UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Commission

In the Matter of	)	
	)	Docket No. 50-353-OL-2
Philadelphia Electric Company	)	
	)	
(Limerick Generating Station Unit 2)	)	(Severe Accident Mitigation Design Alternatives)

RESPONSE BY LICENSEE PHILADELPHIA ELECTRIC COMPANY TO COMMISSION'S REQUEST FOR COMMENTS BY MEMORANDUM AND ORDER DATED JULY 26, 1989

In its Memorandum and Order dated July 26, 1989, the Nuclear Regulatory Commission recited the events leading up to its authorization of the NRC Staff to issue a low-power operating license for Limerick Generating Station, Unit 2, concluding that "the public interest does not dictate that a safe facility which is ready to operate should stand idle while litigation on SAMDAs [severe accident mitigation design alternatives] proceeds if compliance with NEPA [the National Environmental Policy Act of 1969, 42 U.S.C. §4321, et seq.] can otherwise be achieved."1/ In part, the public interest to which the Commission referred included the cost

1/ Philadelphia Electric Company (Limerick Generating Station, Units 1 and 2), "Memorandum and Order" at 5 (July 26, 1989).

of delaying operation of Limerick Unit 2, estimated at that time at $47.6 million for each month of delay.[2/]

In order to determine whether Limerick Unit 2 could be licensed to operate before completion of the litigation, the Commission framed the legal issue as "whether the relative environmental impact of letting the plant run without installation of SAMDAs up to the first refueling outage is significant in comparison with the impact of letting the plant remain idle for the same period of time while the Licensing Board considers the SAMDA issue."[3/]

The Commission has identified three areas of potential environmental impacts which might result from permitting full power operation before completion of the litigation on SAMDAs:

> 1. The incremental increase in occupational exposure resulting from the installation of SAMDAs after one fuel cycle is completed;
>
> 2. An arguably higher level of risk associated with operating the plant without SAMDAs rather than with SAMDAs, for one fuel cycle;
>
> 3. The environmental effect of generating electricity by burning fossil fuel or using other replacement generating sources should the facility be compelled to stand idle.[4/]

2/ *Id.* at 4-5.

3/ *Id.* at 5.

4/ *Id.* at 5-6.

As an aid to its determination, the Commission invited each party to address these three areas. The NRC Staff was also directed, and the other parties were invited, to address five specific questions bearing on these issues. As Appendix A attached hereto, Licensee has provided the requested comments on each of the five questions.

Licensee believes that its comments fully cover each of the three areas identified by the Commission as relevant to its consideration of potential environmental impacts associated with full-power operation prior to completion of the pending SAMDA litigation. Briefly summarized, the attached comments show:

1. The incremental increase in occupational exposure resulting from the installation of SAMDAs after one fuel cycle is completed is expected to be comparable to doses received during routine operation and maintenance activities. The highest occupational doses associated with the potential SAMDAs are substantially less than doses experienced during major maintenance. None of the occupational doses for any particular SAMDA should significantly affect the cost/benefit balance if installation of SAMDAs is postponed until the first refueling outage.

2. The incremental level of risk associated with operating the plant without SAMDAs rather than with SAMDAs for the first fuel cycle is practically

negligible. Because the projected risk of a severe accident from operation of Limerick Unit 2 is already small (i.e., early fatality risk of 5.7×10^{-4} during the first fuel cycle), any risk reduction achieved through installation of a SAMDA will necessarily be proportionally small.

Although no SAMDA has been calculated to be anywhere near cost effective, the most nearly cost effective SAMDA would reduce severe accident risk at Limerick Unit 2 for the first fuel cycle, expressed as mean individual exposure for population within 50 miles, from 2.1×10^{-5} rem to 1.7×10^{-5} rem. Accordingly, postponing the addition of a potential SAMDA until the first refueling outage creates an almost indiscernible environmental impact in terms of risk.

3. If Limerick Unit 2 is compelled to stand idle for what would be the first fuel cycle, significant environmental (health) impacts are expected. These include coal mine worker fatalities and injuries due to mining and processing accidents and respiratory disorders as well as deaths and injuries among the general population due to increased pulmonary diseases and transportation accidents. Increased fossil fuel effluents of about 8 to 16 million tons of carbon

dioxide and 105 to 145 thousand tons of the sulfur and nitrogen oxides will aggravate "greenhouse" and "acid rain" conditions.

PECO and the Pennsylvania-New Jersey-Maryland (PJM) System are counting on Limerick Unit 2 to meet increasing power demands. If Limerick Unit 2 were not available during the summer of 1990, PECO would not meet its capacity obligation to PJM. Increased power demand is expected to add 706 MW to PJM's load from 1989 to 1990 requiring 861 MW of new capacity. PJM will therefore be deficient in needed capacity without Limerick Unit 2.

Accordingly, the benefits achieved by not delaying full-power operation of Limerick Unit 2 (availability of power from the unit, $854.4 million in cost savings, averting adverse health effects from alternate energy sources) greatly outweigh the minor, incremental impacts upon the general public and Unit 2 workers resulting from later installation of any potential SAMDA. On the basis of the information provided herewith as well as the legal analysis previously submitted,[5/] Licensee respectfully

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5/ Licensee hereby refers the Commission to, and incorporates herein by reference, its previously filed (Footnote Continued) requests the Commission to issue a full-power operating license for Limerick Unit 2, conditioned upon the outcome of the pending SAMDA litigation.

Respectfully submitted,

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August 2, 1989

(Footnote Continued)
Motion for Clarification (June 5, 1989); Reply Memorandum in Support of Motion for Clarification (June 21, 1989); and Answer by Licensee PECO to Motion of LEA to Reconsider/Stay/Suspend/Revoke Order Authorizing Issuance of Low-Power License for Limerick Unit 2 (July 26, 1989).

APPENDIX A

Response of Philadelphia Electric Company to Question 1

1. Provide an evaluation of the incremental increase in occupational radiation exposure associated with postponing the installation of SAMDAs to the first refueling outage.

The incremental increase in occupational radiation exposure associated with postponing the installation of SAMDAs on Limerick Unit 2 to the first refueling outage was estimated for each of the SAMDAs identified by the Licensing Board in its July 18, 1989 Memorandum to be given further consideration in the remand proceeding.*/ The methodology used to estimate the radiation exposures is as follows:

1. Each SAMDA was analyzed to identify the various plant locations where installation work would result in radiation exposure.

2. Estimated dose rates for each of the above locations were based on surveys performed at Limerick Unit 1 during the first and second refueling outages and on experience in dose rate reductions achieved with temporary shielding, decontamination efforts and other generally accepted "as low as reasonably achievable" (ALARA) practices.

3. Installation manhours spent in each of the above areas were estimated based upon the specific activities to be carried out in the plant

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*/ As noted in Licensee's letter of June 23, 1989 at Table 2-3, the vacuum breaker SAMDA was determined to have no benefit. Accordingly, its costs were not developed.

locations where installation work would result in radiation exposure.

4. Radiation exposures were calculated utilizing the installation manhours and dose rates for each location.

5. All Commission requirements imposing individual exposure limits were met.

These are conservative scoping estimates and are expected to bound the actual exposures should a SAMDA be installed. The occupational doses associated with the installation of the SAMDAs examined are for the most part quite modest, i.e., comparable to doses received during routine operation and maintenance activities. The highest occupational doses associated with the SAMDAs are substantially less than those experienced during major maintenance. For example, the recirculation and Residual Heat Removal (RHR) pipe replacement project at Peach Bottom Atomic Power Station, Unit 3 had an associated occupational dose of 1313 person rem.

None of the doses is expected to significantly affect the cost/benefit balance associated with the installation of individual SAMDAs should their installation after the first refueling outage be required. The occupational exposures for each SAMDA considered are reported in Table 1-1.

Response of Philadelphia Electric Company
to Question 3

3. Provide an evaluation of the incremental environmental effect of generating non-nuclear replacement energy equivalent to one fuel cycle's energy production by Limerick Unit 2.

In order to evaluate the incremental environmental effects of generating non-nuclear replacement energy equivalent to one fuel cycle's energy production by Limerick Unit 2, the following methodology was used:

1. The mix of replacement energy sources, including the relative contributions to the overall mix by the various generating facilities which together would supply it, was determined from unit-by-unit generating data for utilities in the Pennsylvania-Jersey-Maryland (PJM) System. The analysis conservatively assumed that marginal replacement power sources beyond the PJM System would represent the same mix, when in fact they would disproportionately represent coal-fired units.

2. Generic analyses were performed for two alternative mixes of replacement energy sources, comparing the environmental (health) risks of nuclear- and coal-fuel energy. The resulting data were compared to determine the differential (i.e., incremental) effects of replacement power.

3. Using the proportions derived for each replacement source and the environmental (health) risks developed generically, incremental unit risks were calculated for worker and public deaths and injuries attributable to each replacement fuel in the overall mix.

4. The data developed in the previous steps were applied to the estimated first-cycle energy output from Limerick Unit 2, and hence to be replaced by alternative sources, based on the first-cycle experience of Limerick Unit 1.

The analysis is provided in Attachment A hereto. Based upon this analysis, it was concluded that an additional 1.5 to 2 worker deaths and 80 to 100 worker injuries, and more than 10 projected public fatalities and 24 injuries, would result from the use of replacement energy for the first fuel cycle of Limerick Unit 2. Projected worker deaths and injuries result mainly from coal mining and processing accidents, while projected public fatalities result from respiratory diseases. Public injuries are mainly attributable to transportation accidents. There are insufficient data to quantify public health risks from operating oil-fired units, although it is expected that such effects should lie between those of nuclear and coal-fired generation.

Further, it is estimated that about 8 to 16 million tons of carbon dioxide would be created by use of replacement fuel sources. This would contribute to the atmospheric "greenhouse" problem. Also, about 105 to 145 thousand tons of sulfur oxides and nitrogen oxides would be created by use of the replacement energy source. These oxides contribute in part to acid rain. These incremental, adverse environmental effects can be avoided by use of Limerick Unit 2 for the first fuel cycle.

Finally, PECO and the Pennsylvania-New Jersey-Maryland (PJM) System are counting on Limerick Unit 2 to meet increasing power demands. If Limerick Unit 2 were not available during the summer of 1990, PECO would not meet its capacity obligation to PJM. Increased power demand is expected to add 706 MW to PJM's load from 1989 to 1990 requiring 861 MW of new capacity. PJM will therefore be deficient in needed capacity without Limerick Unit 2.

RESPONSE TO COMMISSION QUESTION 3.
ATTACHMENT A

I. INTRODUCTION

This is an evaluation of the incremental environmental effects of replacing energy equivalent to one fuel cycle's energy production by Limerick Unit 2.

II. REPLACEMENT ENERGY MIX

The incremental environmental impacts of replacing energy from Limerick Unit 2 with that from other sources will vary with the relative contributions to the overall mix of replacement energy by the various generating facilities which together would supply it. Older, less efficient oil- and coal-fired stations which would be called into such service would have significantly greater effects than, for example, energy from hydroelectric facilities. The particular sources from which any needed replacement energy would be obtained can be assumed, but not known with certainty until the need arises and available alternatives assessed.

For purposes of this analysis, two alternatives mixes of replacement energy sources were examined: the first is represented by a mix of marginal Pennsylvania-Jersey-Maryland (PJM) System (and beyond) coal- and oil-fired capacity (referred to as the "marginal mix") which is the best estimate of the actual plants likely to be required to make up the shortfall in capacity. A second evaluation was made based on the 1988 mix of generation sources (exclusive of purchases) used in 1988 by PJM utilities (referred to hereafter as the "1988 mix") as representative of the risks of the more usual mix of energy sources, including nuclear generation.

The "marginal mix" was determined from an analysis of replacement capacity within PJM and beyond, as presented in summary form in Table 3-1. Those alternatives were simplified by combining all coal- and all oil-supplied energy, and combining non-utility generation with hydroelectric in one category having the same impact. Thus, the "marginal mix" replacement energy for Limerick Unit 2 assumed for this analysis was that presented in the following tabulation.

Limerick Unit 2 Replacement Energy,
"Marginal Mix", % Contribution

Coal	Oil	Hydro
48.7	50.7	0.6

To establish the 1988 mix, historic data on the PJM system were assembled and analyzed. Table 3-2 presents the total megawatt-hours distributed by PJM (also identified as the Mid-Atlantic Area Council, MAAC) utilities in 1988 by energy source, based on information supplied by the UDI Utility Data Base. Of the electrical energy distributed within the PJM system in that year, 55.6% was derived from fossil fuels (coal, oil and gas), 27.2% from nuclear, 2.0% from hydro and 15.0% imported from beyond the PJM system. No breakdown within the fossil fuels is available from this data set.

To make that breakdown into the mix of fuels used for generation within PJM, and determine their airborne emissions, unit-by-unit generating data for fossil and nuclear steam-electric units in MAAC utilities were compiled by UDI for 1987 (the latest data available). These data permit the derivation of the individual fuel contributions to MAAC energy generation as a basis for emissions and risk estimates. The fossil fuel use data for each MAAC utility are presented in Table 3-3, together with estimates of emissions of sulfur oxides, nitrogen oxides and carbon dioxide, and are summarized in the following tabulation:

Percent Generation by Fuel in MAAC, 1987

Coal	Oil	Gas	Nuclear
61.3	3.9	2.1	32.7

Of the total fuel-generated electric energy generated in 1987, fossil fuels generated about twice as much as did nuclear (67% to 33%), essentially the same ratio as that in 1988 (55.6% to 27.2%). On this basis, the ratio of generation by oil and gas relative to coal for 1988 was assumed to be the same in 1988 as in 1987. Since the 1988 data (Table 3-2) show no gas generation, the relatively minor gas-derived energy usage identified for 1987 was assumed to be contributed by oil in 1988. Accordingly, the hypothesized "1988 mix" was assumed to be distributed as follows within the 85% of the internally-generated PJM sources:

Hypothesized Limerick Unit 2 Replacement Energy,
"1988 Mix", % Contribution

Coal	Oil	Nuclear	Hydro
59.9	5.8	31.9	2.3

Based on these two energy source distributions, incremental risks were determined as the total of the risks per unit energy generated by each source weighted by its respective contribution to the total of PJM-generated energy (i.e., the total less that purchased), minus the risks of Limerick Unit 2. Mathematically, this is represented by the relationships described below.

Incremental risk = Incremental unit risk x units of replacement energy

Incremental unit risk = {Replacement energy unit risk - nuclear energy unit risk}

Replacement energy unit risk = { (unit risk [C] x fraction)$_{coal}$

+ (unit risk [O] x fraction)$_{oil}$

+ (unit risk [N] x fraction)$_{nuclear}$

+ (unit risk [H] x fraction)$_{hydro}$ }

For the "1988 mix":

Incremental unit risk = {0.599xC+0.058xO+.319xN+0.023xH} - 1xN

= 0.599C + 0.058O + 0.023H - 0.681N

For the "marginal mix":

Incremental unit risk = {0.487xC+0.507xO+0.006xH} - 1xN

III. UNIT RISK FACTORS

Generic analyses for both the nuclear and non-nuclear alternatives were used to provide a consistent basis for determining the differential or incremental effects. Most of these analyses were published in the mid- to late-1970s and compared the environmental and health risks of nuclear- and coal-fueled energy. For the most part, these analyses were concerned with comparing the health risk aspects of the environmental impact.

Occupational risks are by far the best known, since they are usually documented for fatalities and injuries from both accidents and occupational diseases. Both mine accidents and miner respiratory disorders are well publicized, as are the accidents involving oil platforms and uranium miner lung cancers. Some public injuries resulting from segments of the various fuel cycles are also documented, such as those involving coal train or truck accidents injuring or killing members of the public. However, the risks to public health from the pollutants emitted by various energy facilities are much more uncertain.

The pollutants emitted from fossil plants include particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, carcinogenic polycyclic organic matter (POM), and trace metals including arsenic, cadmium and mercury, much more so in the case of coal plants than from those burning oil or gas. Although no specific cases are attributed to particular constituents, except in past severe pollution episodes such as those in Donora, Pa., and London, a number of studies have correlated increases in respiratory and cardiac mortality rates with ambient particulate-sulfate exposures. It is these studies that form the basis for the estimates of the disease component of public health risk.

Oil was usually not included in these evaluations and comparisons because of its relative cleanliness compared with coal, its declining role in electricity generation and its non-competitive nature relative to uranium or coal as a fuel for large base-load generating stations. Although several estimates of occupational risks from oil extraction, processing, transport and use have been reported, public health effects have been estimated by only a single author, and would provide a mean public health risk estimate greater than that for coal, which is unreasonable. Accordingly, although no public health risks are assigned to oil-fired generating facilities in this analysis, it is expected that such effects should lie between those of nuclear and coal generation.

Hydropower was also essentially excluded from these comparisons for similar reasons, and with the view that there were no substantial emissions or other environmental impacts other than the flooding of large land and wetland areas. Accordingly, no health risks are assigned to hydroelectric generation. However, it should be noted that, based on dam failures in the U.S. between 1928 and 1958, a major disaster rate of 1.3×10^{-4} per dam-year has been estimated, and that 1680 persons were killed by such failures over that period (9). However, there is no existing correlation of these deaths with hydroelectric generation, and those risks are also ignored in this analysis.

A number of generic evaluations were examined to select several which provided more complete comparisons of risks of nuclear generation with other energy sources; an earlier site-specific coal/nuclear evaluation by the author (2) was also included for comparability with other generic values in the literature. The fuel-specific analyses are tabulated in the Appendix for both occupational and public health risks, together with the references from which they were obtained. A summary of these health risk effects for each fuel is presented in Table 3-4.

Despite the ranges of risks in the individual estimates of components of the overall risk displayed in the supporting tables in the Appendix, as Table 3-4 indicates, there is a very substantial difference in total risk per unit energy between coal and nuclear fuel generation in both worker and public health effects. Oil generation would appear to lie between coal and nuclear fuel in its unit occupational risk impacts and presumably in its public health risks as well. For example, if the public health risks from oil were only one-tenth those from coal, they would still substantially exceed those from nuclear power plants - by a factor of almost 5 in public fatalities per GW(e)-yr, and by about a factor of 10 in injuries to the public.

To provide proxies for the combustion product contributions to the "greenhouse" and "acid rain" effects, unit emissions of carbon dioxide, sulfur dioxide and nitrogen oxides (NO_x) were determined for the MAAC system. The sulfur oxide estimates in Table 3-3 were based on the annual fuel burn, average heat content and sulfur content reported, as well as reductions appropriate for any scrubbers in use. Nitrogen oxide estimates were made by UDI using the emission factors of AP42 for the relevant boiler types. The generation and emission data in Table 3-3 were combined to produce the unit emission rates by fuel which are presented in Table 3-5.

IV. INCREMENTAL UNIT RISKS FROM REPLACEMENT ENERGY

Using the relationships for incremental unit risk presented in Section II for each of the alternative replacement fuel "mixes" for Limerick Unit 2, and the health risks presented in Table 3-4 incremental unit risks were calculated for worker and public deaths and injuries and are presented in Table 3-6 for each replacement fuel mix.

As indicated in that table, 1 GW(e)-yr of "1988 mix" replacement energy for Limerick Unit 2 would result in an incremental risk of more than 1 worker fatality and about 7 additional public fatalities from disease and accidents in excess of those that would be calculated to accrue from the operation of a nuclear power plant to generate the same energy. Further, increments above nuclear energy of about 61 occupational and 18 public injuries are estimated to result, per GW(e)-yr of replacement energy.

Similar values for the "marginal mix" replacement energy indicate occupational risks to be about 30% greater than for the "1988 mix" due to the absence of the low-risk nuclear option in the former. However, the public health risk is substantially understated for the "marginal mix" because of the absence of a unit risk value for oil generation, and the significant fractional contribution of oil-fired generation in that mix. It would be reasonable to expect that the incremental public health risk for that mix would increase in roughly the same proportion over the "1988 mix" risk as does the occupational value, i.e., by about 30%, although no quantitative support can be provided for that estimate.

The unquantified impacts from the emitted gaseous precursors of "acid-rain" and "greenhouse" are all increments beyond the nuclear option (except for the energy for uranium enrichment assumed to come from coal-fired capacity). These were calculated in the same way as for the health risks above from the data in Table 3-5 and are presented below.

INCREMENTAL ACID-RAIN AND GREENHOUSE GASEOUS PRECURSORS
EMISSIONS, 1000 T PER GW(e)-YR OF REPLACEMENT ENERGY

FUEL MIX	SO_2	NO_x	CO_2
"1988"	59.3	19.4	6163
"Marginal"	72.1	30.2	11989

V. INCREMENTAL RISKS OF REPLACEMENT ENERGY FOR LIMERICK 2

The final step in the estimation of the incremental risks arising from the replacement of energy from Limerick Unit 2 for one fuel cycle is the determination of the magnitude of the energy required. The estimate of the first-cycle energy output to be expected from Limerick Unit 2, and hence to be replaced by alternative sources, is based on the first cycle experience of Limerick Unit 1. That unit's net generation during its first cycle was 465 Effective Full Power Days (EFPD); at a net capacity of 1055 MW(e), the energy generated totaled 490,575 MW-days, or 1.344 GW(e)-yr.

Thus, the total incremental risk of the replacement energy for Limerick 2 is determined as 1.344 times the fuel-weighted unit risk values. These are summarized in Table 3-7 for the two alternative fuel mixes. As indicated in that table, replacement of the nuclear energy from Limerick Unit 2 by either the 1988 MAAC mix of fossil and nuclear generation, or the marginal unit mix likely to be required, is estimated to result in an additional 1.5 - 2 worker deaths and 83 - 106 worker injuries, and more than 10 projected public fatalities and 24 injuries from such replacement energy.

Further, it is estimated that additions of about 8 - 16 million tons of carbon dioxide would be made to the atmospheric reservoir of this "greenhouse" gas by this replacement energy, as well as about 105 - 145 thousand tons of the sulfur and nitrogen oxides which contribute, in part, to acid rain and which would not be produced by Limerick Unit 2 operation.

TABLE 3-1

REPLACEMENT ENERGY BY FUEL TYPE
LIMERICK UNIT 2 - FUEL CYCLE 1

FUEL TYPE	GW-HR	PERCENT
PECo Coal (Low Sulfur)	279	2.8
Other Coal *	4656	45.9
#6 Oil & Gas (Steam)	4547	44.8
#2 Oil & Gas(Comb. Turb.)	601	5.9
Net Hydro	22	0.2
Non-Utility Generation	43	0.4
TOTAL	10148	100.0

Note: Analysis also includes replacement of precommercial energy.

* Other Coal includes energy sources inside and out ide the PJM Interconnection

Source: System Planning Division, PECo, 7/31/89

TABLE 3-2

1988 TOTAL GIGA.ATT YEARS BY ENERGY SOURCE FOR MAAC (PJM) UTILITIES

UTILITY	TOTAL ENERGY DISTRIBUTED	NUCLEAR STEAM GENERATION	FOSSIL STEAM GENERATION	HYDRO/ OTHER GENERATION	PURCHASED/ INTERCHANGE GENERATION
ACE	0.922	0.152	0.411	0.106	0.252
BG&E	2.946	1.339	1.516	0.019	0.071
DELMARVA P&L	1.235	0.112	1.100	0.004	0.019
JCP&L	2.096	0.559	0.355	0.115	1.067
MET ED	1.204	0.310	0.559	0.019	0.260
PENN ELEC	1.628	0.155	1.336	0.118	0.019
PP&L	4.111	1.469	3.515	0.072	-0.945
PECO	3.971	1.412	1.167	-0.042	1.433
PEPCO	2.753	-------	2.326	0.021	0.406
PSE&G	4.513	1.399	1.816	0.065	1.232
TOTALS	25.378	5.908	14.102	0.498	3.813

Source: UDI Utility Data Base, 7/89

TABLE 3-3

1987 EEI FUEL DATA FOR MAAC (PJM) FOSSIL PLANTS a

UTILITY	COAL (1000 T)	OIL (1000 BBL)	GAS (MMCF)
ACE	651	1225	-----
BG&E	2680	2262	2451
DEEPWATER	414	229	2276
DELMARVA P&L	2451	2902	6451
DOVER ELEC	-----	390	1433
JCP&L	-----	419	10191
MET ED	1250	39	-----
PENN ELEC	15117	232	-----
PP&L	9706	7114	-----
PECO	1245	4440	368
PEPCO	6130	2349	6834
PSE&G	1955	4121	40831
UGI/LUZERNE	194	2	-----
TOTALS	41793	25724	70835
GENERATION (GW-yr)	13.03	0.82	0.44
SO_2 EMITTED (1000 T)	1225.8	42.7	-----
NO_x EMITTED (1000 T)	383	26	15
CO_2 EMITTED b (1000 T)	114931	12509	2113

a Data from UDI EEI POWER STATISTICS Data Base except for CO_2
NO_x estimates assume AP42 emission factors
SO_2 emissions include FGD systems where applicable
32.7% (6.95 GW-yr) generated by nuclear plants

b CO_2 emissions assume 75 wt% C in coal, 85 wt% C in fuel oil, and 75 wt% C in gas

TABLE 3-4

SUMMARY
ALTERNATIVE ELECTRIC GENERATION
HEALTH RISK PER GW(e)-YR

RISK	FUEL: COAL	FUEL: NUCLEAR	FUEL: OIL
Occupational			
Deaths	2.35	0.44	0.64
Injuries	114	13	46
Public			
Deaths	13	0.27	a
Injuries	31	0.29	b

a Mean literature value too high

b No estimates in literature

TABLE 3-5

UNIT EMISSION RATES BY FUEL [a]
(1000 Tons/GW-yr)

	FUEL		
EMISSION	COAL	OIL	GAS
SO_2	94.1	51.8	0
CO_2	8820	15176	4752
NO_x	29.4	31.3	33.0

a Based on Table 3-3 generation and emission estimates

TABLE 3-6

INCREMENTAL FUEL-WEIGHTED HEALTH RISKS

	FUEL MIX	
RISK TYPE	"1988 MIX" a	"MARGINAL MIX" b
Occupational		
Deaths	1.15	1.47
Injuries	62.10	78.84
Public		
Deaths	7.60	6.33 c
Injuries	18.37	15.10 c

a Replacement fuel mix is 59.9% coal, 5.8% oil, 31.9% nuclear and 2% hydroelectric

b Replacement fuel mix is 48.7% coal, 50.7% oil, and 0.6% hydroelectric

c Public risks and injuries are greatly under-estimated due to the absence of risk assigned to oil; if the public risk from oil were half that from coal, these risks would be 50% greater

TABLE 3-7

TOTAL FUEL-WEIGHTED HEALTH RISKS
FROM 1.344 GW(e)-YR REPLACEMENT ENERGY FOR LIMERICK UNIT 2

	FUEL MIX	
RISK TYPE	"1988 MIX" a	"MARGINAL MIX" b
Occupational		
Deaths	1.54	1.97
Injuries	83.46	105.96
Public		
Deaths	10.22	8.51 c
Injuries	24.69	20.29 c
Atmospheric Emissions (1000 Tons)		
Acid Rain Precursors		
SO_2	80.5	96.9
NO_x	26.1	40.6
Greenhouse Effect Precursor		
CO_2	8283	16113

a Replacement fuel mix is 59.9% coal, 5.8% oil, 31.9% nuclear and 2% hydroelectric

b Replacement fuel mix is 48.7% coal, 50.7% oil, and 0.6% hydroelectric

c Public risks and injuries are greatly underestimated due to the absence of risk assigned to oil; if the public risk from oil were half that from coal, these risks would be 50% greater

APPENDIX

UNIT HEALTH RISKS TO WORKERS AND PUBLIC BY FUEL

Table 3-OC

OCCUPATIONAL DEATHS AND INJURIES
PER GW(e)-YR
COAL

DEATHS (Accidents and Diseases)

(Reference)

RISK SOURCE	(1)	(2)	(3)	(4)	(7)	AVERAGE
Fuel Extraction	1.30 a	0.98 b	1.38 c	1.83 e	3.245 f	
Processing			0.06	0.08	0.035	
Transportation	0.07	0.03	0.55 d	0.54 d	1.225	
Power Generation	0.05	0.08	0.13	0.15	0.02	
TOTAL	1.42	1.09	2.12	2.59	4.53	2.35

NON-FATAL CASES

RISK SOURCE	(1)	(2)	(3)	(4)	(7)	AVERAGE
Fuel Extraction	54 a	98 b	134 c	148 e	75 f	
Processing			4	4	3	
Transportation	7	3	8 d	8 d	12	
Power Generation	2	3	5	5	1	
TOTAL	63	104	149	165	91	114

a Includes accidents only in both mining and preparation; assumes 50% underground/50% surface extraction

b Includes both mining and processing, but excludes CWP; assumes 54.5% underground/45.5% surface extraction

c Assumes 75% underground, 25% surface extraction and includes CWP; means of ranges from Table 10

d Assumes 1/3 rail, 1/3 barge and 1/3 truck transport

e Assumes 75% underground, 25% surface extraction and includes CWP; means of ranges given

f Includes accidents and disease; means of ranges given

Table 3-ON

OCCUPATIONAL DEATHS AND INJURIES
PER GW(e)-YR
NUCLEAR

DEATHS (Accidents and Diseases)

(Reference)

RISK SOURCE	(1)	(2)	(4)	(5)	(7)	AVERAGE
Fuel Extraction	0.13 a	0.18 b	0.51 c	0.30 b	0.15 c	
Processing		0.08	0.06	0.10	0.27 d	
Transportation	0.002	0.06	0.01	0.01	0.004	
Power Generation	0.01	0.08	0.14	0.06	0.06	
TOTAL	0.15	0.40	0.72	0.47	0.49	0.[illegible]4

NON-FATAL CASES

RISK SOURCE	(1)	(2)	(4)	(5)	(7)	AVERAGE
Fuel Extraction	6.9 a	6.1	11.4 c	9.4 d	5.9 d	
Processing		6.4	1.7	1.6	1.1	
Transportation	0.1	5.3	0.1	0.1	0.1	
Power Generation	1.7	1.8	1.5	3.5	1.3	
TOTAL	8.7	19.6	14.7	14.6	8.3	13

a Includes mining and processing; includes accidents only

b Includes both accidents and radiogenic cancers

c Includes accidents, radiogenic cancers and other diseases

d Based on means of ranges given

Table 3-00

OCCUPATIONAL DEATHS AND INJURIES
PER GW(e)-YR
OIL

DEATHS (Accidents and Diseases)

(Reference)

RISK SOURCE	(1)	(6)	(7)	AVERAGE
Fuel Extraction	0.15 a	0.18 b		
Processing		0.67		
Transportation	0.04	0.09		
Power Generation	0.05	0.03		
TOTAL	0.24	0.97	0.72 c	0.64

NON-FATAL CASES

Fuel Extraction	13.3 a	19.0		
Processing		43.3		
Transportation	1.5	6.7		
Power Generation	2.0	1.4		
TOTAL	16.7	70.5	51 c	46

a Includes mining and processing; includes accidents only

b Based on means of ranges given

c Only totals for effect given, mean of range listed

Table 3-PC

PUBLIC DEATHS AND INJURIES
PER GW(e)-YR
COAL

DEATHS (Accidents and Diseases)

(Reference)

RISK SOURCE	(2)	(3)	(4)	(7)	AVERAGE
Fuel Extraction	-----	-----	-----	-----	
Processing	-----	-----	-----	5.50 bc	
Transportation	0.36 a	0.58 b	1.21 b	0.93	
Power Generation	7.53	15.60 c	15.00	151.50	
TOTAL	7.89	16.18	16.21	157.93	50

NON-FATAL CASES

Fuel Extraction	-----	-----	-----	----- d	
Processing	-----	-----	-----	-----	
Transportation	1	7 b	7 b	-----	
Power Generation	-----	-----	77	-----	
TOTAL	1	7	84		31

a Rail transportation assumed

b Assumes 1/3 rail, 1/3 barge and 1/3 truck transport

c Represents mean of ranges

d No non-fatal effects listed

Table 3-PN

PUBLIC DEATHS AND INJURIES
PER GW(e)-YR
NUCLEAR

DEATHS (Accidents and Diseases)

(Reference)

RISK SOURCE	(2)	(4)	(5)	(7)	AVERAGE
Fuel Extraction	0.001	0.050	0.142 b	-----	
Processing	0.370 a	0.013	0.204	-----	
Transportation	0.002	0.011	----- c	-----	
Power Generation	0.011	0.120	0.053	0.085 d	
TOTAL	0.385	0.194	0.399	0.085	0.266

NON-FATAL CASES

Fuel Extraction	-----	0.010	0.160 b	----- e	
Processing	0.135	0.003	0.280	-----	
Transportation	0.350	0.100	----- c	-----	
Power Generation	0.001	0.020	0.082	-----	
TOTAL	0.486	0.133	0.521	0.000	0.285

a Predominantly from assumed coal-energy used for U enrichment

b Represents mean of ranges; only cancer mortality included

c No transportation mortality risks presented

d Public mortality risks only for generation

e No non-fatal effects listed

Table 3-PO

PUBLIC DEATHS AND INJURIES
PER GW(e)-YR
OIL

DEATHS
(Accidents and Diseases)

(Reference)

RISK SOURCE	(6)	(7)
Fuel Extraction	-----	
Processing	-----	
Transportation	-----	
Power Generation	50.50 a	
TOTAL	50.50	50.50 a

NON-FATAL CASES

Fuel Extraction	----- b	----- b
Processing	-----	-----
Transportation	-----	---
Power Generation	-----	-----
TOTAL	0.0	0.0

a Presents a range of 1 - 100 fatalities, based on Reference (8)

b No non-fatal effects listed

HEALTH RISK REFERENCES

(1) "Health Effects of Alternative Means of Electrical Generation", K.A. Hub and R.A. Schlenker, in "Population Dose Evaluation and Standards for Man and His Environment", IAEA-SM-184/18, 1976

(2) "Comparative Health Effects of Generating Electricity at Erie Nuclear Plant and a Coal-Fired Alternative", Testimony of Morton I. Goldman, July 21, 1978, Ohio Public Service Commission

(3) "Health Risks of Coal Energy Technology", S. C. Morris, in "Health Risks of Energy Technologies", C.C. Travis and E.E. Etnier, Eds. 1981, AAAS Selected Symposium 82, Westview Press, Boulder, CO

(4) "Health and Environmental Risks of Energy Systems", L.D. Hamilton, in "International Symposium on the Risks and Benefits of Energy Systems", IAEA-SM-273, April 1984

(5) "Health Risks from the Nuclear Fuel Cycle", R.L. Gotchy, in "Health Risks of Energy Technologies", C.C. Travis and E.E. Etnier, Eds. 1981, AAAS Selected Symposium 82, Westview Press, Boulder, CO

(6) "Health Effects of Energy Production and Conversion", C.L. Comar and L. A. Sagan, in "Annual Review of Energy", 1976

(7) "Health Evaluation of Energy-Generating Sources", Report of the Council of Scientific Affairs, American Medical Association, 1978

(8) "The Health and Environmental Effects of Electricity Generation - A Preliminary Report", L.D. Hamilton, Ed., Brookhaven National Laboratory, 1974

(9) "Energy in Transition, 1985 - 2010", Final Report of the Committee on Nuclear and Alternative Energy Systems, National Research Council", National Academy of Sciences, pp. 459-460, 1980

Response of Philadelphia Electric Company
to Question

4. Provide an evaluation of whether operation of Unit 2 for one fuel cycle would foreclose later installation of SAMDAs.

Operation of Limerick Unit 2 for one fuel cycle would not foreclose later installation of SAMDAs. The design concepts and estimated costs for each of the SAMDAs addressed by PECO in its June 23, 1989 submittal to the NRC Staff were examined as to whether they could be installed after Limerick Unit 2 operation had begun. There were no matters identified for any of the SAMDAs which would preclude installation due to full-power operation of Limerick Unit 2.

The occupational doses associated with postponing installation of the SAMDAs until after the first refueling outage, as discussed in response to Commission Question 1, would also not preclude installation. As discussed in that response, the SAMDA closest to being cost beneficial (but clearly not) entails a modest occupational dose. All of the SAMDAs studied have the same or less occupational exposure associated with their installation compared with typical outage maintenance activities. Even the highest occupational exposures associated with the installation of some

SAMDAs studied are far less than those associated with major outage maintenance.

Response of Philadelphia Electric Company
to Question 5

5. Provide an evaluation of the dollar cost resulting from a delay in starting up Limerick Unit 2 for a period of time equivalent to one fuel cycle.

In evaluating the cost of delaying the commercial operation of the plant, three costs must be considered. They are (1) the additional financing costs associated with the delay (AFUDC); (2) additional direct costs (capitalized operating and maintenance expenses); and (3) lost fuel savings.

Financing Costs

In accordance with the Federal Energy Regulatory Commission (FERC) accounting rules, the cost of financing a project under construction are capitalized as part of the project cost. These capitalized financing charges are called AFUDC. The calculation of the additional AFUDC associated with the delay is done in accordance with FERC accounting rules. The 9.5% AFUDC rate is approximately equal to the Company's after tax cost of capital and is calculated in accordance with FERC rules. The AFUDC is calculated by multiplying the AFUDC rate by the funds invested in the project to date.

Operation and Maintenance Expense

Once a plant starts to generate power, operating personnel are required and maintenance costs are incurred. The costs associated with operating the plant prior to commercial operation are capitalized as part of the plant cost, in accordance with FERC accounting rules. Also included in this category are expenses associated with retaining the necessary construction and startup personnel at the site.

Lost Fuel Savings

Delaying the commercial operation of Limerick 2 delays the benefit of the lower cost of nuclear power generation. The cost calculation of monthly fuel savings herein was derived from estimated savings for the period April 1990 (projected commercial availability of Unit 2) to March 1991. The average monthly savings were then applied to the applicable fifteen-month period (eighteen months of the first fuel cycle minus three months refueling).

Total Costs

Total financing costs and operation and maintenance expenses resulting from an 18-month delay in commercial operation of Limerick Unit 2 are $675.9 million. Lost fuel savings are $178.5 million. The total costs of delay are $854.4 million. Details are provided in Table 5-1.

Table 5-1

CALCULATION OF THE COSTS OF DELAYING
LIMERICK UNIT 2 COMMERCIAL OPERATION
FOR FIRST FUEL CYCLE (EIGHTEEN MONTHS)

ASSUMPTIONS:

1. Commercial operation date for Limerick Unit 2: February 1990.

2. Cost for bringing Limerick Unit 2 and 50% common areas on line by February 1990: $3,836 million.

3. Refueling cycle is 18 months.

4. The impact of the cost recovery cap imposed by the Pennsylvania Public Utility Commission is not reflected in the calculation.a/

FINANCING COSTS:

Allowance for Funds Used During Construction (AFUDC) $30.4 million per month ($3,836 x 9.5%/12): $547.2 million

AFUDC is compounded every six months (AFUDC/AFUDC): $26.4 million

OPERATING AND MAINTENANCE EXPENSE:

Direct expenditures: $95.4 million ($5.3 million per month x 18)

AFUDC accrued on capitalized operating and maintenance expense: $6.9 million

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a/ The estimated cost of Limerick Unit 2 (excluding common areas) for on-line commercial operation by February 1990 is $2,888.7 million. This is approximately $309 million below the $3,197 million cost cap imposed by the Pennsylvania PUC. Any increase in cost above the PUC-imposed cost cap may prevent Licensee from capitalizing additional costs for Limerick Unit 2, *i.e.*, cost of delay estimated herein at $675.9 million might be disallowed as recoverable cost by the PUC to the extent they exceed $309 million.

FUEL SAVINGS:

$11.9 million per month x 15: $178.5 million[b/]

SUMMARY OF COST OF DELAY FOR
UNIT 2 OPERATION (Millions $)

	Capital	Capitalized O&M Expenses	Total Increase In Plant Cost
Direct	0.0	95.4	95.4
AFUDC	547.2	6.9	534.1
AFUDC/AFUDC	26.4	0.0	26.4
Total	573.6	107.3	675.9

Total Increase in Plant Cost	=	675.9 M
Lost Fuel Savings	=	178.5 M
Total Cost	=	854.4 M

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b/ An 18-month refueling cycle consists of 15 months running and 3 months refueling.