0.074 |
| 15 | -0.011 | -1.875 | 0.062 | -0.085 |
| 16 | 0.003 | 0.523 | 0.602 | -0.082 |
| 17 | 0.001 | 0.248 | 0.805 | -0.081 |
| 18 | 0.004 | 0.677 | 0.499 | -0.077 |
| 19 | 0.002 | 0.258 | 0.797 | -0.075 |
| 20 | -0.010 | -1.774 | 0.077 | -0.086 |
| 21 | -0.006 | -1.027 | 0.305 | -0.092 |
| 22 | -0.008 | -1.329 | 0.185 | -0.100 |
| 23 | 0.003 | 0.524 | 0.601 | -0.096 |
| 24 | 0.000 | -0.012 | 0.990 | -0.097 |
| 25 | 0.000 | -0.060 | 0.925 | -0.097 |
| 26 | -0.002 | -0.266 | 0.790 | -0.098 |
| 27 | -0.004 | -0.618 | 0.537 | -0.102 |
| 28 | -0.009 | -1.420 | 0.157 | -0.111 |

**Table 2 (cont.)**
**Prediction Errors and Cumulative Prediction Errors**

Nuclear Utilities
(20)

| | |
|---|---|
| Alpha | 0.0004 |
| Beta | 0.745 |
| R-squared | 0.517 |
| Adjusted R-squared | 0.457 |
| F value | 8.601 |
| p value | 0.0001 |

| Event Day | PE | SPE (t) | p value | CPE |
|---|---|---|---|---|
| -1 | -0.005 | -1.04 | 0.301 | -0.005 |
| 0 | -0.010 | -1.95 | 0.053 | -0.015 |
| 1 | -0.004 | -0.80 | 0.423 | -0.020 |
| 2 | 0.006 | 1.23 | 0.221 | -0.013 |
| 3 | 0.004 | 0.82 | 0.415 | -0.009 |
| 4 | -0.002 | -0.35 | 0.726 | -0.011 |
| 5 | 0.000 | 0.05 | 0.958 | -0.011 |
| 6 | -0.005 | -0.93 | 0.355 | -0.016 |
| 7 | 0.002 | 0.43 | 0.671 | -0.013 |
| 8 | -0.004 | -0.70 | 0.483 | -0.017 |
| 9 | 0.001 | 0.29 | 0.774 | -0.015 |
| 10 | -0.002 | -0.33 | 0.743 | -0.017 |
| 11 | -0.002 | -0.32 | 0.748 | -0.019 |
| 12 | 0.007 | 1.25 | 0.214 | -0.012 |
| 13 | 0.004 | 0.79 | 0.433 | -0.008 |
| 14 | -0.002 | -0.39 | 0.698 | -0.010 |
| 15 | -0.008 | -1.46 | 0.147 | -0.018 |
| 16 | 0.003 | 0.50 | 0.620 | -0.015 |
| 17 | -0.003 | -0.57 | 0.570 | -0.018 |
| 18 | -0.005 | -0.97 | 0.332 | -0.023 |
| 19 | 0.000 | 0.00 | 0.999 | -0.023 |
| 20 | 0.002 | 0.44 | 0.663 | -0.021 |
| 21 | -0.003 | -0.59 | 0.555 | -0.024 |
| 22 | 0.002 | 0.45 | 0.657 | -0.022 |
| 23 | 0.008 | 1.48 | 0.140 | -0.014 |
| 24 | 0.001 | 0.16 | 0.874 | -0.013 |
| 25 | -0.004 | -0.78 | 0.438 | -0.017 |
| 26 | 0.000 | 0.06 | 0.953 | -0.017 |
| 27 | 0.000 | -0.02 | 0.985 | -0.017 |
| 28 | 0.004 | 0.69 | 0.492 | -0.013 |

**Table 3**
**Interval Test Statistics**

Conventional

| Time Period | CPE | F Values | p values |
|---|---|---|---|
| -1 through 0 | -0.012 | 2.987 | 0.085 |
| 1 through 5 | 0.013 | 1.304 | 0.255 |
| 6 through 10 | -0.003 | 0.090 | 0.764 |
| 8 through 13 | 0.003 | 0.074 | 0.786 |
| 14 through 21 | -0.003 | 0.053 | 0.819 |
| 7 through 21 | 0.001 | 0.002 | 0.967 |
| 22 through 28 | 0.010 | 0.527 | 0.469 |

Mixed

| Time Period | CPE | F Values | p values |
|---|---|---|---|
| -1 through 0 | -0.027 | 10.117 | 0.002 |
| 1 through 5 | -0.017 | 1.671 | 0.197 |
| 6 through 10 | -0.030 | 5.191 | 0.024 |
| 8 through 13 | -0.023 | 2.502 | 0.115 |
| 14 through 21 | -0.017 | 0.980 | 0.323 |
| 7 through 21 | -0.041 | 3.028 | 0.083 |
| 22 through 28 | -0.019 | 1.412 | 0.236 |

Nuclear

| Time Period | CPE | F Values | p values |
|---|---|---|---|
| -1 through 0 | -0.016 | 4.438 | 0.036 |
| 1 through 5 | 0.005 | 0.167 | 0.683 |
| 6 through 10 | -0.006 | 0.306 | 0.580 |
| 8 through 13 | 0.005 | 0.154 | 0.695 |
| 14 through 21 | -0.016 | 1.107 | 0.294 |
| 7 through 21 | -0.009 | 0.173 | 0.678 |
| 22 through 28 | 0.011 | 0.579 | 0.447 |

**Table 4**
**Risk Estimates for Electric Utility Portfolios Classified by Relative Nuclear Exposure**

Conventional

| Time Period (Event Days) | Correlation Coefficient | Standard Deviation | Beta |
|---|---|---|---|
| t - 250 to t - 1 | 0.280 | 0.013 | 0.560 |
| t - 250 to t - 126 | 0.296 | 0.013 | 0.680 |
| t - 125 to t - 1 | 0.262 | 0.013 | 0.478 |
| t + 1 to t + 125 | 0.353 | 0.015 | 0.585 |
| t + 126 to t + 250 | 0.381 | 0.014 | 0.576 |
| t + 1 to t + 250 | 0.360 | 0.014 | 0.570 |

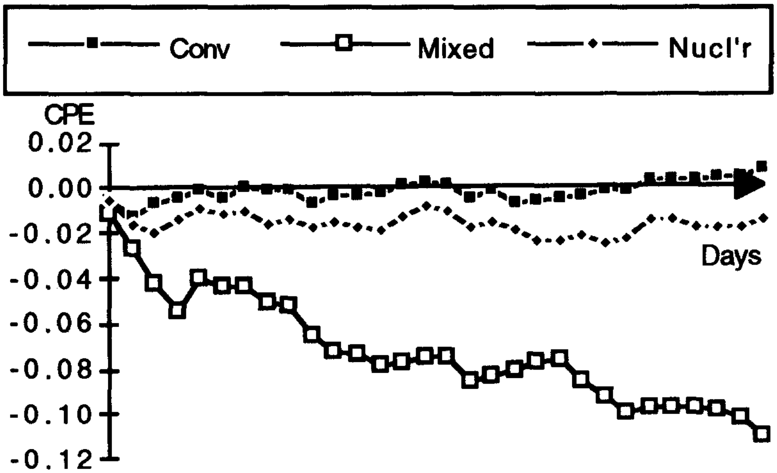
Mixed

| Time Period (Event Days) | Correlation Coefficient | Standard Deviation | Beta |
|---|---|---|---|
| t - 250 to t - 1 | 0.236 | 0.017 | 0.627 |
| t - 250 to t - 126 | 0.221 | 0.017 | 0.686 |
| t - 125 to t - 1 | 0.246 | 0.017 | 0.587 |
| t + 1 to t + 125 | 0.334 | 0.018 | 0.688 |
| t + 126 to t + 250 | 0.398 | 0.016 | 0.691 |
| t + 1 to t + 250 | 0.362 | 0.017 | 0.685 |

Nuclear

| Time Period (Event Days) | Correlation Coefficient | Standard Deviation | Beta |
|---|---|---|---|
| t - 250 to t - 1 | 0.327 | 0.015 | 0.745 |
| t - 250 to t - 126 | 0.308 | 0.016 | 0.904 |
| t - 125 to t - 1 | 0.354 | 0.013 | 0.641 |
| t + 1 to t + 125 | 0.406 | 0.014 | 0.644 |
| t + 126 to t + 250 | 0.446 | 0.014 | 0.657 |
| t + 1 to t + 250 | 0.420 | 0.014 | 0.641 |

**Figure 1**
**Cumulative Prediction Errors**



## Appendix A
## Chronological Listing of Events Following the Chernobyl Accident

| Date | Event |
|---|---|
| April 28, 1986<br>t = -1 | Sweden reports abnormal radiation levels in the atmosphere. USSR acknowledges accident at the Chernobyl nuclear power plant |
| April 29, 1986<br>t = 0 | UPI picks up the story. *Wall Street Journal, Los Angeles Times* and other newspapers publish the news |
| April 30, 1986<br>t = 1 | U.S. suspects second reactor may be involved. Level of fallout suggests major accident |
| May 1, 1986<br>t = 2 | U.S. government says nuclear reactor fire in Soviet Ukraine may continue to burn for weeks, spewing radioactive material into atmosphere |
| | USSR claims to have Chernobyl nuclear crisis under control, cites 197 injuries in accident |
| | France expresses confidence over safety of its nuclear plants |
| | U.S. energy officials say Soviet nuclear disaster could not be repeated in U.S. |
| May 2, 1986<br>t = 3 | Water around accident site reported to be contaminated. |
| | Howard Rosenberg comments on enormous difficulty U.S. and other Western media had in covering the accident at Chernobyl |
| | Department of Energy warns of potential problems at nuclear reactor in Richland (WA) as concern grows over safety of several U.S. nuclear plants that, like the Chernobyl facility in the Soviet Union, do not have containment structures to prevent release of radioactivity |
| | Soviet Union lists 18 persons in serious condition as a result of Chernobyl |
| May 3, 1986 | U.S. advises women of child-bearing age and all children not to travel to Poland because of potential radiation hazard from fallout from the nuclear reactor accident at Chernobyl |
| May 4, 1986 | Soviet official reports that 49,000 people were evacuated from the vicinity of Chernobyl plant, and that 20 to 25 people are critically ill in wake of the accident |
| | U.S. expert says that initial studies indicate little radiation from Chernobyl reaching Poland, and no possibility of future health hazard |
| | Soviets shut down 18 nuclear power plants |
| May 5, 1986<br>t = 4 | U.S. expresses concern that cooling problems at second reactor at Chernobyl could result in release of more radioactivity into the atmosphere |
| May 6, 1986<br>t = 5 | Radioactivity from accident sweeps high over U.S. |
| May 7, 1986<br>t = 6 | Walter C. Patterson argues Chernobyl may spell demise of nuclear power industry around the world |

**Appendix A (cont.)**
**Chronological Listing of Events Following the Chernobyl Accident**

| Date | Event |
|---|---|
| May 7, 1986<br>t = 6 | Soviet Union says that work to clean up vicinity of Chernobyl nuclear plant continues |
| May 8, 1986 | Hundreds of women and children, concerned about the radiation, leave Kiev on trains heading for Moscow |
| | Soviet officials say no public health danger exists outside a 19 mile radius |
| May 9, 1986<br>t = 8 | Soviet officials report evacuation of 84,000 people from the accident vicinity, hint at partial core meltdown |
| | *New York Times'* "Market Place" column says that the accident may have provided indirect benefit to companies that provide other forms of energy |
| May 10, 1986 | Nuclear Energy Agency says that Chernobyl causes no significant risk to public health in Western industrialized nations and Japan |
| | Federal task force monitoring Chernobyl accident says that State Department is no longer warning against travel to Poland by children and women of childbearing age |
| May 11, 1986 | Chernobyl disaster sparks antinuclear protests in West Germany |
| | Common Market bans import of fresh food from Eastern European nations due to the accident |
| | Questions arise over safety at nuclear power plants operated under regulation of the U.S. Energy Department |
| | Soviet officials report declining levels of radiation from Chernobyl plant as well as cooler reactor core |
| May 12, 1986<br>t = 9 | Senior Soviet officials assert that turning point has been reached in the accident and that Chernobyl no longer threatens catastrophe |
| May 13, 1986<br>t = 10 | Official death toll in the Chernobyl disaster rises to 8; 35 others are listed in grave condition |
| May 14, 1986<br>t = 11 | Goodwin calls for U.S. to dismantle its nuclear plants in light of Chernobyl disaster |
| May 15, 1986<br>t = 12 | Gorbachev says accident showed sinister force of nuclear power going out of control |
| May 19, 1986<br>t = 14 | Article in *Pravda* admits government delayed informing public about Chernobyl accident |
| May 20, 1986<br>t = 15 | Designer of Chernobyl plant blames human error for the accident |
| May 21, 1986<br>t = 16 | EPA to stop monitoring radiation levels of Chernobyl fallout over U.S. |
| | Soviet government reportedly plans to reactivate three reactors at Chernobyl |
| May 22, 1986<br>t = 17 | U.S. scientists estimate thousands may die of cancer in USSR and Europe as a result of the accident |

**Appendix A (cont.)**
**Chronological Listing of Events Following the Chernobyl Accident**

| Date | Event |
|---|---|
| May 25, 1986 | U.S. embassy in Moscow warns Americans against using local dairy products |
| May 27, 1986<br>t = 20 | Death toll rises to 19 |
| May 28, 1986<br>t = 21 | Soviet news agency reports 1,000 injured in the accident including evacuees from an 18 mile danger zone around Chernobyl plant |
| May 30, 1986<br>t = 23 | Chernobyl death toll increases to 23 |

Note: Sources are the *Los Angeles Times Index* (1986) and *New York Times Index* (1986). A similar compilation is provided by Pruitt *et al.* (1987)

## Appendix B
## Sample and Portfolios

### Nuclear Portfolio

| Company Name | Percent Nuclear |
|---|---|
| Carolina Power& Light Co. | 33.40 |
| Central Vermont Public Service Corp. | 77.26 |
| Commonwealth Edison | 60.84 |
| Duke Power Co. | 48.12 |
| FPL Group, Inc. | 40.12 |
| General Public Utilities Corp. | 24.75 |
| Green Mountain Power Corp. | 64.58 |
| IE Industries | 53.11 |
| Iowa Illinois Gas & Electric Co. | 36.83 |
| Kansas City Power & Light Co. | 26.94 |
| Kansas Gas & Electric Co. | 41.46 |
| Middle South Utilities, Inc. | 33.03 |
| Northeast Utilities | 61.64 |
| Pacific Gas & Electric Co. | 24.39 |
| Pennsylvania Power & Light Co. | 26.47 |
| Portland General Corp. | 54.87 |
| San Diego Gas & Electric Co. | 39.12 |
| SCANA Corp. | 32.67 |
| Southern Co. | 25.68 |
| Union Electric Co. | 19.92 |

### Mixed Portfolio

| Company Name | Percent Nuclear |
|---|---|
| American Electric Power, Inc. | 11.47 |
| Atlantic Energy, Inc. New Jersey | 17.30 |
| Central Maine Power Co. | 12.18 |
| CMS Energy Corp. | 12.56 |
| Duquesne Light Co. | 17.10 |
| Eastern Utilities Association | 11.49 |
| Fitchburg Gas & Electric Light Co. | 10.44 |
| Florida Progress Corp. | 10.47 |
| Gulf States Utilities Co. | 9.46 |
| New England Electric System | 9.94 |
| Niagara Mohawk Power Corp. | 16.78 |
| Ohio Edison Co. | 9.02 |
| Public Service Co. of New Hampshire | 4.60 |
| Southern California Edison Co. | 12.43 |
| United Illuminating Co. | 4.02 |
| Wisconsin Power & Light Co. | 18.22 |

**Appendix B (cont.)**
**Sample and Portfolios**

Conventional Portfolio

| Company Name | Percent Nuclear |
|---|---|
| Allegheny Power Systems, Inc. | 0.00 |
| Black Hills Corp. | 0.00 |
| Centel Corp. | 0.00 |
| Central & Southwest Corp. | 0.00 |
| Empire Distribution Electric Co. | 0.00 |
| Hawaiian Electric Industries | 0.00 |
| Idaho Power Co. | 0.00 |
| Illinois Power Co. | 0.00 |
| Interstate Power Co. | 0.00 |
| Iowa Resources, Inc. | 0.00 |
| IPALCO Enterprises, Inc. | 0.00 |
| Kentucky Utilities Co. | 0.00 |
| Louisville Gas & Electric Co. | 0.00 |
| Maine Public Service Co. | 0.00 |
| MDU Resources Group, Inc. | 0.00 |
| Midwest Energy Co | 0.00 |
| Minnesota Power & Light Co. | 0.00 |
| Montana Power Co. | 0.00 |
| NECO Enterprises, Inc. | 0.00 |
| Nevada Power Co. | 0.00 |
| Northern Industrial Public Service Co. | 0.00 |
| Oklahoma Gas & Electric Co. | 0.00 |
| Pacificorp | 0.00 |
| Potomac Power & Light Co. | 0.00 |
| Public Service Co. of Indiana, Inc. | 0.00 |
| Puget Sound Power & Light Co. | 0.00 |
| Savannah Electric & Power Co. | 0.00 |
| Southwestern Public Service Co. | 0.00 |
| TECO Energy, Inc. | 0.00 |
| Texas Utilities Co. | 0.00 |
| TNP Enterprises, Inc. | 0.00 |
| Tucson Electric Power Co. | 0.00 |
| Utah Power & Light Co. | 0.00 |

Deleted Due to Data Limitations

| Company Name | Percent Nuclear |
|---|---|
| Brascan Ltd. | - |
| British Columbia Power Ltd. | - |
| California Electric Power Co. | - |
| Canadian International Power Ltd. | - |
| Catalyst Energy Corp. | - |
| Cleveland Electric Illumination Co. | - |
| Columbus & Southern Ohio Electric Co. | - |
| Dayton Power & Light Co. | - |
| Gatineau Power Co. | - |
| Hartford Electric Light Co. | - |
| O'Brien Energy Systems | - |
| Quebec Power Co. | - |
| Toledo Edison Co. | - |

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