Archive

Health Implications of Oil-to-Coal
Conversion in New England Power Plants

J. Gruhl

Report #MIT-EL 76-013WP

April 1976

This report is a collection of statistics and references relevent to the quantification of health effects resulting from the conversion of oil-fired power plants to coal-fired facilities. This material was prepared for use by the Center for Energy Policy, Inc., Suite 2805, One Boston Place, Boston, Mass. 02108 in the FEA sponsored report "The Impact of Power Plant Coal Conversion on New England Energy Policy," May 1976.

The two categories into which pollutant impacts upon health are generally divided include 'occupational health effects' and 'public health effects.' Occupational effects at the power plant site, that is, in the conversion process, are 20% higher for coal than for oil in terms of deaths (.012 vs .010 per 1000MW), injuries (1.38 vs 1.15 per 1000MW), and workdays lost (152.9 vs 127.2 per 1000MW, CEQ, 1973). Including fuel extraction, processing, and so on, the total fuel-cycle effects are shown in Table 1 (CEQ, 1973, pp. 42 and 48).

	Coal Deep Mined	Coal Surface Mined	Oil Onshore	Oil Offshore	Oil Imported
Deaths	4.00	2.64	0.35	0.35	0.06
Injuries	112.3	41.2	32.3	32.3	5.7
Workdays Lost	15,280	3,091	3,609	3,609	689

Table 1 U.S. occupational health effects of 1000MW coal and oil powerplants per year

Whether or not these occupational health effects should carry weight in the policy-making process is a matter of wide disagreement: some feel the workers are wage-compensated for their voluntary risk and that this extra cost is adequately reflected in the higher fuel costs; others feel the dollar-equivalent treatment of health is outmoded. At any rate, the information should probably be made available.

The <u>public</u> health impact is a more sensitive issue because it represents an involuntary risk, nevertheless and unfortunately it has not been as well specified as the occupational hazards. There are numerous reasons for this lack of good information, some of them are:

(1) the air is filled with a huge number of potentially harmful substances,

(2) various pollutants are often simultaneously present and thus the effects are difficult to associate with the particular causative agents,

(3) it is difficult to determine the impacts of chemical interactions and synergistic combinations (that is, potentiating or antagonizing combinations of pollutants),

(4) there are many causative agents in addition to the air pollutants,

(5) there is a general lack of well-defined dose data for past exposures, and

(6) age, sex, latency periods, and pre-existing ailments all contribute to the susceptibility of populations.

Without good dose-response information, broad ranges of uncertainty must show up around speculations about public health effects.

The first step in assessing the health effects of fuel conversion in New England is the evaluation of the resulting differences in ambient concentrations. For specifically defined scenarios, including assumptions of plants to be converted and respective qualities of fuels (particularly sulfur contents) there are methods (NAS,1975) for estimating changes in ambient pollutant concentrations. Without going into this type of detail a rough idea of the difference in concentrations can be gotten from the difference in emissions between coal- and oil-fired plants, refer to Table 2 from (University of Oklahoma,1975,pp.12-40 and 12-41). As can be seen, between coal and oil the significant differences in emissions are the sulfur oxides (assuming no use of scrubbers) and the particulates (203.2×10^3 tons is the totally uncontrolled particulate level, see CEQ,1973,p.48, thus the 48.5 on plant 1 in the Table uses 76% efficient removal, 2.6 on plant 8 is equivalent to 98.7% efficient removal). With no scrubbers and 98% to 99% efficient precipitators the sulfur oxides and particulates both increase by roughly a factor of 2 in an oil to coal conversion.

First, looking at the public health implications of that increase in sulfur oxide emissions, a major difficulty arises from the time-varying composition of the components of the sulfur oxides group. At emission the ratio of SO_2 to the higher oxidated sulfur states is about 70:1, but at equilibrium the ratio reverses to about 1:3. The rate of the oxidation process that takes the apparently harmless SO_2 emissions into the toxic sulfates has been measured at values between .001%/min and 11.7%/min (Urone and Schroeder,1969) depending upon atmospheric levels of moisture, fine particles, metal vapors deposited on the particles, ammonia, sunlight, olefins, NO_2, ozone, and so forth. Thus, although it is known that the

Table 2- Major Residuals for 1,000-Mwe Plants at 75 Percent Load Factor

Plant Number	Description	Primary Efficiency	Nitrogen Oxides (10^3 tons)	Sulfur Oxides (10^3 tons)	Particulates (10^3 tons)	Thermal (10^{12} Btu's)	Solid (10^3 tons)
1[a]	Coal: Conventional steam No controls	38	21.8	119.2	48.5	31.1	298
2[a]	Oil: Conventional steam No controls	38	21.1	47.3	1.6	31.1	0
3[a]	Gas: Conventional steam No controls	38	11.2	.02	.43	31.1	0
4[b]	Eastern Coal: Conventional Boiler with wet limestone scrubbing	35	19.2	16.0	3.2	0	955
5[b]	Eastern Coal: Conventional Boiler with magnesium oxide scrubbing	35	19.2	16.0	3.2	0	410
6[b]	Western Coal: Conventional Boiler with wet limestone scrubbing	35	25.0	5.1	2.2	0	487
7[b]	Physically Cleaned Eastern Coal: Conventional Boiler with wet limestone scrubbing	35	17.6	6.4	1.4	0	417
8[a]	Coal: Steam plant with controls	38	23.2	19.1	2.6	0	1,009
14	Hypothetical Plant: Similar to #1 but with high conversion efficiency	60	14.0	80.8	130	19.7	41.1
15	Hypothetical Plant: Similar to #4 but with high efficiency	58	11.6	9.7	1.9	0	576

Sources: [a]Hittman, 1974: Vol. I; 1975: Vol. II.

[b]Battelle, 1973.

current acid sulfate levels in Eastern U.S. urban areas are 16 - 19 micrograms per cubic meter, it is not possible to say precisely how these figures would change due to changes in local emission levels. Besides the atmospheric chemical problems, another reason for this imprecision is that it is currently not possible to determine what proportions of the sulfate levels in New England are due to the direct effect of regional emissions, the return of regional emissions that have gone out over the ocean, miscellaneous organic sources, emissions from the Mid-western and Mid-atlantic states, and ocean spray.

To further complicate the task of evaluating health effects, the dose-response data for sulfates is currently undergoing reexamination due to some apparent EPA data tampering. For what it is worth, Figure 1 shows mortality data used by the National Academy of Sciences (Rose,1975). The "best judgement" line in Figure 1 shows some apparent cushion between the current levels and the 25 microgram per cubic meter mortality threshold. Using the results in Figure 1 "the EPA has estimated that if the 1975 acid sulfate standards were all met, the excess mortality in 1980 on that account would be very small--in the order of less than one death per power-plant-year"for a 1000MW plant (Rose,1975,p.17). If the 1975 air standards are not met the numbers go to 20 deaths per 1000MW and if the "mathematical best fit" of

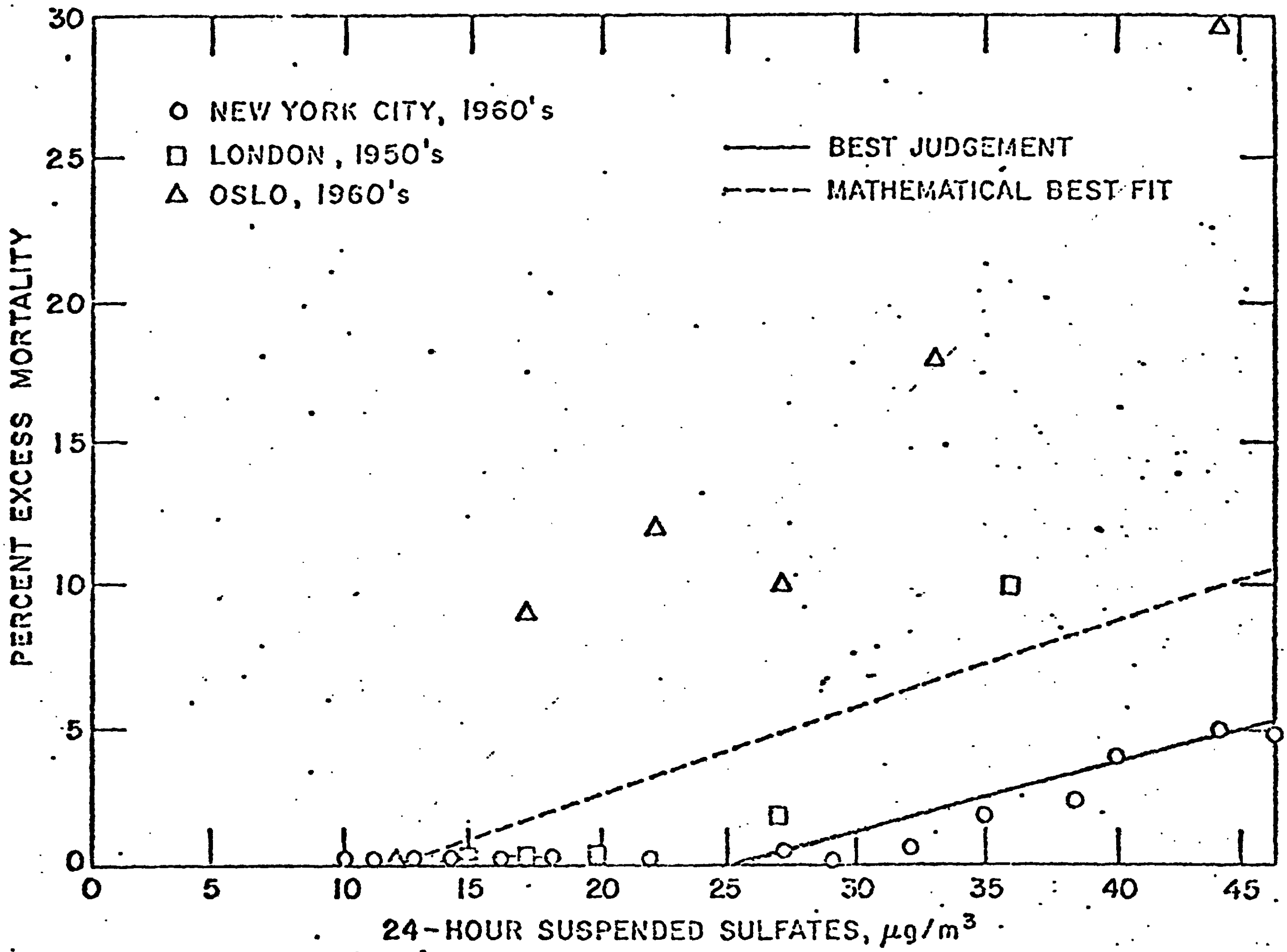

Figure 1 Percent excess mortality expected on account of acid sulfates in the air; from EPA data

Figure 1 is used (probably pessimistic due to extenuating, highly respirable, fog aerosol conditions for the acute episodes plotted) the deaths go to about 100 per plant (Rose,1975,p.18). Figure 2 gives a sampling of the morbidity data (on the next page) used by the N.A.S. (Rose,1975) and the summary given in Table 3 (EPA,1974) shows that if these EPA data are correct then there already exist significant sulfate-caused health problems (in the 16 to 19 microgram range). Any increases in concentrations due to fuel conversion would then be accompanied by increased health effects (as reflected in the slopes of the various dose-response curves such as in Figure 2).

Adverse Health Effect	Sulfate Concentration ($\mu g/m^3$)	Exposure Time
Aggravation of Heart & Lung Disease in the Elderly	9	24 hours or longer
Aggravation of Asthma	6-10	24 hours or longer
Excess Acute Lower Respiratory Disease in Children	13	several years
Excess Risk of Chronic Bronchitis	10	up to 10 years

Table 3 Estimated Levels of Adverse Effects From Sulfates

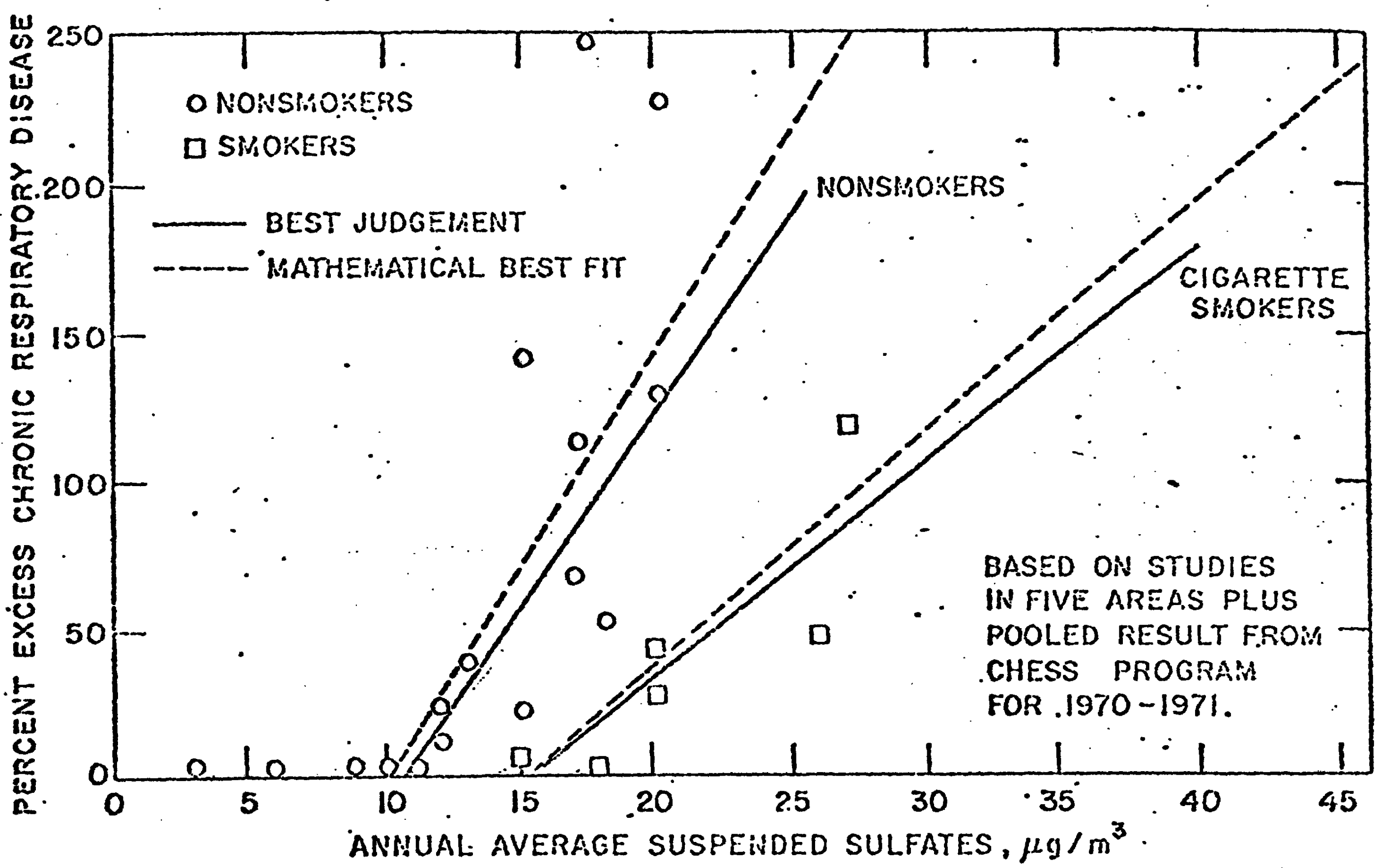

Figure 2 Excess chronic respiratory disease expected from acid sulfates; from EPA data

Before the sulfate data was obtained, a large amount of evidence was collected to show a synergistic effect of SO_2 and suspended particulate concentrations. Whether this combination is just an indicator of sulfate concentrations, or an indicator of general air pollution levels, or in fact a combination of true etiological agents, the correlation between their concentrations and health effects have often been documented, see Figures 3 (Ross,1972) and 4 (Rall,1973). Other studies that specify dose-response relations for these pollutants include, among many others: (Schimmel and Greenburg, 1972) 2.8 excess deaths per million due to increased levels of

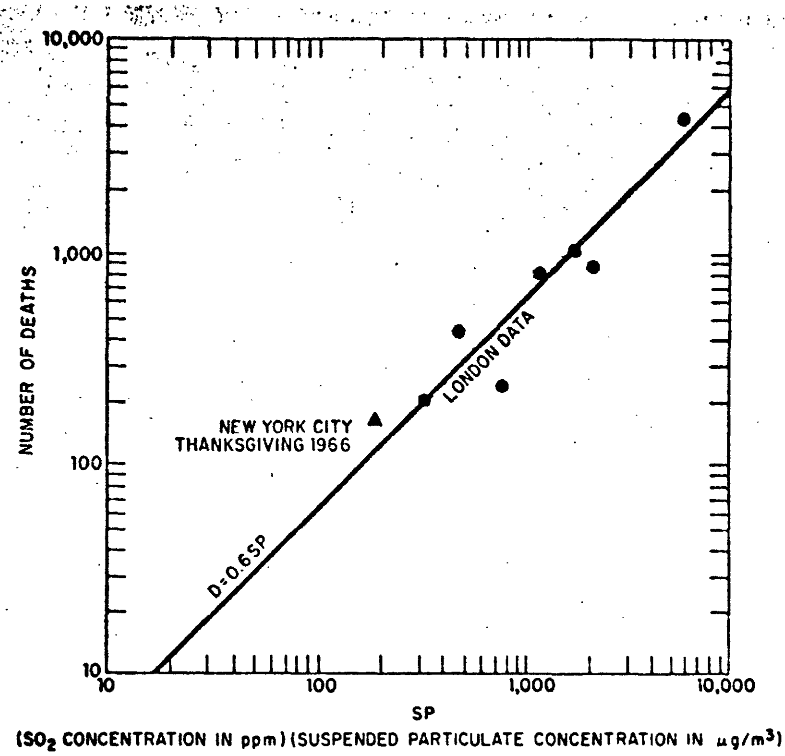

Figure 3 Number of deaths as function of the product of SO_2 and particulate concentrations

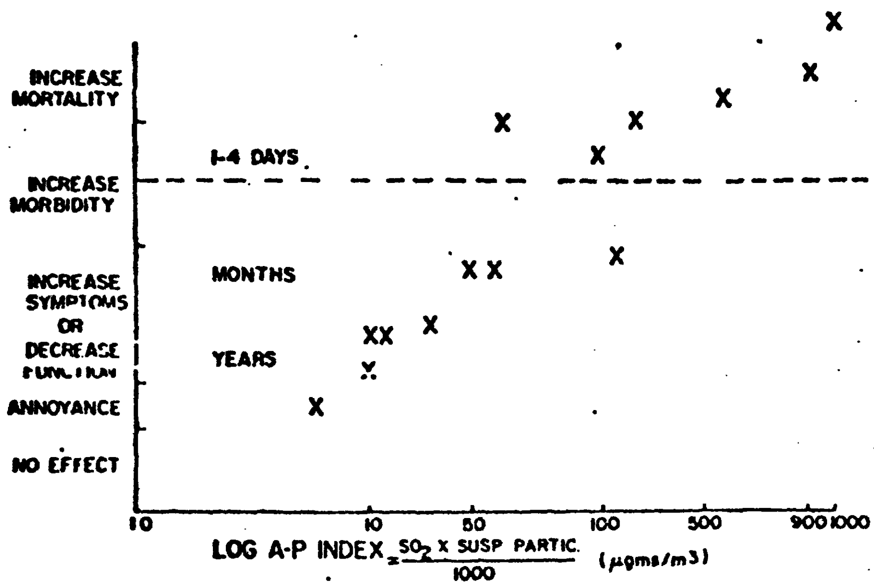

Figure 4 Dose-response of the SO_2 - particulate product from (Rall,1973) a personal communication from Dr. Benjamin Ferris.

SO_2 and particulates (Smokeshade); (Lave and Freeburg,1973) 3.9 excess annual deaths per million per $\mu g/m^3$ of SO_2; (Glasser and Greenburg,1971) .005 to .01 excess daily deaths per million per ppb for SO_2 concentrations greater than 200ppb; and (Buechley, et al., 1973) 14 additional deaths in the New York-New Jersey metropolis on days with SO_2 concentration greater than 500 $\mu g/m^3$ as compared with 30 $\mu g/m^3$ (with effects in the range from 30 $\mu g/m^3$ to 1300 $\mu g/m^3$ approximately linear in the logarithm of SO_2 concentration).

These levels translate (Hub and Schlenker,1974) to a 1000MW coal-fired plant causing between .2 (Buechley, et al., 1973) to 1.0 excess annual deaths per million (Glasser and Greenburg,1971). A 1000MW oil-fired plant would presumably cause about half this many excess deaths using the earlier emission assumption, a linear dose-response curve, and SO_2 as the air pollution indicator.

Particulates by themselves are quickly accelerating forward in the respect given them as health effects causative agents. The source (Lave and Freeburg,1973) gives about twice the annual additional deaths due to particulate concentration increases, $8.5/10^6$ people per $\mu g/m^3$, as it does to SO_2. Increasingly, particulates are being examined not as a general pollutant class but in a number of subclasses, focusing especially on the toxic groups of organic particulates and trace metals.

Despite the fact that many of the air pollutant organic particles are known to be identical or similar in action to carcinogenic components of tobacco smoke (Watson,1970) little is known about their dose-response curves at community levels.

Trace metals, on the other hand, have received somewhat greater attention but there is still no general dose-response data. Most of the more than 30 trace elements found in coal are either not toxic to man or are generally assumed to be sufficiently removed in the fly ash recovery processes. Some of the elements, however, are very volatile and adsorb or condense into small particles that completely escape removal processes and, in addition, happen to be in highly respirable particle size ranges. Included in this group are arsenic, antimony, beryllium, cadmium, lead, mercury, selenium, and thallium. Studies (ANL,1973) show that using national average concentrations of elements in coal, beryllium is closest to the recommended community ambient limits and it is a factor of five below that limit. In some low grade western coals, however, elements such as "beryllium, arsenic, and uranium sometimes occur in concentrations 100 to 1000 times greater than the national averages" (ANL,1973,p.33), and thus there definitely could be health implications here. There is little else known in this area; one other study (Hickey,1971) examines the correlations between mortalities caused by specific diseases and concentrations of 16 air pollutants. Arsenic, cadmium, and lead are the only ones considered that are in that group of highly volatilized coal elements. For several diseases each of these three pollutants shows some significant correlation with specific disease occurrences (although not nearly as significant as the correlations between SO_2 or particulate sulfates and those diseases).

Obviously, more research is needed in all these areas before precise health effects predictions can be made. "Information about long-term health effects of continuous low level exposure is meager and thus is not taken into account in the present standards even though they may in the long run be the major health cost" (ERDA,1975,p.5). This major gap in information about health effects must be considered as a potential major change in standards, and as such represents a large element of uncertainty in the decision making process. These environmental uncertainties will be very important factors for risk-averse persons deciding about commitment of capital for fuel conversions.

References

ANL, Argonne National Laboratory,1973; "A Study of Social Costs for Alternative Means of Electrical Power Generation for 1980 and 1990," for USAEC, ANL-8092, Argonne, Ill., 37pp.

Battelle,1973;"Environmental Considerations in Future Energy Growth," Vol. I, Columbus and Pacific Northwest Laboratories, for EPA, Columbus, Ohio.

Buechley, R.W.,et al.,1973;"SO_2 levels and perturbations in mortality, a study in the New York-New Jersey metropolis," Arch. Environ. Health, 27, pp.134-137.

CEQ, Council on Environmental Quality,1973; "Energy and the Environment, Electric Power," USGPO, Washington D.C., August 1973.

EPA, Environmental Protection Agency,1974;"Alternative Control Strategies for Sulfates," October 17,1974.

ERDA, Energy Research and Development Administration,1975; "Health Effects of Coal Combustion and Conversion," Internal Program Overview and Objectives, August 8,1975.

Glasser,M. and L.Greenburg,1971;"Air pollution, mortality, and weather, New York City, 1960-1964," Arch. Environ. Health, 22, pp. 334-343.

Hickey,R.J.,1971;"Air Pollution," Chapter 9 in Environment, Resources, Pollution & Society, W.W.Murdock(Ed.), Smauer Associates Inc., Stamford, Conn.

Hittman,1974 and 1975;"Environmental Impacts, and Cost of Energy Supply and End Use,"Vol I and Vol II, Hittman Associates Inc., Columbia, Md.

Hub,K.A. and R.A.Schlenker,1974;"Health Effects of Alternative Means of Electric Generation," Argonne National Lab, IAEA-SM-184/18, 24pp.

Lave,L.B., and L.C.Freeburg,1973;"Health effects of electricity generation from coal, oil, and nuclear fuel," <u>Nuclear Safety</u>, <u>14</u>, pp. 409-428.

NAS, National Academy of Sciences, et al., 1975; "Air Quality and Stationary Source Emission Control," prepared for the Senate Committee on Public Works, March 1975.

Rall,D.P.,1973;"A review of the health effects of sulfur oxides," National Inst. of Environ. Health Sciences, Research Triangle Park, N.C., October 9,1973.

Rose, D.J.,1975; "Nuclear power vis-a-vis its alternates, chiefly coal," Department of Nuclear Engineering, M.I.T., presented to U.S.Congress O.T.A.,27pp.,July 9,1975.

Ross,R.D.,1972;<u>Air Pollution and Industry</u>, van Nostrand Reinhold Co., N.Y.

Schimmel,H., and L.Greenburg,1972;"A study of the relation of pollution to mortality, New York City, 1963-1968," <u>J. Air Pollution Control Association</u>, <u>22</u>(8),p.616, August 1972.

University of Oklahoma,1975;"Energy Alternatives: A Comparative Analysis," for CEQ, ERDA, et al., USGPO, May 1975.

Urone,P. and W.H.Schroeder,1969;"SO_2 in the atmosphere: A wealth of monitoring data but few reaction rate studies," <u>Environ. Sci. Tech.</u>,<u>3</u>,436.

Watson, D.E.,1970;"The risk of carcinogenesis from long-term low-dose exposure to pollution emitted by fossil-fueled power plants," Lawrence Radiation Laboratory, TID-4500,UC-48,UCRL-50937, October 1970.

November 16, 1976

Statement of Dr. James Gruhl[1]
for the Harvard Medicine and Society Forum

There are several aspects of the prepared environmental impact reports for the Medical Area Total Energy Plant that are quite disturbing. One of the most disturbing aspects is the lack of proper respect for the unknowns: in the data, in the criteria, and in the modeling. In most areas, such as economics, construction planning, plant performance, fuel cost and availability, and so on, disregarding the unknowns can result in painful awakenings to sensitive issues. For example, one such rude awakening could come from forgetting to consider the cost per kilowatt that hospitals with their own power sources generally must pay to local utilities for "standby" power. These consequences, however, can generally all be reduced to economic losses. Disregard of environmental uncertainties, on the other hand, amounts to gambling with far graver stakes and includes moral implications.

What types of environmental uncertainties are involved in the MASCO decision? First, there are uncertainties in the amounts and types of emissions that are possible from such a facility. A second and more obvious area of environmental uncertainty comes from the different problems encountered in the exercise of trying to accurately simulate the impact of the emissions upon air quality. Under ordinary conditions the modeling of pollution patterns over an area can be accomplished with some degree of certainty. The acute episodes, however, are not easily simulated and it is under these types of inversions, downwashes, and other upset conditions that the damages from power plant effluents can run into the millions of dollars in damages to materials and additional health care expenses.[2]

The final area of uncertainty is in the ambient air quality standards that are likely to be in force over the 30-year lifetime of such a facility. Changes in levels of the standards by as little as 16% would put this district in violation (Kenmore Square, annual SO_2) just with the existing sources. Not only are the levels of the standards likely to change but the number of pollutants that are regulated will certainly be increased with time so as to more accurately reflect the health effects information as it becomes available. (EPA, 1974) shows sulfate effects; (Hickey, 1971) shows effects of a number of trace metals and other air pollutants at urban concentrations; and other studies appear regularly on pollutants that are corelated with "increased mortality harvests." As an indication of how little is now known about effects of pollutants an ERDA report (ERDA, 1975, p5) recently stated that "information about long-term health effects of continuous low level exposure is meager and thus is not taken into account in the present standards even though they may in the long run be the major health cost."

Although a lack of due regard for uncertainties is disturbing, more distressing is the lack of intelligent use of known information. Estimates of premature mortalities in the populations surrounding a 1000 megawatt oil-fired plant include numbers like 16 deaths per year (Leskovjan, 1974), 25 per year (National Academy of Sciences, 1975),[3] and 60 per year (Starr, Greenfield and Hausknecht, 1972) and range up to 100 deaths per year (Comar and Sagan, 1976). For a 40 megawatt plant with a 30-year expected lifetime these numbers translate to about 20, 30, and 72 excess mortalities and ranging up to 120 mortalities in the surrounding populations. Looking into the assumptions used to calculate those particular numbers it becomes immediately apparent that they are likely to be very low estimates for the MASCO situation. Here is why:

First, these numbers do not take into account anything but the electric

---

1. The views presented here are those of the author and do not necessarily represent those of MIT, the MIT Energy Lab, or any other persons that are associated with those organizations.
2. Up to $5 million per episode has been estimated as caused by the power plants in the Los Angeles basin in a single episode.
3. Using a coal-to-oil scaling factor of 1/2 as computed in (Gruhl, 1976).

generation and thus do not include effects from the daily emissions from incineration of 70,000 pounds of plastics, hospital materials, and garbage.

Second, the sites used in those studies were orders of magnitude less dense than a mid-city location.

Third, the susceptibility of the impacted populations in the MASCO area is much higher than the susceptibilities of the normal populations assumed in those mortality studies. Susceptibilities to the effects of pollutants are greatly increased in densely populated areas, socio-economically depressed areas, infants, children, students, elderly, pregnant women, and persons with cardiovascular and respiratory ailments.

A final area that has not been accounted in those excess mortality studies involves the effects of the pollutants on increased levels of birth defects, genetic mutations, and incidence of cancer. Although these effects could be very widespread they have been largely unstudied due to the difficulties in devising, funding, and carrying out research in this field. Many of the carcinogenic impacts, for example, can be delayed 15 to 30 years from the time of exposure. And staying with the example of carcinogenic pollutants, it is possible that relatively large quantities are emitted from fossil-fueled power plants. Included among these pollutants are many of the same carcinogenic hydrocarbons as there are in cigarette smoke (Watson, 1970), and quantities of suspected organic sulfur, organic nitrogen, and trace metal carcinogens. One quick example will illustrate the potential magnitude of the problem. Coal-fired power plants can emit about 600 tons per year of nickel into the air (Argonne National Lab, 1973), yet they account for only a couple of percent of the national output. Oil-fired plants, accounting for only about 10% of all electric generation, contribute 24% of the national nickel air emissions (Goldberg, 1973). Also present in the oil-fired plant emissions are large quantities of carbon monoxide. It appears that noone has measured, however, the extent to which this disproportionately large amount of nickel and the carbon monoxide are combining. What is known is that their combination, nickel carbonyl, is a carcinogen at part-per-trillion levels (Federal Register latest levels of acceptable occupational exposures).

Why are these types of concerns not displayed? The EPA (Federal Register, 41, 21402, May 25, 1976) has clearly requested that all new facilities which could be emitting known or suspect carcinogens must go through a rigorous appraisal of the risks and benefits of those emissions. Perhaps the reason facilities such as oil-fired power plants have escaped these rigorous requirements is because we have become more complacent about their existence than we have about the existense of, say, some new pesticide factory or a nuclear power facility.

Just to show the lack of balance in the types of decisions that are currently being made use this oil-versus-nuclear comparison as an example. Two billion dollars have been spent studying effects of nuclear power plant emissions. This nation could not afford to perform a proportionately exhaustive investigation of emissions from oil-fired plants, and yet the sum of all the well-known effects from the nuclear plants is a factor of 100 to 1000 below that which has been uncovered so far for oil-fired facilities. This is for ordinary plant operations, but even in the cases of worst accidents for both types of facilities the oil-fired plant is more damaging in many categories. A conflagration of the 1.2 million gallon MASCO oil storage area would result in many hundreds of premature deaths from downwind smoke inhalation (Starr, Greenfield and Hausknecht, 1972), to say nothing of the numbers of people that would be directly consumed in the flames. If this new facility used nuclear fuel the potential for such an accident would have to be studied with an exhaustive analysis including tedious surveys of all people downwind from the facility in all wind directions.

What can in fact be done now about all of these environmental uncertainties and imbalances? There are two courses of action that should be taken: (1) an examination of the known and suspected environmental and human effects of this facility should be performed, and (2) a similar examination should be made of the possible consequences of alternatives to this facility. Both these courses involve looking slightly beyond the legal obligations as set down in the current standards. They involve an obligation to the people and they would result in exactly what common sense would dictate: in light of the severity of the known and suspected impacts the facility should be cited in the most sparsely populated area that is available.

The determination of the public health impacts of energy facilities will soon be performed as a matter of course (OTA, 1975, pp223-226). It will be difficult for decision makers of the future to see the actual health implications of even the best of the alternatives they are faced with, but it will be even more difficult to see the assessments of the ramifications of the poorer decisions of the past. It is clear that compared to a remotely sited nuclear facility this MASCO plant will without any doubt cause some people there lives (Beckmann, 1976). On the surface the economic gains of a total energy plant may look attractive, but it would be in the best interest of all concerned, including Harvard University, to have an early and thorough determination of the environmental and human losses that are implicit in these economic and resource gains.

Argonne National Lab, 1973. "A study of social costs for alternative means of electrical power generation for 1980 and 1990," ANL-8092, ANL-8093 Vols 1-4, February/March.

Beckmann, P., 1976. The Health Hazards of Not Going Nuclear, University of Colorado, The Golem Press, Boulder Colo., 190pp.

Comar, C.L. and L.A. Sagan, 1976. "Health effects of energy production and coversion," in Annual Review of Energy 1976, J.M. Hollander and M.K. Simmons(eds), pp581-600.

Environmental Protection Agency, 1974. "Alternative control strategies for sulfates," EPA Washington D.C., October 17.

ERDA, 1975. "Health effects of coal combustion and conversion," internal program overview and objectives, ERDA, Washington D.C., August 8.

Goldberg, A.J., 1973. "Survey of emissions and controls for 'hazardous' and other pollutants," EPA, NTIS #PB-223 568, Springfield Va.

Gruhl, J., 1976. "Health implications of oil-to-coal conversion in New England power plants," MIT Energy Lab #MIT-EL 76-013wp, see also 76-020wp and 76-024wp, Cambridge Mass.

Hickey, R.J., 1971. "Air pollution," Chapter 9 in Environment, Resources, Pollution & Society, W.W. Murdock(ed), Smauer Assoc. Inc., Stamford Conn.

Leskovjan, L.L., 1974. "An estimate of the public health costs of air pollution from fossil-fueled power plants," Env. Eng. Thesis, MIT Dept. of Nuclear Eng., Cambridge Mass.

National Academy of Sciences, 1975. "Air quality and stationary source emission control," US Senate Serial No. 94-4, USGPO, Washington D.C.

OTA, Office of Technology Assessment, 1975. "An analysis of the ERDA plan and program," US Congress, USGPO, 318pp, October.

Starr, C., M.A. Greenfield, and D.H. Hausknecht, 1972. "A comparison of public health risks: Nuclear vs. oil-fired power plants," Nuclear News, p37, October.

Watson, D.E., 1970. "The risk of carcinogenesis from long-term low dose exposure to pollution emitted by fossil fuel power plants," Univ. of Calif., Law. Liv. Lab.UCRL-50937.