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PENNSYLVANIA PUBLIC UTILITY COMMISSION

v.

PHILADELPHIA ELECTRIC COMPANY

SECRETARY
Public Utility Commission

DIRECT TESTIMONY

OF

CHARLES KOMANOFF

DOCKETED
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CONCERNING

ECONOMICS OF LIMERICK UNIT 1

DOCUMENT
FOLDER

ON BEHALF OF

PENNSYLVANIA OFFICE OF CONSUMER ADVOCATE

January, 1986

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1. WITNESS IDENTIFICATION AND QUALIFICATIONS

Q. Please provide your name, business address and a summary of your professional qualifications.

A. My name is Charles Komanoff. I am director and principal of Komanoff Energy Associates, an energy and economic consulting firm located at 270 Lafayette Street, New York, NY 10012.

I am a consultant, analyst and author on the economics of the electric utility, nuclear power and coal sectors of the United States economy. I have consulted for two agencies of the U.S. Congress, the U.S. Department of Energy, and governmental agencies of 15 States, including the nine most populous States. My three books on the monetary and societal costs of nuclear and coal electric generation, published in 1972, 1976 and 1981, identified and anticipated critical trends in electric power economics, technology and regulation, and are considered leading texts on their subjects.

Q. Please summarize your work experience in energy and electricity issues.

A. My professional study of the U.S. electric power, nuclear and coal sectors dates from 1971. I have worked for the Council on Economic Priorities (1971-72 as a research fellow, 1974-76 as energy projects director); for the New York City Environmental Protection

Administration (1972-73 as quantitative analyst, 1973-74 as senior quantitative analyst); and for Komanoff Energy Associates, which I founded in January 1977. While my work experience has focused on power plant capital, fuel and operating costs and performance, it has extended to virtually every aspect of energy and electricity policy, from nuclear power safety to the environmental impact of coal burning, from generation planning to energy conservation.

Q. Please summarize your consulting activities for governmental agencies.

A. My consultancies for governmental clients generally concern economic and/or environmental aspects of electric power, coal and nuclear policy and facilities, particularly nuclear power issues. Since 1976 I have performed consulting studies for the General Accounting Office and Office of Technology Assessment of the U.S. Congress, and governmental agencies of the States of Pennsylvania, California, New York, Texas, Ohio, Illinois, Florida, and eight other states. I recently assisted the federal Department of Energy in formal review of a DOE study of nuclear plant construction costs and lead times. Exhibit CK-1 includes a listing of my governmental clients.

Q. Please summarize your publications on energy and electricity matters.

A. My books are briefly described in Exhibit CK-1. I have also published numerous articles in both general periodicals and professional journals, including Nuclear Safety (published at Oak

Ridge National Laboratory by the DOE), Journal of the Air Pollution Control Association, Public Utilities Fortnightly, The Wall Street Journal, and The New York Times. In May I will present a paper to the American Association for the Advancement of Science, on the economic impact of the Three Mile Island accident, as part of a panel that includes Pennsylvania Gov. Richard Thornburgh and former Nuclear Regulatory Commissioner Victor Gilinsky. A list of my articles appears in Exhibit CK-1.

Q. Were you assisted in preparing the analysis and exhibits you are presenting here?

A. Yes. I was assisted by John Plunkett, Senior Economist at Komanoff Energy Associates. Mr. Plunkett performed much of the quantitative analysis underlying my testimony, particularly the calculations of revenue requirements for Limerick 1's capital cost and capital additions costs.

Q. Please summarize Mr. Plunkett's qualifications and work experience.

A. Mr. Plunkett is responsible for developing and maintaining KEA data bases and quantitative methodologies. These include data bases of nuclear and coal capital costs, nuclear operating and capital additions costs, and nuclear capacity factors; and computer software for estimating nuclear and coal generating costs, utility financing costs, and the profitability of technologies for reducing utility costs including cogeneration, renewables and end-use efficiency measures. Mr. Plunkett's credentials and work experience are summarized in Exhibit CK-2.

Q. Have you previously testified before the Pennsylvania Public Utilities Commission?

A. Yes. I filed direct and surrebuttal testimony on behalf of the Pennsylvania Office of Consumer Advocate (OCA) in the Commission's Limerick 2 Investigation (I-840381) in early 1985. My testimony concerned the lifetime owning and operating costs of Limerick 2 as well as the costs of alternative generating facilities, primarily new coal-fired capacity.

2. PURPOSE AND SUMMARY OF TESTIMONY

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to determine when, if ever, PECO's Limerick 1 facility is expected to produce net economic benefits to ratepayers. More specifically, I calculated Limerick 1's annual benefits and costs to estimate how many years it would take for the annual benefits to exceed the costs, and also to determine whether the cumulative benefits will outweigh the cumulative costs on a lifetime present-worth basis. To make these determinations, I estimated the annual owning and operating costs, as well as the annual energy and capacity benefits, of Limerick 1. This entailed reviewing PECO's estimates as well as developing independent calculations of the factors contributing to Limerick 1's costs and benefits.

Q. What did you conclude regarding Limerick 1's annual costs and benefits?

A. Limerick 1's annual benefits, in terms of capacity provided and generation produced, should not be expected to exceed its annual owning and operating costs until 1998. (This excludes a small, temporary net savings expected for 1995, since that is immediately offset by net costs roughly ten times as great in 1996-97.) The expected net benefits turn negative again in 1999 and 2000, so that not until 2001 do annual benefits persistently outweigh costs throughout the remainder of Limerick 1's economic life.

Thus, except for the single year 1998, the annual costs of Limerick 1 may be expected to exceed annual benefits throughout the rest of the century, although by steadily decreasing amounts. In 1986, Limerick 1's projected first year of commercial operation, the net annual costs (costs less benefits) will be $762 million. Five years later, in 1991, the net annual costs, although smaller, will still be $512 million, while in 1996 they will be $111 million. Through 2000, the last year in which the expected annual costs exceed annual benefits, the net present value of all of the years' net costs -- that is, the sum of all costs minus the sum of all benefits, discounted to mid-1985 -- will be $3.317 billion.

Q. What did you conclude regarding Limerick 1's lifetime costs and benefits?

A. The present value of Limerick 1's expected net benefits starting in the "turnaround year" 2001 -- the first year that annual benefits permanently exceed annual costs -- will fall far short of the present value of the prior years' expected net costs. Assuming, as PECO does, that Limerick 1 achieves a useful life of 39 years and operates through the year 2024, the discounted net benefits from the years 2001 through 2024 will be $1.319 billion. Since Limerick 1's expected discounted net costs during 1986-2000 are $3.317 billion, the lifetime net cost will be $1.998 billion.

In the event that Limerick 1 has a useful life of 30 years, which I believe is a more realistic expectation than a 39-year life, the discounted net benefit after 2000, through 2015, the last operating year, would be only $739 million. After netting against the total 1986-2000 net costs of $3.317 billion, the lifetime net cost would be $2.578 billion.

Q. Please summarize your conclusions regarding Limerick 1's annual and lifetime costs and benefits.

A. First, the first year in which Limerick 1 will provide robust net benefits to ratepayers will be 1998. Second, on a net discounted present-worth basis, Limerick 1 will cost ratepayers between $2.6 and $2.0 billion over its 30-39 year life. As I discuss below, relaxing PECO's extreme assumptions regarding the availability of two-party purchases outside of PJM results in an even later turnaround date and even greater net costs for Limerick 1.

The expected costs and benefits from Limerick 1, both annual and cumulative, are shown in Exhibit CK-3.

Q. How do your conclusions on Limerick 1 economics compare with PECO's?

A. PECO's analysis of Limerick 1 economics finds that Limerick won't provide benefits to ratepayers on an annual basis until 1994. On a cumulative net present-worth basis, Limerick 1's impact on ratepayers will not turn positive until either 2006 or 2008 (the precise year depends upon whether PECO assumes either a complete elimination or a one-half reduction in two-party power purchases). Savings thereafter will result in a positive net economic benefit between $2 and $4 billion, according to PECO.

Q. What accounts for the wide divergence -- a swing of at least $5 billion -- between your and PECO's estimates of Limerick 1's net economic cost/benefit?

A. PECO's and my analyses both employ the same basic calculational framework to estimate Limerick 1's annual and cumulative costs and benefits, with one exception regarding carrying charge rates that I describe below. We differ in positing the following five key input assumptions bearing on the costs and benefits:

1. annual Limerick 1 operating and maintenance (O&M) costs;

2. annual Limerick 1 capital additions (post-completion capital investment) costs;

3. Limerick 1 capacity factor, including expected plant operational life;

4. costs of fossil fuels which Limerick 1 generation will displace;

5. capacity deficiencies and charges that Limerick 1 will avert.

Further below I specify my input assumptions and explain how and why they differ from PECO's.

Q. Are there any other PECO input assumptions which you have used in calculating Limerick costs and benefits, but with which you disagree?

A. Yes. I have followed PECO in assuming the elimination of PECO's two-party purchases -- purchases of economy energy from utilities in neighboring pools, outside of PJM -- after 1993. (Although PECO's economic analysis had two alternative cases, which reduced two-party purchases after 1993 by 50 and 100 percent, respectively, the Company assumed the 100 percent reduction in its SOBIG runs using OCA's assumptions for fossil fuel prices and nuclear capacity factors. This requires me to assume the complete elimination of two-party purchases in my calculations.)

Q. Why is this assumption questionable?

A. First, PECO provided no rationale for reducing or eliminating two-party purchases after 1993. Second, the assumption appears extreme on its face. ECAR, the large reliability council immediately to the west of PJM, enjoys a very large reserve margin. In 1984 (the last year for which data are available), ECAR's installed summer capability was 90 GW while its summer peak was only 66 GW, indicating a summer reserve of 24 GW, or 37 percent. Moreover, the 1985 appraisal of future supply and demand by NERC (North American Electric Reliability Council) foresees adequate supplies for ECAR through 1994 (the last year to which NERC forecasts extend). If <u>peak</u> demands in ECAR appear likely to be met with little difficulty at least through 1994, then economy energy should also be available, particularly in view of the relatively high percentage of base-load capacity (primarily coal-fired) in ECAR's capacity mix.

Q. How much do PECO's assumptions of reduced or eliminated two-party purchases add to the calculated benefits of Limerick 1?

A. PECO's calculated net benefit for Limerick 1 reduces to $2.2 billion assuming continuation of the present level of two-party purchases after 1993. This contrasts with PECO's result of a $3.0 billion benefit with a 50 percent reduction, and $3.8 billion with a complete reduction.

My finding of a $2.0 billion net <u>cost</u> for Limerick 1 assumed no two-party purchases after 1993. I cannot calculate precisely Limerick's added cost (or shrunken benefit) from assuming half or full purchases, since this would require performing new runs of PECO's SOBIG model. However, a rough but reasonable way to estimate the effect of assuming continued purchases is to apply the ratio of

Limerick 1 fuel savings calculated under OCA assumptions (60% nuclear capacity factor and lower fossil fuel escalation rates), to the savings calculated under PECO assumptions. That ratio is 70-75 percent (i.e., Limerick 1 generates somewhat smaller fuel savings under OCA assumptions). Applying this ratio to the decline in Limerick benefits shown above indicates that only halving two-party purchases would raise Limerick's net cost to $2.6 billion (or $3.0 billion with a 30-year life), while maintaining two-party purchases at their present level raises Limerick's net cost to $3.2 billion (or $3.5 billion assuming a 30-year economic life for Limerick 1).

Q. Please enumerate the effect on Limerick 1's net economics of each of your five differences in key input assumptions from PECO.

A. The effects of the different assumptions vary according to whether Limerick 1 is expected to have a 30 or 39-year operating life. They are as follows:

1. My higher assumed annual O&M costs increase the net lifetime cost by $96 million for a 30-year life, and $218 million for a 39-year life.

2. My higher assumed annual capital additions costs increase the net lifetime cost by $1,287 million for a 30-year life, and $1,835 million for a 39-year life. (Both figures reflect PECO's calculational assumption of a constant cost of capital; assuming a varying cost of capital, as discussed below, the differences are $1,285 million for a 30-year life, and $1,825 million for a 39-year life.)

3&4. The effects of my lower nuclear capacity factor and lower PECO and PJM fossil fuel prices cannot be separated, because the two were coupled in the SOBIG run performed by PECO at OCA's request. Their combined effect on the net lifetime cost, assuming two-party purchases are eliminated after 1993, is an increase of $1,683 million for a 30-year life, and $2,161 million for a 39-year life.

5. Recalculation of the capacity charges avoided by Limerick 1, under the assumptions (a) that PECO retains (rather than retires in 1986) 458 megawatts of combustion turbines through 1996, and (b) that PJM capacity-deficiency charges do not double as PECO's calculations assume, increases the net lifetime cost by $1,179 million for a 30-year life, and by $1,335 million for a 39-year life.

Q. Please describe the difference between your and PECO's treatment of Limerick 1 carrying charge rates, to which you alluded earlier.

A. PECO projects that its costs of debt and equity capital will be less during the later years of Limerick 1 than in the early years. PECO projects a constant 15.0% rate of return on equity during 1986-1990, but this declines rapidly thereafter to as low as 13.6%, and averages 13.78% for the rest of the anticipated 39-year life, during 1991-2024. Similarly, PECO projects that its cost of debt will average 14.24% during 1986-1990 but only 11.77% thereafter. (These figures are calculated from the annual costs of capital given in PECO Interrogatory Response IR-OCA-2-25b, Attachment, Item 5, p. 2 of 2.)

I have employed PECO's assumed costs of capital in calculating carrying charge rates for Limerick 1, since they determine what ratepayers are actually expected to pay in carrying charges. Yet in its own calculations of Limerick 1 carrying costs, PECO ignored its annual projections of debt and equity rates and instead assumed a constant rate, equal to the average of the annual costs of capital. That is, in figuring annual Limerick 1 carrying charges, PECO applied the <u>average</u> of the costs of capital it expects over the life of Limerick 1, rather than the changing <u>annual</u> rates that PECO actually projected.

Q. How does PECO's use of a constant, average cost of capital affect its calculation of Limerick 1 costs?

A. PECO's use of a single average cost of capital results in understating Limerick 1's cumulative carrying costs. This is because of two independent, but mutually reinforcing, factors. First, Limerick 1's depreciated rate-base cost declines over time. Whereas in reality PECO's high cost of capital in the early years will be applied against Limerick 1's high rate-base cost, PECO's calculations lose this effect by applying a lower, average cost of capital against the high early costs. Although the missing costs are partially offset by the higher average cost of capital applied in the later years, PECO's calculations understate the carrying charges in the early years more than they overstate the carrying charges in the later years.

Second, this effect is magnified by the discounting process, which assigns a greater present worth to early dollars than to later ones. Thus, not only does PECO's averaging method fail to fully offset uncounted early dollars with extra late dollars, but each later dollar has less clout in the final calculation of present-worth costs.

Q. What is the overall effect of PECO's use of an average, rather than specific cost of capital in calculating Limerick 1 carrying charges?

A. PECO's practice reduces the apparent lifetime present worth of revenue requirements associated with Limerick 1's original capital cost by $273 million. Correcting it restores $271 million to the calculation of Limerick 1's life-cycle costs (since using the specific costs of capital reduces the present worth of revenue requirements associated with PECO's assumed future capital additions by $2 million).

Q. How have Limerick common costs been treated in your calculations of annual and lifetime Limerick costs and benefits?

A. Consistent with the method used by PECO witness Dr. Hieronymus in his analysis, I have assumed that only half of common costs in the original book cost of Limerick 1 are reflected in rates. Were I to assume that all Limerick common costs are entered in rate base, as PECO has requested from the Commission (but has not assumed in its figures), Limerick 1's net life-cycle costs would increase by $1,164 million, to a total of $3.7 billion, assuming a 30-year life, and by $1,177 million to a total of $3.2 billion, for a 39-year life. The turnaround year, in which annual benefits first consistently exceed costs, would be pushed back from 1998 to 2001 (excluding a temporary net benefit in 1998, which is more than offset by net costs in 1999 and 2000).

So far as common costs for O&M and capital additions are concerned, I have effectively assigned all such costs to Limerick 1, by estimating its costs as if Limerick 1 were a one-unit station. This is appropriate for two reasons. First, Limerick will be a one-unit plant at least until 1990, and further if Unit 2 is delayed or cancelled. Second, both PECO and OCA assigned common O&M and capital additions costs to Unit 1 in the Limerick 2 investigation, resulting in relatively low forecasts of incremental O&M and capital additions costs for Unit 2. That is, to the extent that a second Limerick unit would be expected to reduce overall station per-kW O&M and capital additions costs, due to economies generally exhibited by multi-unit plants, both PECO and OCA assigned all of the per-kW savings to Unit 2. For consistency, I have employed that approach here as well.

3. DIFFERENCES BETWEEN KEA AND PECO INPUT ASSUMPTIONS

Q. You have stated that your calculation of Limerick I costs and benefits differs from PECO's primarily because of your higher estimates of future Limerick 1 O&M costs and capital additions, and your lower estimates of Limerick 1 and other nuclear capacity factors, future PECO and PJM fossil fuel prices, and PECO capacity deficiencies. How did you develop your estimates of these factors?

A. Throughout, I have used the same methods, and in some cases the same numerical results, that I employed in the Limerick 2 investigation (I-840381). For fossil fuel prices and nuclear capacity factors I have used the same escalation rates and performance factors, respectively, that I applied in the Limerick 2 investigation. For Limerick O&M and capital additions costs, I have used the same statistical and conceptual models as a year ago to trend U.S. empirical O&M and capital additions costs, but I have improved and updated the data base, leading to somewhat different numerical results.

3A. Limerick 1 O&M and Capital Additions Costs

Q. Please describe how you developed your estimates of Limerick 1 O&M and capital additions costs.

A. My estimates of future Limerick 1 O&M and capital additions costs are shown in Exhibits CK-4 and CK-5. I have based them on Komanoff Energy Associates' statistical analysis of O&M and capital additions costs actually experienced at U.S. nuclear plants, from 1970 through 1984. The analysis identifies empirically observed technical and institutional factors bearing on nuclear O&M and capital additions costs. These include higher costs for: (i) recently completed plants and (ii) all plants as they age, and, to a somewhat lesser extent, (iii) all plants since the 1979 accident at Three Mile Island, and (iv) plants in higher-wage areas. I applied these trends to Limerick 1's characteristics -- its completion date, aging pattern, wage rates, etc. -- to obtain an estimate of future O&M and capital additions costs under the assumption that Limerick 1's costs parallel U.S. nuclear cost experience to date.

Q. Why do you consider this a more valid approach to estimating O&M and capital additions costs than PECO's approach, which extrapolated from O&M and capital additions experience at the Company's Peach Bottom nuclear facility?

A. PECO's approach requires that Limerick be extremely similar to Peach Bottom in design, construction and operation, so that costs experienced at one can be ascribed to the other, after allowing for specific itemized differences. However, Limerick was built in a different era of nuclear power than Peach Bottom, under a considerably more exacting regulatory regime. Not surprisingly, after adjusting for inflation, Limerick's original per-kW cost is approximately twice that of Peach Bottom's, indicating that Limerick's design and construction used roughly double the engineering, equipment, labor and materials built into Peach Bottom. As a result, the two facilities differ importantly as to what will be required to maintain, operate and upgrade them.

Q. What does this difference portend for Limerick O&M and capital additions costs vis-a-vis Peach Bottom's?

A. U.S. cost experience to date, as reflected in KEA's statistical analysis, demonstrates that O&M and capital additions costs generally increase as plant completion date increases. For each year of later completion, O&M costs rise by as much as $3 per kW of capacity, and capital additions by roughly $2/kW. (These figures are in 1985 dollars, assume a plant of Limerick's capacity using freshwater for cooling, and employ the "linear" model for O&M costs.) Thus, despite measures intended to enhance performance and maintainability, the later plants' greater size, scope, detail and complexity cause them to require more operating personnel, more repairs, more spare parts, and more equipment replacement. Limerick, as a decade-later plant than Peach Bottom, should cost roughly $30/kW more each year to operate and maintain, and $20/kW more annually to refurbish and upgrade.

Q. What do aging trends in O&M and capital additions costs signify for Limerick 1, vis-a-vis Peach Bottom?

A. Industry experience also demonstrates that older nuclear units generally have higher O&M and capital additions costs than younger plants -- by roughly $2/kW for each year older. (These figures are also in 1985 dollars, assume a plant of Limerick's capacity using freshwater for cooling, and employ the "linear" model for O&M costs.) This is to be expected, since older plants suffer greater wear-out of equipment, which is a major contributor to maintenance, repair and replacement activities. Thus, relying on Peach Bottom experience, which encompasses only the first 11 years of operating life (through 1985), leads to understated O&M and capital additions costs over the 30-year (or 39-year, in PECO's economic calculations) life of Limerick 1.

Q. In your 1985 testimony in the Limerick 2 investigation, you also developed statistically-based estimates of Limerick O&M and capital additions costs from U.S. nuclear experience. How closely does your present method for estimating costs for Limerick 1 follow your past approach?

A. I have used the same statistical models here as a year ago. These control for cost differences associated with area wage rates, saltwater vs. freshwater cooling, and multiple vs. single-unit plants, in order to isolate the extent to which O&M and capital additions costs vary with each reactor's completion date, age, and operation before or after TMI. The results of these models in the Limerick 2 investigation -- lifetime projections of annual Limerick 2 O&M and capital additions costs -- were accepted by the ALJ as the most reasonable projections advanced in that proceeding. (Recommended Decision of ALJ Allison K. Turner, pp 246 and 253.)

Q. Did you alter the O&M and capital additions data bases underlying the statistical models, between your Limerick 2 testimony a year ago and your Limerick 1 testimony here?

A. I made several improvements to the underlying cost data for this testimony. First, I updated the data to include U.S. O&M and capital additions experience for an additional year, 1984. In addition, whereas a year ago I employed a data base developed by Energy Systems Research Group, for my present testimony I relied upon Komanoff Energy Associates' own independently compiled O&M and capital additions cost data base.

Q. How do the new 1984 data compare with prior O&M and capital additions costs?

A. U.S. nuclear plants reached record-high average costs for both O&M and capital additions (particularly the latter), in 1984, in real (inflation-adjusted) terms, as shown in Exhibit CK-6. O&M costs, measured in constant 1984 dollars, increased from $54/kW in 1983 to

$61/kW in 1984. This was the second largest year-to-year increase to date, surpassed only by the increase in 1980, the first full year after Three Mile Island. The increase maintained the unbroken string of annual increases in average U.S. nuclear O&M costs, even after adjusting for inflation.

Capital additions costs increased even more steeply, from $36/kW in 1983 to $52/kW in 1984, the biggest year-to-year increase in average capital additions costs on record. In percentage terms, the 45% increase was the third largest to date. Thus, neither O&M nor capital additions costs showed signs of slackening at U.S. nuclear plants in 1984.

Q. As a conservatism in projecting Limerick 2 O&M and capital additions costs in last year's Limerick 2 investigation, you limited your extrapolation of completion-date trends and post-TMI trends. Have you done so here as well for Limerick 1?

A. Yes. As before, I halved the post-TMI factor, which captures the extra increase in nuclear O&M and capital additions costs since 1979, in estimating future costs for Limerick 1. This will allow for possible diminution of the extra TMI costs, which could result from easing regulatory pressures as the accident fades into history, or from development of management systems and technical fixes to cope with the closer surveillance and more extensive backfitting required since 1979. Halving the TMI effect is also appropriate in view of its reduced statistical significance in the updated data base with 1984 costs.

In calculating the effects of Limerick 1's later completion date relative to operating units, I "froze" the completion date at 1984, the last date of completions in the data base. As a result, the well-established industry-wide trends toward higher maintenance and repair costs for new units are factored into Limerick 1's costs only as far as they have been observed to date, and are not extrapolated beyond the data base. This will allow for the possibility that some of the additional equipment built into newer plants such as Limerick 1 will enhance plant operability and longevity, offsetting somewhat the expenses of maintaining and upgrading the increased equipment.

My adjustments of the TMI and completion-date effects result in lower projected costs for Limerick 1 than would obtain from using the statistical equations without adjustments. However, as in my Limerick 2 testimony, I did not mitigate the aging effect, insofar as aging is well-entrenched both statistically and in the nature of nuclear plant equipment.

3B. Limerick 1 Capacity Factor and Life Expectancy

Q. What capacity factor have you assumed for Limerick 1 and other nuclear units in calculating the value of fossil fuels to be displaced by generation from Limerick 1?

A. I assumed an average 60 percent capacity factor for all nuclear units in PJM, including Limerick 1.

Q. Do you consider that an optimistic assumption?

A. I consider 60 percent somewhat optimistic for Limerick 1 and other boiling water reactors (BWRs) in PJM. For pressurized water reactors (PWRs), which have generally had a higher performance level than BWRs, I think 60 percent is a realistic estimate.

Q. Why is 60 percent optimistic for BWRs such as Limerick 1?

A. Through the end of 1984, U.S. commercial BWRs had averaged only 57 percent capacity factor, and only 54 percent for the five years (1980-84) after the Three Mile Island accident, as Exhibit CK-7 shows. Although data for the full year 1985 aren't yet available, preliminary data indicate that the average BWR capacity factor for 1985 was only 54 percent, matching the 1980-84 performance level. Thus, for Limerick 1 to achieve 60 percent would entail surpassing the historical BWR average.

Q. You have noted in the past that reliance upon historical averages may not necessarily be the most accurate way of projecting future capacity factors, because the historical data vary with respect to plant age, size, type of cooling water used, etc. Have you performed a statistical analysis -- controlling for variations in plant age and size and other factors -- to support your conclusion that 60 percent is somewhat optimistic for Limerick 1?

A. Yes. In my direct testimony in the Limerick 2 investigation a year ago, I presented a comprehensive statistical analysis performed on historical commercial U.S. BWR capacity factor experience (using data through 1983 and preliminary data for 1984). This analysis controlled for all of the statistically significant factors that could be linked to higher or lower BWR capacity factors to date. My conclusion was that after adjusting the BWR performance record to make it most comparable to the characteristics of Limerick 2 and the likely circumstances under which Limerick 2 would operate, the record indicated a 50 to 54 percent lifetime capacity factor for Limerick 2. However, I chose to modify the statistical result somewhat, to account for learning effects which, although not yet empirically demonstrated, could plausibly be expected. The result was an "optimistic" forecast of 60 percent for Limerick 2.

Q. How did the statistical analysis lead to the 50 to 54 percent unadjusted prediction for Limerick 2?

A. Briefly, the analysis demonstrated that BWR capacity factors were higher for (i) smaller units, (ii) operation before the TMI accident, (iii) units cooled by freshwater, and (iv) older units through age 12. When the typical unit making up the BWR capacity factor sample was adjusted to Limerick 2's characteristics -- (i) a large unit,

(ii) operating after TMI, (iii) cooled by freshwater, and (iv) operating over a 20-year or longer period in which it will improve with age for some years but eventually decline -- the 57 percent average at that time to date converted to a 50-54 percent projection for Limerick 2 averaged over its life.

In effect, the 57 percent average was weighted slightly by helpful factors that Limerick 2 won't enjoy, particularly smaller plant size. Compensating for these factors in the statistical analysis led to the 50-54 percent projection.

Q. In the Limerick 2 proceeding, how and why did you modify this statistical result to indicate that a 60 percent capacity factor was optimistically plausible for Limerick 2?

A. Statistical analysis should be open to informed judgment as to differences to be expected between future and past performance. Based on my reading of factors affecting nuclear plant performance, I noted two phenomena which, though not yet statistically observable, I considered reasonably likely to emerge in the future.

First I believe that much of the almost 10 percentage point drop in BWR capacity factors since TMI reflects containment backfitting and pipe repairs which will not recur to the same extent. On the other hand, the post-TMI decline also reflects closer regulatory surveillance and greater utility concern with assuring safety, which

I expect will largely persist. To account for both of these effects, I applied only half of the post-TMI decline -- 5 percentage points instead of 10 -- to Limerick 2.

Second, I concluded that it was reasonable, if slightly optimistic, to expect that newer units such as Limerick 2 will show some capacity factor gain from the investments committed to newer reactors to improve their performance. This expectation had to be tempered, however, by the fact that higher capacity factors for newer units had yet to materialize in the nuclear industry, despite continual predictions that newer-model reactors would outperform earlier ones. Balancing these considerations, I added several percentage points to the statistical projection of Limerick 2's capacity factor, resulting in a 60 percent estimate.

Q. How did the ALJ in the Limerick 2 investigation evaluate your projection of a 60 percent capacity factor?

A. While ALJ Turner concluded that both PECO's and my capacity factor arguments on behalf of OCA "contain[ed] assailable assumptions," she found that "the OCA position on capacity factor for Limerick 2 of 60% appears to be the capacity factor which best depicts what may be expected over the total life of Limerick 2." Accordingly, ALJ Turner "recommend[ed] that the Commission use a 60% capacity factor in evaluating the decision to complete Limerick 2 versus other alternatives." (Recommended Decision of ALJ Allison K. Turner, p. 238.)

Q. If the best estimate of Limerick 2's capacity factor is 60 percent, what does that indicate for Limerick 1?

A. BWR capacity factors to date have shown no difference between performance for first and second identical units. Thus, from a strictly statistical standpoint, Limerick 1 should fare no differently from Limerick 2. Nevertheless, Limerick 2 could have been expected to benefit somewhat as a later unit, both from greater accumulation of industry-wide learning and from an easing in the post-TMI environment. Indeed, Limerick 2's late completion date was one of the considerations that led me to increase the statistical projection of the Limerick 2 capacity factor from 50-54 percent to 60 percent. Limerick 1 is less likely to experience these improvements, indicating that a 60 percent capacity factor is at least as much optimistic as realistic.

Q. Have you explicitly reflected PECO's experience at Peach Bottom in projecting a 60 percent capacity factor for Limerick 1?

A. All BWR units, including PECO's Peach Bottom 2 and 3 units, were accorded equal weight in the statistical analysis which, with adjustments, led to my 60 percent capacity factor projection last year. In my Limerick 2 testimony, I noted that based on data through

1984, Peach Bottom's performance was 1 to 2 percentage points higher than would have been expected on the basis of overall U.S. BWR experience -- an insignificant difference. Today, following Peach Bottom's poor experience in 1985 -- Units 2 and 3 had capacity factors of roughly 30 and 40 percent, respectively -- Peach Bottom's lifetime average capacity factor equals the U.S. BWR average. Accordingly, PECO's nuclear performance record conveys no reason to impute a higher or lower capacity factor to Limerick 1.

Q. In your testimony in the Limerick 2 investigation, you said that you doubted that Limerick 2 could operate for 39 years, the plant lifetime that PECO assumed. Do you hold the same doubts about Limerick 1?

A. Yes. The tendency for U.S. nuclear plants to experience increased operating problems beyond the first dozen or so years of plant life is well established, both statistically and in the engineering literature. Although increased expenditures to maintain, upgrade and replace aging equipment and systems -- which I have assumed in projecting rising real O&M and capital additions expenditures for Limerick 1 -- will counter this tendency to an extent, it isn't realistic to expect that nuclear units such as Limerick 1 will be able to function for more than three decades without incurring such expenditures past the cost-effective point.

Q. Have 1985 performance data changed BWR aging trends?

A. Older BWRs -- those past age 12 -- had a very good year in 1985, averaging 73 percent capacity factor through November (although end-of-year refuelings will probably reduce this preliminary average slightly when December data become available). This average contrasts sharply with the previous 36 percent average (through 1984) for older BWRs. The one-year improvement isn't entirely surprising; in my Limerick 2 testimony I cautioned that "additional performance data for older nuclear units [might] smooth or move the statistical 'dropoff' point somewhat." More importantly, despite the fine 1985 performance, the older BWRs still show a lower average lifetime capacity factor than units operating at lesser ages. In addition, the next younger cohort of BWRs, those aged 10 and 11, averaged only 32 percent capacity factor in 1985 through November. This suggests that aging problems are indeed being smoothed over a wider period, as I had indicated might occur in my Limerick 2 testimony.

3C. Future Fossil Fuel Prices

Q. What assumptions did you make concerning future PECO and PJM fossil fuel prices, in calculating the benefits of Limerick 1 generation?

A. I have taken PECO's base (1985) prices, as specified in the original Att. IR-OCA-1-11a (OCA Exhibit 14), and as used in the SOBIG runs in which the Company calculates the value of fossil fuels displaced by

Limerick 1. But I have assumed lower real escalation rates than PECO: for coal, zero real escalation through 1990, 0.5% annual escalation through 2000, and 1% thereafter; for oil, negative 1% annual real escalation through 1990, positive 1% through 2000, and 3% thereafter. These real rates are in addition to the overall rate of inflation, so that under PECO's assumed long-term annual inflation rate of 6%, the 1% real escalation in coal prices after 2000, for example, implies 7% annual "nominal" increases in coal prices. Similarly, the negative 1% real escalation for oil prices through 1990 actually allows for nominal increases of 4-5% each year.

Q. How do these escalation rates compare with what PECO assumes?

A. PECO assumes much steeper escalation: annual real increases of 2% for coal and 3% for oil. As a result, PECO's coal and oil prices are considerably higher than mine for most of Limerick 1's expected life. Since more coal and oil will be burned without Limerick 1 than with it, PECO's steeper fossil fuel price forecasts translate into larger benefits from Limerick 1 generation.

Q. On what basis does PECO project high real rates of increase in coal and oil prices?

A. PECO has provided no explanation for its fossil escalation rates in this case. However, as I discuss further below, PECO's fossil price forecasts far exceed those of its consultant, Data Resources Inc.

(DRI). For coal, PECO's projections exceed DRI's by as much as 25 percent in some years, and by an average of 15 percent over the 20-year period for which DRI projects coal prices. For oil, PECO's projections exceed DRI's by more than 50 percent during much of the 1990s, and by an average of 35 percent over the 20-year period for which DRI projects oil prices. Thus, PECO's estimate of Limerick fuel savings depends in part on expectations of fossil fuel prices that diverge markedly from those of its fossil fuel price consultant.

Q. Did you and PECO both stipulate the same respective escalation assumptions in this case as in the Limerick 2 investigation?

A. Yes. Both PECO and I have retained our coal and oil escalation assumptions from the Limerick 2 investigation. PECO's only change, which I adopted for uniformity, was to reduce its 1985 base prices to reflect the continued softness in oil and coal markets during the past year. Compared to its forecasts for 1985 from the Limerick 2 investigation a year ago, PECO's current 1985 base prices are down by 3 percent for coal, 5 percent for residual oil and 8 percent for distillate oil.

Q. How did the ALJ in the Limerick 2 investigation assess your and PECO's fossil price escalation assumptions?

A. The ALJ expressed a clear preference for my lower escalation rates. Regarding coal, she concluded that "the evidence indicates that coal price growth rates will be lower than PECO predicts, and that Mr. Komanoff's projections are reasonable." (Recommended Decision of ALJ Allison K. Turner, p. 284.) Regarding oil prices, the ALJ concluded that PECO's escalation rates were "overstated" and that "a lower forecast would be more reasonable," although she did "not specifically adopt" my forecast. (Recommended Decision of ALJ Allison K. Turner, p. 286.)

Q. How did you derive your coal and oil price escalation rates?

A. Both sets of rates are intended to correspond to what I consider reasonable judgments about future trends in resource availability, demand, technology and regulation. The rates reflect my judgment that coal prices will be primarily cost-based, and will be largely contained in real terms by technical and managerial progress; whereas oil prices, although tending to fluctuate with imbalances between supply and demand, will not undergo concerted escalation until at least the turn of the century, due to abundant worldwide supplies.

Q. Explain your judgments about coal prices.

A. As I stated in the Limerick 2 investigation, my coal price assumptions rest on two main premises. First, competitive forces in the coal industry and the more-than-adequate size of the coal resource base should ensure that coal prices will be determined primarily by costs, rather than by market power or price manipulation. Second, the long-run real cost of supply for coal will be flat or nearly flat because technological improvements should roughly offset any increased stringency in environmental, health and safety regulations as well as real increases in coal-mining wages. In addition, the coal resource base will deplete so gradually as to exert only a very small pull on prices.

Q. Is there empirical support for this view?

A. Yes. Historical coal prices for the U.S. as a whole, for coal delivered to Pennsylvania utilities, and for coal delivered to PECO, all point toward little or no real increases in future coal prices.

Q. What aggregate U.S. coal price data support this view?

A. Between 1950 and 1984, the average price of coal delivered to U.S. electric utilities has increased at a compound annual average rate of 0.7 percent a year above the general rate of inflation. This is close to the escalation rate I assumed here in calculating the value of Limerick 1 generation. The relatively modest past rate of increase belies the notion that coal prices paid by electric utilities have grown much faster than inflation. Moreover, sweeping new environmental, health and safety regulations, generous real wage gains, and two oil shocks made this 34-year period unusually turbulent. The lack of severe overall price escalation over this period is evidence of the stable nature of coal prices over the long haul.

Q. How do historical Pennsylvania coal prices support your forecast of relatively low escalation in coal prices?

A. As I pointed out in the Limerick 2 investigation, PECO and the Commonwealth of Pennsylvania have been benefiting from declining real delivered coal prices since the mid-1970s.

For the Commonwealth as a whole, from 1975 through 1984, the average delivered price of coal <u>declined</u> at an average rate of 0.7% per year, adjusted for inflation. For plants owned or shared by PECO, the declines in real prices have been greater, averaging 4% at Conemaugh and 2% annually at Eddystone, Cromby and Keystone, as Exhibit CK-8 demonstrates.

Q. What accounts for these impressive declines in real coal prices for PECO and other Pennsylvania utilities?

A. The prime reason for falling real coal prices has been rising coal mining productivity, that is, increases in tons mined per worker per day. Productivity in U.S. Coal Producing District No. 1, which comprises west-central Pennsylvania and accounted for two-thirds of all coal delivered to Pennsylvania coal plants in 1983 -- increased at an annual average rate of 3% from 1977 (the earliest year for