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RESOURCES
AND THE ENVIRONMENT

VOLUME 5 OF 5

Assembled By

F. Eugene McJunkin

International Program in Environmental

Aspects of Industrial Development

Department of Environmental Sciences and Engineering

University of North Carolina

Chapel Hill, N.C. 27514

U.S.A.

1975 - 1976

INTERNATIONAL ENVIRONMENTAL PROGRAMS AT THE UNIVERSITY OF NORTH CAROLINA

The Department of Environmental Sciences and Engineering at the University of North Carolina has a long standing interest and involvement in international activities and programs concerned with environmental quality and, in particular, with the environmental problems of developing countries. Departmental activities have included special educational programs, on campus and abroad, long and short term; technical assistance; research and development; information transfer, including publications; and consulting and service activities by faculty and staff. These programs have included the International Program in Sanitary Engineering Design, the AID Engineers' Environmental Program, the International Program in Environmental Aspects of Industrial Development, the publication series Water Supply and Sanitation in Developing Countries, technical assistance to several overseas universities, and numerous technical studies.

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ENERGY AND THE ENVIRONMENT

by

Rémi Barré

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"The optimist proclaims that we live in the best of all possible worlds; and the pessimist fears this is true."

INTRODUCTION

Energy is the new "in-thing" at present; it is fashionable to talk about the problems of energy development, especially since the discovery of the "energy crisis." If we bring into the picture the fact that obviously very serious environmental damages have stemmed from the energy industry, and that energy has become a symbol of our entire system of industrial development and economic growth, we link together the three key-words of the 70's: energy - environment - development.

The purpose of this paper is not to explore in any depth those linkages, but, focusing on the environmental consequences of energy systems, to provide a framework for analysis and decision-making in an area where rational evaluation and planning is often obscured behind amounts of unrelated and partial pieces of information, and shaky conceptual basis.

In a first part, we will put the energy systems concept in perspective, and relate it to development and collective choices. Then, in a second part, we will assess the various environmental impacts of energy systems. Finally, in a third part, we will discuss the possibilities and means of controlling and reducing those impacts by structural and non-structural methods, with special attention to the relationship between the costs of the possible measures to be taken, and their objective results

Clearly, for all environmental problems linked to industrialization, the issues and goals are extremely different between developing and developed nations; the standards to be applied, the relevant techniques and policies,

the priorities, costs and benefits: almost nothing can be held universally true. Nevertheless, it is not because information and results concerning the relationships between energy and the environment are to be interpreted and translated into policies in a different way, nor that it means the information and results are not needed; on the contrary, if they have to be re-discussed, re-analyzed, re-framed into policies relevant to developing nations - and they indeed do - then the information and results have to be all the more accurate and carefully studied.

The goal of this paper is to help make a step in that direction.

NOTA: We call the energy system, the system which consists of all the components necessary to bring a basic energy resource from its natural state to a place and in a form in which it is used: extraction, processing, sometimes conversion into another form (electricity), transportation between operations, delivery or transmission to the final users, and use.

FIRST PART: THE ENERGY - A PERSPECTIVE VIEW

Energy is the ability to do work. It is the potential for useful work, in storage batteries, in muscles, in coal or flowing water. Man's use of energy was for long limited to that provided by his muscles. Later he learned to use fire for cooking and protection against the cold. Later still he captured the energy of the wind with sailboats and windmills. Today, we are exploiting a broad array of energy resources based mainly on fossil fuels, and tomorrow on nuclear fission and maybe later on solar and nuclear fusion energy - virtually unlimited energy sources.

But where does this energy come from? The earth's energy balance is composed for more than 99% of solar radiation reaching its surface - part of it being immediately reflected (about 35%), part of it heating the atmosphere (about 43%), used for evaporation, atmospheric and sea movements (about 20%), the remaining 1% being used by plants to convert CO_2 and H_2O into carbohydrates by the process of photosynthesis[1], simultaneously releasing oxygen in the atmosphere. When plants decay, the process is reversed. Over geologic periods of time, since half a billion years ago, a fraction of these organisms have been buried before complete oxydation; they underwent chemical changes and were transformed into natural gas, coal, oil, lignite. The stored energy is released by oxydation, emitting CO_2 and H_2O and heat.

The radioactive materials have been formed when the whole solar system still was a big diffuse star, subject to intense nuclear activity. In nuclear plants, it is the energy stored at that time which is released.

The shift from agrarian to an industrial economy resulted in vast increase in energy consumption, both for powering the industry and for mechanizing and fertilizing agriculture to increase productivity. In addition, an energy-intensive transportation system ties together any highly specialized, and

therefore interdependent economy (see Table 1)[2] (note: 1 BTU = 0.26 calories).

TABLE 1

The Shift to Energy-Intensive Passenger Transport

	Percent of total passenger-miles			Average Btu's per passenger-mile	Load factor
	1950	1960	1970		
Urban					
Walking	.....	NA	NA	300 (human energy)	
Bicycle	.....	NA	NA	180 (human energy)	
Bus	.....	5.9	2.7	2,100 (diesel fuel and gasoline)	[1] .36
Automobile [2]	.....	89.2	94.5	8,100 (gasoline)	[1] .28
Intercity					
Bus	4.5	2.5	2.1	1,600 (diesel fuel and gasoline)	[1] .45
Railroad	6.5	2.8	.9	2,900 (diesel fuel)	.35
Automobile	86.8	90.1	86.6	3,400 (gasoline)	[1] .48
Airplane	2.0	4.3	10.1	8,400 (gasoline and jet fuel)	.50

[1] Based on 50-passenger average capacity for buses and 5-passenger capacity for automobiles.
[2] Includes taxicabs.

Sources: Transportation Association of America. 1972. *Transportation Facts & Trends, Ninth Edition*. Washington, D.C.: T.A.A., p. 16; U.S. Department of Transportation. July 1972. *1972 National Transportation Report*. Washington, D.C.: D.O.T., p. 189; personal communication with Richard Stromboine, U.S. Department of Transportation; Rice, Richard A. 1971. "Historical Perspective in Transport System Development," in *Advanced Urban Transportation Systems*. Pittsburgh, Pa.: Transportation Research Institute, Carnegie-Mellon University, p. 89; and Hirst, Eric, and Robert Herendeen. January 1973. "Total Energy Demand for Automobiles." A paper presented before the Society of Automotive Engineers, Inc., New York, N.Y., International Automotive Engineering Conference, Detroit, Mich. p. 3.

Total world energy consumption has increased 5 times in the last 50 years, and the rate of increase has been increasing: +2.2% per year between 1925 and 195 +4.9% between 1950 and 1960, +5.5% since then.[3] The very characteristics of "modern living" and the technological age, namely, urbanized area development, high productivity, industrial production, high specialization, are extremely energy-intensive processes. Actually, half the coal burned by man has been burned in the last thirty one years, and half the petrol consumed has been burned in the last thirteen years.

The relative share of Europe and North America tends to decline, but there are still huge disparities in the per capita energy consumption per year: three times more in North America than in Europe and the USSR, ten times more than in Latin America, thirty times more than in Africa and Asia (excluding Japan); North America, with 8% of the global population consumes 37% of the

world's energy, whereas the poorest half of the world population consumes only 10% of the total energy produced.

There is a definite positive correlation between energy consumption and GNP per capita, and between the rate of increase of those two variables. Nevertheless, the industrial structure plays a significant role and countries like Canada, Norway, Czechoslovakia, East Germany, Poland and Venezuela show a higher use of energy per unit of GNP than the USA. Clearly it would be hazardous to draw a simple causal relationship between GNP and energy use but there is a definite linkage.

Between 1950 and 1960, there has been a drastic shift in energy sources: coal declining from 56 to 34%, oil and natural gas increasing from 38 to 60%, hydroelectricity staying at 6%, but nuclear energy's share is expected to boom from about zero to 21% of the world's energy production in 25 years from now. Let us now focus on a few issues related to energy:

1. Energy and food production[4]: there is a particularly clear interdependence between agricultural productivity and energy use: fertilizers, farm machinery and irrigation are highly energy-intensive products, as well as the food transportation and processing industry. For many countries though, and indeed for all countries in the longer run, the US type of this very energy-intensive agriculture doesn't make any sense, when 10 calories of energy are needed to produce 1 calorie of food output. The critical variable in food production is precisely this energy subsidy to food output ratio, provided the protein diet is adequate.

2. Energy and international relations. There is no need to elaborate the fact that the world balance of power is drastically affected by the dependence of many countires on imported oil, generally from the Middle East. The whole monetary system is threatened by the importance of the transfers this dependence generates and the interdependency between political and military alliances

industrial and technological power and fossil fuel supply is every day more clear. The oil embargo of November 1973, which helped bring oil to a more realistic price, has been the first sign of the deep meaning of the basic interdependency between the world's nations, which has shown the power of any nation upon the whole system, and therefore the responsibility of all nations in the world's affairs.

The economic and social systems are increasingly dependent on energy, and Buckminster Fuller has estimated that if we took away the whole industrial network of energy consuming machinery in the world, half of humanity would die of starvation within 6 months.

3. Energy and collective responsibility. Energy is certainly the field for which the exhaustion of resources has been the most discussed, which contributed to the consciousness of the fundamental finiteness and limits of the earth's resources. This brought a major technological challenge in the form of the need of alternative energy system developments. It brought too, wide discussions and criticism of highly energy-intensive societal models, first of all because of the dubious feasibility of their world-wide application (24,000 power plants of 5000 mega-watts each would be necessary to supply electricity to the world, if everyone had to have the same electricity consumption rate as the USA). Finally, it brought the notion of the environmental impact of the scale far beyond the individual, both in terms of space (world-wide pollution) and time (exhaustion of resources or necessity of storage of nuclear wastes for thousands of years).

All these elements are important in that while they stress the very sharp and inadmissible world inequalities in energy consumption (50% of the world consumes 10% of the energy), they stress not less strongly the interdependence between nations: the responsibility for energy development for further increase in material welfare and a more equitable repartition - its far-reaching

good and bad potential consequences - is really collective.

We will focus now on the environment, energy systems linkages, which we consider as one of the basic elements to assess in order to define an energy policy which would be rational both at local level in terms of the development objectives of a country, and at global level in terms of long term feasibility and viability; as the Council on Environmental Quality put it:

> "the conflicts between the consumption we all want and the environmental ill effects we all wish to avoid is sharper for energy than perhaps any other aspect of natural resources use."[5]

Precisely, energy is a natural resource (fossil fuels), an industry of major importance (energy systems) and a major waste product (heat).

SECOND PART: THE ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS

We will make a review of the adverse or potentially adverse effects due to the various energy systems. and not about the various benefits of power production.

These adverse effects concern human health, the natural environment (plants, forests, crops, fish, the atmosphere...) and man-made structures thus impacting upon the social, economical and ecological systems, from very local to global scale, through air, water and earth. Some of these effects are monetary, others non-monetary but measurable, others non-measurable; some are direct, others indirect effects, reversible or irreversible, short term or long term. In other words, energy systems, being a very substantial element of man's industrial activity has complex, widespread and significant impacts at the level of society as a whole.

1. Hydroelectric power generation systems.

The most obvious impact there is the presence of an artificial lake which can have various effects on the local climate and more generally the whole natural-physical systems and the hydrology of the area. In fact, their interactions are so complex and so little understood that ecologists cannot predict those effects with any certainty, and several unpredictable situations can develop. Very often a dam has a role of flood regulation, but this can adversely affect the soil quality by preventing the salt deposits due to evaporation of irrigation water, to be annually washed out. This happened for example in the Kaipur area of Pakistan[6]. Sometimes too, a reservoir has an impact on the amount and flow of downstream waters which can have its nutrients composition changed, which can affect the fishlife. This has happened with the Aswan dam in Egypt where soil salination and sardine disapparition in the Mediterranean have become major problems. The presence of an artificial lake

has a social impact by displacing populations, disrupting communication channels and taking land of agricultural value. We have to take into account too the increased health hazard due to the presence of a large body of water, as has been the case for the Kariba dam in Zambia.

Finally, if we consider the total energy system of hydroelectric production, we have the following table (Table 2)[7].

TABLE 2

Energy from Hydro–Potential Environmental Damage

	Air	Water	Land	Other
Exploration and Extraction				
Upgrading				
Transportation			Transmission lines	
Utilization	Micro-climate Evaporation	Changes in water quantity (level, discharge, velocity, groundwater and losses) and quality (sediments, nutrients, turbidity, salinity and temperature)	Flooding Submerged Land Loss of Animal Habitat Landslides Earthquakes Drawdown Zone	Food Chain Repercussions Disease Vectors Submerged Vegetation Benthos Aufwuchs Zooplankton Phytoplankton

2. Fossil fuel energy systems (coal, natural gas, petroleum)

By very far they represent the largest share of energy production (more than 93% for the whole world in 1968). Coal's share is decreasing and will continue to do so, from about 34% in 1968 to about 12% in 2000, but this still means, in absolute terms a 50% increase. Oil, which reserves are far less important than coal or natural gas will increase its share from 43% in 1968 to 48% in 2000, which means a production at that time 4 times the actual one, and which will begin to decrease in relative terms at the turn of the century. Natural gas, an abundant and clean source will slowly increase its share, with a production multiplied by 5 in 2000[8].

2.1 Exploration, extraction and upgrading steps

Coal extraction is a notoriously dangerous occupation, where accidents still regularly occur, and with a long term negative impact on health. It is also a well known source of water pollution. In the US for example, 13,000 miles

of streams and 145,000 acres of lakes and reservoirs have been affected by acid mine drainage and siltation from coal extraction. Surface mining degrades land to a point of precluding any posterior use. Mining wastes are another problem, and represent in the US almost 40% of the total solid waste generation.

Oil pollution occurs during accidents at the exploration and extraction phases or during normal and accidental operations during the transportation phase. 2.2 million metric-tons of oil go annually in the seas, 90% of which is during normal operations. (See Table 3)[11]

TABLE 3

Estimate of Petroleum Oils Entering Oceans, 1969

	Metric tons/Year
Normal Operations	
Tankers	500,000
Other Ships	500,000
Offshore Oil Production	100,000
Accidental Spills	
Ships	100,000
Other	100,000
Refinery and Petrochemical	
Plant Operations	300,000
Industrial and Auto Wastes	
in Rivers	500,000
in Sewage Outfalls	100,000
Partial Total	2,200,000
Natural Seepage	100,000
Naturally Occurring Hydrocarbons	
In the Sea	large
Airborne Petroleum Hydrocarbons	large
Airborne Terpenes	large

This figure is projected to be 4.5 million annually in 25 years, and even more if off shore drilling goes on increasing so sharply (+175% in 4 years), thus multiplying the risks of major accidents. The main consequences of that are the poisoning of marine life, and of the food chain process, changes in the radioactive properties of sea-water (less evaporation), and degradation of the coastal areas.

Oil refineries produce oil spills, air pollution by burning some residual gases, water and earth pollution due to the chemical catalysts used in the refining process and which enter the environment with largely unknown consequences

2.2 Utilization step

Fossil fuel combustion is the most important source of air pollution generation in the world. The fuel's energy can be used directly (heating, transportation) or indirectly through the production of electricity by power plants. The share of electric energy is increasing rapidly, especially in the developed countries, and the world wide percentage of energy used in the form of electricity is expected to go from 22.4% now to 39% in 2000.[12]

In the US, fossil fuel combustion accounts for 98% of the SO_2 generation 80% of the CO, 60% of the hydrocarbon, and 40% of particulates.[13] The emissions characteristic for a fossil fuel plant are: (Table 4).[14]

TABLE 4

Pollutant	Emission in pound per KWH
Particulates	.0306
SO_2	.0294
Nitrogen oxydes	.0073
CO	.00014
Hydrocarbon	.000078

Furthermore, fossil fuel combustion also contributes to environmental pollutants which can be highly toxic. In the US, in 1968, 180,000 tons of lead have been emitted in the air by automobiles, oil combustion also releases significant amounts of vanadium[16] and mercury.

Let us examine the economic effects of air pollution, which as we have seen, is due roughly for 2/3 to energy systems burning fossil fuels. These air pollutants are generally found in low concentrations, and their effects have long been unknown, because they develop over long periods of time. Now, several epidemiological studies have clearly shown the impact of air pollution on human health, nature and materials. In the US, it is now recognized that 50% of the bronchitis cases, 25% of other respiratory diseases and 25% of lung cancer, as well as 10% of all other cancers and cardiovascular diseases are due to

air pollution.[17] It is considered, too, that about 4.5% of all health costs can be attributed to air pollution. An amount of economic loss of the same order of magnitude can be attributed to the effects on materials: paint, zinc, cement, metals, building stones, rubber, glass, paper, are damaged. There is also a damage of vegetation and crops. Even though much more needs to be known, we know the economic cost of air pollution is very high. An estimate has been done for the US (Table 5).[18]

TABLE 5

Year	HEALTH		PROPERTY - MATERIAL VEGETATION	
	Stationnary sources	Transportation	Stationnary sources	Transportation
1968	8.2	2.8	8.4	0.5
1985	16.7	3.9	19.0	1.2

(in billions $)

Table 5: economic effects of energy related air emissions.

Another aspect of air pollution is the global impact. Many scientists suspect CO_2 and energy production contributed to the temperature increase of the earth up to 1940 (CO_2 tends to absorb the infrared waves reflected by the surface of the earth, and thus "traps" more solar energy) and that this trend was overtaken by the cooling effect of the increased particulate matter emitted into the atmosphere, which directly reflects more and more incoming solar radiation. But the question cannot be resolved yet with much confidence. Nevertheless, it is clear that the CO_2 of the whole atmosphere, from 1860 to now has increased from 290ppm to 320ppm on the average, and could reach 600ppm in 50 years. Another global effect is the acidification by SO_2 of the water contained in the atmosphere, thus giving place to the so called "acid rains", which can have very detrimental effects on some soils and bodies of water. This is particularly the case of Scandinavia which receives rain of a PH sometimes around 4. due to the SO_2 production in England and the Rhur Valley.

Another major effect of energy production is the heat generation: the laws of thermodynamics tell us the process of transformation of heat into useful energy -- mechanical or electrical - is necessarily a very inefficient one, and fossil fuel plants reject 45 to 50% of the heat in water, and 15% i the air, using effectively only 35 to 40% of the initial heat. A power plan on the average releases 10,494 BTU/KWH in the environment.[19] The effects of thermal discharge are far from being fully understood, and can have benefici effects too. But in general, thermal discharges in streams and lakes alter drastically the natural balance of the aquatic life and can damage lakes, ba estuaries and rivers, especially in hot climates. Temperature elevation doe increase the activity and toxicity of some waterborne pollutants such as nitrates and phosphates, by speeding up the chemical reaction processes, increases the BOD levels by favorizing biological activity.

Finally, let us mention the aesthetically damaging and land intensive aspects of overhead electric transmission lines. In the US for example, the total land occupied by the 300,000 miles of lines is almost as vast as the state of Massachusetts. There are also the oil and gas pipelines, covering more than 1 million miles in the US only, with risks of breakage, explosion, and seepage.

Table 6 shown a summary of the effects for all fossil fuels,[20] per step, and Table 7 shows, for electric power plants using coal, gas and oil, the impact per environmental medium (land, air, water).[21] A qualitative estimate of the severity of each impact is provided on a 0-5 scale, to facilitate the reading.

Appendix A[22] shows these impacts broken down per step or element of the energy system and per medium of transmission.

TABLE 6

	Energy from Coal–Potential Environmental Damage			
	Air	Water	Land	Solid Waste
Exploration and Extraction	Fuel combustion products Waste pile fire	Acid mine drainage Leaching of waste piles Erosion and silting of watercourses	Strip mining effects Land subsidence	Underground mining waste
Upgrading	Particulates from fine coal drying Waste bank fires	Plant effluents Leaching of waste piles		Coal cleaning waste Sulphur
Transportation				
Utilization	*Power Plant* Carbon dioxide Sulphur oxides Nitrogen oxides Particulates *Coke oven* Particulates Hydrogen Sulphide Carbon Monoxide Hydrocarbons	Thermal discharges	Aesthetic pollution of landscape	Fly ash and slag Failure of slag heaps

	Energy from Oil–Potential Environmental Damage			
	Air	Water	Land	Solid Waste
Exploration and Extraction	Fuel combustion products	Drilling accidents Brine disposal		
Upgrading	Sulphur oxides Nitrogen oxides Carbon monoxides Hydrocarbons	Thermal discharge Sulphuric acid Spent caustic		Spent phosphoric acid catalyst Spent clay
Transportation	Power sources	Oil Spills	Pipeline accidents Effect on permafrost	
Utilization	Emissions from internal combustion engines Sulphur oxides Nitrogen oxides Particulates	Thermal discharge Used oil disposal		

	Energy from Gas–Potential Environmental Damage			
	Air	Water	Land	Solid Waste
Exploration and Extraction				
Upgrading				
Transportation	Nitrogen oxides at compressor stations		Pipeline problems	
Utilization	Thermal discharge Nitrogen oxides			

Environmental Impacts of 1,000-Megawatt Electric Energy Systems Operating at a 0.75 Load Factor With Low Levels of Environmental Controls or With Generally Prevailing Controls[1]

System		Air emissions			Water discharges				Solid waste			Land use		Occupational health		Potential for large-scale disaster
		Tons ($\times 10^3$)	Curies ($\times 10^3$)	Severity	Tons ($\times 10^3$)	Curies ($\times 10^3$)	Btu's ($\times 10^{12}$)	Severity	Tons ($\times 10^3$)	Curies ($\times 10^3$)	Severity	Acres ($\times 10^3$)	Severity	Deaths	Workdays lost ($\times 10^6$)	
Coal	Deep-mined	383	.....	5	7.33	.....	3.05	5	602	.....	3	29.4	3	4.00	8.77	Sudden subsidence in urban areas, mine accidents
	Surface-mined	383	.....	5	40.5	.....	3.05	5	3,267	.....	5	34.3	5	2.04	3.09	Landslides
Oil	Onshore	158.4	.....	3	5.99	.....	3.05	3	NA	.....	1	20.7	2	.35	3.61	Massive spill on land from blowout or pipeline rupture
	Offshore	158.4	.....	3	6.07	.....	3.05	4	NA	.....	1	17.8	1	.35	3.61	Massive spill on water from blowout or pipeline rupture
	Imports	70.6	.....	2	2.52	.....	3.05	4	NA	.....	1	17.4	1	.00	.69	Massive oil spill from tanker accident
Natural gas		24.1	.....	1	.81	.....	3.05	2	.....	.....	0	20.8	2	.20	1.09	Pipeline explosion
Nuclear		.....	480	1	21.3	2.68	5.20	3	2,620	1.4	4	19.1	2	.15	.27	Core meltdown, radiological health accidents

NA = Not available.

Severity rating key: 5 = serious, 4 = significant, 3 = moderate, 2 = small, 1 = negligible, 0 = none.

[1] See the Appendix for details.

3. Nuclear power plants

Nuclear power is now on its way to replace fossil fuels little by little and its share of total energy supply will go from about nothing in 1970 to about 21% in 2000, or about 52% of the total electricity production, which means the presence of some 3,200 large nuclear power plants around the world.[23] There has been, and still is, an intense debate over the safety and environmental impact of nuclear power plants, with three important issues not yet definitively settled down:

- the possibility of an accident with catastrophic consequences, or sabotage and stealing of fissible material.
- the question of storage of highly dangerous material in substantial

quantities for 6 to 10 centuries.

- the problem of maintaining very high competence and strict observation of standards of safety when thousands of nuclear plants will be operating.

The most probable kind of very grave accident would be a sudden loss of primary coolant water through the plugging of a cooling duct or pipe of a primary coolant system and resultant melt down of the fuel rods which would be followed then by a transfer of a substantial fraction of radioactive material into the environment causing the loss of several hundred lives and permanent contamination of an area of about 30 square miles. According to the Chairman of the Atomic Energy Commission, such an event has 10^{-6} chances to occur per reactor per year,[24] which means a probability similar to the one of an equal number of person being killed by a meteorite (see Table 8).[25]

TABLE 8

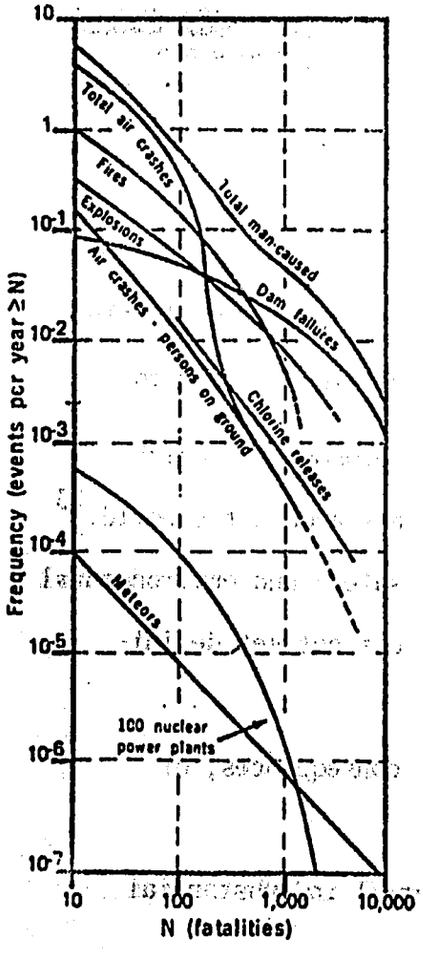


Chart adapted from AEC report compares the probability of accidents in nuclear plants with natural and other man-made disasters.

But it is suspected the limit concentration for plutonium not being dangerous might have been underestimated by a huge factor,[26] thus increasing the damage caused by an accident. Furthermore, the study substantiating the results about the probability of accidents,[27] a 2 year study which cost about $3 million, has been critically discussed by some scientists, including official agencies.[28] Concerning sabotage and irrational conduct, the question is: how many controls are enough? David Rose contends that "illegal use is the most worrisome and least resolved hazard."[29]

The nuclear waste disposal problem is another critical question. The wastes fall into two categories: the fission products, which are dangerous for about 7 centuries, and the

actinides (mainly Plutonium) which must be stored about 10,000 centuries. This second category can be eliminated either by keeping it in the reactor itself, or by using it as a fuel in the next generation of nuclear plants, which will need it. But the fission products, anyway, must be transported (with risks of accidents) and stored for centuries. As a 1000 Mw plant generates about 30 tons of such waste annually, one sees the problem is considerable,[30] and during each operation, small quantities of radioactive material are released into the environment, with quite unknown long term consequences.

Finally, nuclear power plants, operating at lower temperatures than fossil fuel plants, discharge into the environment, as waste heat, 70% of their total produced heat, or about 10,977 BTU per KWH,[31] which poses with even more acuity the problem of heating rivers and lakes.

But, provided that nuclear power plants do not generate almost any air or water pollutant, that the probability of accident is very small, the probability of sabotage uncomputable, as well as the probability of radioactive materials storage leaks, it has been computed that they are by very far less dangerous for the health than coal-burning power plants.[32]

Table 9 shows a summary of health effects of a nuclear power plant of 1000 Mw, in terms of injuries and fatalities for each step of the energy system.[33]

TABLE 9

Summary of health effects of civilian nuclear power, per 1000 Mw(e) plant-year

Activity	Fatalities			Injuries (days off)
	Accidents (not radiation-related	Radiation-related (cancers and genetic)	Total	
Uranium mining and milling	0.173	0.001	0.174	330.5
Fuel processing and reprocessing	0.048	0.040	0.088	5.6
Design and manufacture of reactors, instruments, and so on	0.040		0.040	24.4
Reactor operation and maintenance	0.037	0.107	0.144	158
Waste disposal		0.0003	0.0003	
Transport of nuclear fuel	0.036	0.010	0.046	
Totals	0.334	0.158	0.492	518

Table 10 gives a description of those effects.[34]

TABLE 10

	Energy from Nuclear Fuels–Potential Environmental Damage				
	Air	Water	Land	Solid Waste	Radiation
Exploration and Extraction		Waste banks leaching Uranium mine water	Strip mining effects	Underground mining wastes	Exposure to miners
Upgrading	Particulate emission	Waste banks leaching		Ore dressing waste	Exposure to plant workers
Transportation			Transmission lines		Possible accidents
Utilization	Radiation fallout	Thermal discharge		Waste disposal from fuel processing plants	Exposure during generation and disposal of wastes Possible accidents

And Table 11[35] shows the details of the impact, per step and per transmitting medium.

TABLE 11

Annual Environmental Impacts of a Light Water Reactor Nuclear Electricity System Associated With a 1,000-Megawatt Powerplant With a Load Factor of 0.75 and With Generally Prevailing Controls

Impact		Extraction [1]	Processing [2]	Transport	Conversion	Transmission	Total
Land	Acres	[3] 755	[4] 9.12	0	[5] 800	[6] 17,188	18,300
Water	Tons	[3] 20,400	[4] 42.9	0	[7] 813	0	21,256
	Curies	[3] 1.9	[4] 2,348	0	[8] 332	0	2,682
	Btu's	[3] nil	[4] 3×10^{13}	0	[8] 4.99×10^{13}	0	5.29×10^{13}
Air	Tons	[3] nil	[4] 6,192	[10] nil	0	0	6,192
	Curies	[3] 69.9	[4] 3.49×10^{3}	0	[11] 1.40×10^{3}	0	4.89×10^{3}
Solid or stored waste	Tons	[3] 2.62×10^{6}	[4] 58	0	[12] 0	0	2.62×10^{6}
	Curies	[3] 1,125	[13] 1.4×10^{3}	0	[14] 31,500	0	1.4×10^{3}
Occupational health	Deaths	[15] .09	[16] .048	[16] .002	[16] .013	NA	.153
	Injuries	[15] 3.45	[16] .568	[16] .045	[16] 1.31	NA	5.37
	Workdays lost	[15] 208	[16] 34.3	[16] 2.7	[16] 25.6	NA	270.6

NA=Not available.

[1] Includes mining and milling operations and is based on a 0.75 powerplant load factor. Does not include effects of electric power consumed.

[2] Processing includes UF_6 production, enrichment, fabrication, reprocessing, and waste management. Includes impacts of coal-fired electricity production for the enrichment process.

[3] Developed from U.S. Atomic Energy Commission. Directorate of Licensing, Fuels and Materials. November 1972. *Environmental Survey of the Nuclear Fuel Cycle.* Washington, D.C.: A.E.C., Tables A-1 and B 1. Ten percent solids is assumed.

[4] *Ibid.*, Tables C-1, D-1, E-1, F-1, pp. C-3, C-4, D-3, D-4, E-2, F-1, F-25, G-3, G-9, G-10, G-17, G-18.

[5] Executive Office of the President, Office of Science and Technology, Energy Policy Staff. 1968. *Considerations Affecting Steam Power Plant Site Selection.* Washington, D.C.: Government Printing Office, p. 11. Note that acreage is based primarily on nuclear reactor exclusion area rather than on facility size.

[6] See Table A-2, note 8.

[7] See Table A-2, note 11.

[8] Derived from data in Tennessee Valley Authority. May 1971. *Draft Environmental Statement for Watts Bar Nuclear Plant, Units 1 and 2.* Knoxville, Tenn.: T.V.A.; U.S. Atomic Energy Commission. 1971. *Final Safety Analysis Report, Donald C. Cook Nuclear Plant, Indiana and Michigan Electric Company.* Washington, D.C.: A.E.C., Volume 4, Section 11.1.3; U.S. Atomic Energy Commission. November 25, 1970. *Final Safety Analysis Report, Zion Nuclear Plant, Commonwealth Edison.* Washington, D.C.: A.E.C., Volume VI, Appendix 14A; U.S. Atomic Energy Commission. November 16, 1970. *Environmental Report for Quad Cities Units 1 and 2.* Washington, D.C.: A.E.C., AEC Dockets 50-254 and 50-265; Battelle-Columbus Laboratories. November 1971. *Environmental Impact Assessment: Supplemental Information to the Quad Cities Environmental Report,* and supplements, prepared for Commonwealth Edison Company. Columbus, Ohio: Battelle; U.S. Atomic Energy Commission. 1968. *Quad Cities Safety Analysis Report.* Washington, D.C.: A.E.C., Volume II, Section 9, Radioactive Waste System; and testimony of James M. Smith, General Electric Co., before the Illinois Pollution Control Board, May 24, 1971, PCB 71-20.

[9] See Table A-10, note 5.

[10] Based on 47,000 miles of trucking. *Environmental Survey of the Nuclear Fuel Cycle, op. cit.*, Table H-1, p. H-3; and U.S. Environmental Protection Agency, Office of Air Programs. February 1972. *Compilation of Air Pollutant Emission Factors.* Washington, D.C.: Government Printing Office, Table 3-2.

[11] *Environmental Survey of the Nuclear Fuel Cycle, op. cit.*, p. F-5, based on data in Oak Ridge National Laboratory. July 1971. *Siting of Fuel Reprocessing Plants and Waste Management Facilities* (ORNL-4451). Oak Ridge, Tenn.: O.R.N.L.

[12] Considered as part of waste management. See note 4.

[13] See note 11.

[14] The gross radioactivity of all surface burial of radioactive wastes for nuclear powerplants in 1970 was 101,565 curies, calculated assuming no escape of radioactive materials to the water or air environment. *Ibid.* Nuclear powerplants generated 21.8 billion kilowatt-hours in 1970. Federal Power Commission. 1972. *Annual Report—1971.* Washington, D.C. Government Printing Office, p. 11.

[15] U.S. Atomic Energy Commission. December 1972. *The Safety of Nuclear Power Reactors (Light Water-Cooled) and Related Facilities.* Draft. Washington, D.C.: A.E.C., pp. 6-25, 6-26. Workdays lost per stage are based on the nonfatal accident rates and total workdays lost for the system.

[16] See note 15.

THIRD PART: CONTROL OF ENERGY SYSTEMS' ENVIRONMENTAL IMPACTS

To reduce the environmental impact of energy systems, there are three types of possible directions, complementary in space and time:

- to use less energy, or rather, to reduce the projected consumption levels rate of increase
- to reduce the environmental impact per BTU produced by input modification, technological improvements or various residual control devices; in short - amelioration of the existing systems.
- to introduce totally new technologies for producing energy.

We will successively discuss these three types of strategies.

1. Energy conservation

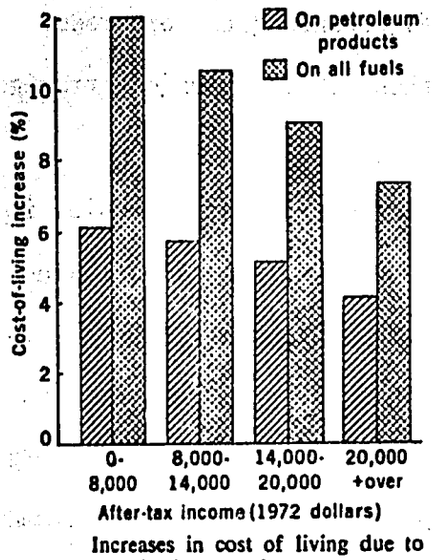
In a very short term, a crisis period for example, it is possible to decrease the energy consumption by some form of rationing of energy distribution. This cannot be considered as a general strategy for the long term, and we will discuss here the ways in which pricing, taxation and regulatory measures can bring an overall more efficient use of energy through technological improvements, changing patterns of the firms' and consumers' behavior, and evolution of the life style in the long run.

A simple idea which is often argued for is to price energy at its real, social cost; that is, including all external costs borne by society, due to environmental impact. To the actual cost we would add: the dollar cost of pollution related illnesses in terms of medical and loss of work costs, loss of commercial fishing resources due to thermal pollution, loss of recreational land and water, cost of relocating housing and industry due to air pollution.

But an "across the board" price increase would be very inefficient though because the social cost of energy depends on its form, its time of demand and other factors, and one could imagine a taxation of petroleum products only,

because, in the long run, they are the most scarce resources and most environmentally dangerous, or tax peak-hours use of energy. This new pricing policy should be designed carefully to be efficient, and to be equitable because as shown in Table 12,[37] a tax on energy is very regressive. The interest of such policy is that, coupled with appropriate regulations, incentives, national research programs, it will bring the technological changes, evolution of consumers' behavior and life pattern which will increase the efficiency of use of energy.

TABLE 12



Increases in cost of living due to energy taxes by income class.

Let us discuss more in detail some of those changes.

1.1 Energy conservation by increased thermal performance of structure.

Space heating can need 20 to 30% less energy with adequate insulation or buildings, new standards for air conditioning and ventilation. Furthermore, municipal waste could be burned in power plant boilers along with coal, further reducing fossil fuels requirements for space heating.

1.2 Thermal effectiveness of industrial processes.[38]

It has been computed that a very substantial fraction of the amount used in the industry can be saved by applying the already developed conservation

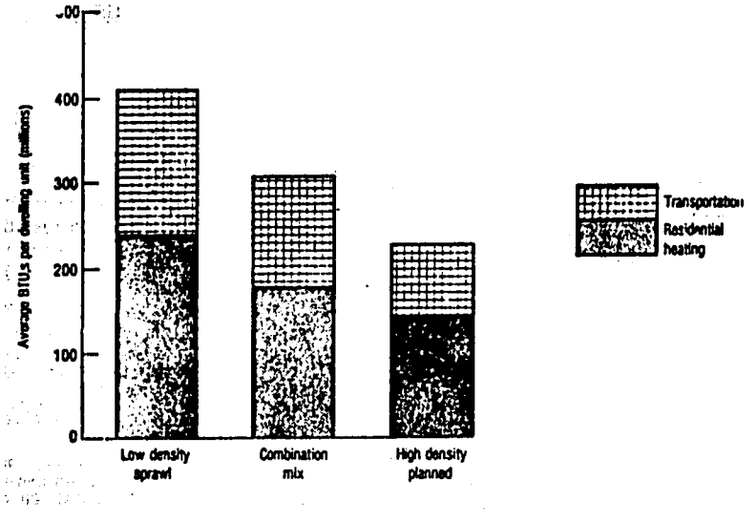
techniques of industrial processes. Furthermore, heat transfer and combustion techniques, waste heat management devices, vacuum insulation principles have been applied to improve equipment design, and new methods for the systematic use of waste heat in plants can yield further energy savings. Actually, the major industrial sectors have all achieved a general decline in energy used per unit of output over the last decade in the US

1.3 Effective use of energy in transportation.

As we have seen in Table 1, enormous differences exist in the energy effectiveness of different transportation modes, from 22 passengers-mile per gallon in a plane, to 200 in a train. Recently, the general shift to the individual automobile has decreased the efficiency of use of transportation and it is urgent to develop mass transit systems, which would probably in turn favor more dense construction patterns of cities and suburbs, which have been proved more energy efficient than low density housing. (See Table 13.)[39]

TABLE 13

Community Cost Analysis
Annual Energy Consumption



This long term type of evolution is an element of what can be called the adaptation of man's life pattern to the needs of energy conservation. Mass transit needs a lot more research and capital investment over the next years.

1.4 Efficient electric power generation.

Over the past 25 years, efficiency in electricity generation has increased by more than 30%, to reach 38 to 40% in modern power plants, and, for the next decade or two, the prospects for significant improvements in overall efficiency of steam electric power plants are not good, because the materials capable of handling higher temperature and pressure have not yet been developed. The most promising approaches lie in changes like advanced power cycles (coal gasification with a gas turbine, steam, turbine power plant), magneto hydrodynamics (direct conversion of heat into electricity) and breeder nuclear reactor.

Tables 14a, b, and c[40] show that total system efficiency for coal, oil and nuclear electricity generating plants is between 15 to 35% of the theoretical energy potential, and it has been argued electricity was an inefficient way of using energy.[41] In fact, direct fuel use would be done by small units which are very difficult to control in terms of pollution and energy efficiency. Furthermore, energy distribution being more efficient in the case of electricity, on total it is not clear that electric power generation and distribution is a wasteful form of energy use.[42]

TABLE 14c

Component Efficiencies of a Light Water Reactor Nuclear Electricity System

[In percent]

	Extraction	Processing	Transport	Conversion	Transmission	System [1]
Resource recovered	[2] 95.0	[3] 62.2	[4] 100.0	[5] 31.0	[6] 91.2	16.7
Energy input	[7] .4	[3] 5.2	0	0	0	.....
Component net efficiency	94.6	57.0	100.0	31.0	91.2	16.3

[1] See Table A-1, note 1.
[2] Extraction includes mining and milling. Mining recovery is assumed to be 100 percent. Milling recovers 95 percent of the resource. U.S. Senate, Committee on Interior and Insular Affairs. 1972. *Conservation of Energy*. Serial No. 92-18. Washington, D.C.: Government Printing Office, p. 25.
[3] Processing includes conversion, enrichment, fabrication, and reprocessing. Resource loss in conversion is based on Kerr-McGee data as conveyed to the Council by Seymour Smiley, U.S. Atomic Energy Commission. Enrichment, fabrication, and reprocessing losses and energy inputs are determined from *Conservation of Energy, op. cit.*, p. 8-6. Energy inputs are from *ibid.*, pp. C-3, D-3, E-2, F-2.
[4] Based on 47,000 miles of trucking. *Ibid.*, Table H-1, p. H-3. At 5 miles per gallon, the consumption is 9,400 gallons, or 224 barrels, capable of producing less than 160 thousand kilowatt-hours.
[5] A 31 percent powerplant efficiency is assumed. Federal Power Commission. 1971. *The 1970 National Power Survey*. Part I. Washington, D.C.: Government Printing Office, p. I-1-25.
[6] See Table A-1, note 8.
[7] Energy input is from U.S. Atomic Energy Commission, Directorate of Licensing, Fuels and Materials. 1972. *Environmental Survey of the Nuclear Fuel Cycle*. Washington, D.C.: A.E.C., pp. A-3, B-3.

Component Efficiencies of Oil-Fired Electricity Systems

[In percent]

	Extraction		Processing [1]	Transport			Conversion	Transmission	System [2]		
	On-shore	Off-shore		On-shore	Off-shore	Import			On-shore	Off-shore	Import
Resource recovered [3]	[4] 30	[4] 40	[5] 97.8	[6] 99.9	[6] 99.9	[6] 99.9	[7] 38	[8] 91.2	10.2	13.5	34.6
Energy input [9]	[10] .15	[10] .2	[11] 10.0	[12] 1.8	[12] 1.8	[12] 2.1	0	0	.....	.....	.....
Component net efficiency [13]	29.9	39.8	37.8	98.1	98.1	97.8	38	91.2	9.8	12.9	33.9

[1] To determine the impacts of refineries attributable to residual oil production for electricity generation, a model is developed of a refinery complex consisting of topping and cracking stages and producing at the same percentage as the national average for oil products.

[2] See Table A-1, note 1.

[3] Percent of energy value of oil energy entering each component which remains after that component.

[4] Approximate percentages of known oil deposits which are considered recoverable. National Petroleum Council. 1972. *An Initial Appraisal by the Oil Supply Task Group. 1971-1985.* Washington, D.C.: N.P.C., p. 45. Note also that there is a resource loss of about 0.019 percent associated with incomplete separation of oil and brine and with spills, based on brine production of 2.7 barrels brine per barrel of crude oil. National Petroleum Council. 1972. *Environmental Conservation: The Oil and Gas Industries.* Volume Two. Washington, D.C.: N.P.C., p. 147. Also based on 0.005 percent oil content in the brine, the Federal regulation applying to offshore drilling. U.S. Department of the Interior, Bureau of Land Management. 1972. *Final Environmental Statement—Proposed 1972 Outer Continental Shelf Oil and Gas General Lease Sale, Offshore Eastern Louisiana.* Washington, D.C.: D.O.I., pp. 132-34.

[5] This refinery produces the following mix: residual fuel oil at 0.0600 barrel per barrel input and other products, 0.9705 barrel per barrel input. U.S. Department of the Interior, Bureau of Mines. December 1971. *Mineral Industry Surveys: Crude Petroleum, Petroleum Products, and Natural-Gas-Liquids: 1970 (Final Summary).* Pittsburgh: D.O.I., B.O.M., Table 14. All inputs and environmental impacts are then weighted by the British thermal unit values of the end products. In terms of British thermal unit values, residual fuel oil represents 6.65 percent of production. *Ibid.* British thermal unit values are taken from American Petroleum Institute. 1971. *Petroleum Facts and Figures—1971 Edition.* Washington, D.C.: A.P.I., p. 589. In terms of volume, therefore, 0.0665 barrels of crude input is attributed to production of 0.0600 barrels of residual fuel oil, a 90.2 percent recovery. In terms of British thermal unit value, however, this is a 97.8 percent recovery.

[6] For prerefinery transport (domestic), assume all oil is transported by pipeline. Approximately 0.0[illegible] percent of the oil transported is lost in spills. *Environmental Conservation: The Oil and Gas Industries.* Volume Two. *op. cit.*, p. 200. For postrefinery transport (domestic and imported), it is assumed that all domestic oil is shipped by barge, all imports by tanker. Barges lose approximately 0.028 percent of their oil in discharges, leaks, and spills; tankers lose 0.11 percent. Porricelli, Joseph D., Keith-Virgil F., and Richard L. Storch. "Tankers and the Ecology." *Transactions.* Vol. 79, 1971, pp. 170, 172, 175. It should be noted that oil as a source of energy for transport is considered an energy input rather than a resource loss.

[7] See Table A-1, note 7.

[8] See Table A-1, note 8.

[9] Expressed as percent of energy content of the oil (or electricity) entering each stage. Based on 5.80 million British thermal units per 42-gallon barrel of crude oil, 6.287 million British thermal units per barrel of residual fuel oil. *Petroleum Facts and Figures—1971 Edition, op. cit.*, p. 589.

[10] Data supplied by InterTechnology Corporation, Warrenton, Va. Pumping energy is 0.5 percent of energy output.

[11] *Mineral Industry Surveys: Crude Petroleum, Petroleum Products, and Natural-Gas-Liquids: 1970 (Final Summary), op. cit.*, Table 19.

[12] For prerefinery transport—0.23 percent (domestic only), *ibid.*; and energy input required for pipeline transport is approximately 450 British thermal units per ton-mile. Hirst, Eric. 1972. *Energy Consumption for Transportation in the U.S.* Oak Ridge, Tenn.: Oak Ridge National Laboratory, p. 5. An average length of movement of 200 miles is assumed. For postrefinery transport—1.58 percent (domestic); fuel oil consumption ton-miles, for a one-way trip. Rice, Richard A. "System Energy and Future Transportation." *Technology Review.* January 1972, p. 32. Fuel oil consumption for transport—1.86 percent (import) by a 50,000-ton tanker is taken at 1 gallon per 850 ton-miles. This is an average of two estimates: one (920) from *ibid.*, obtained by doubling the fuel consumption rate of a 100,000-ton tanker, the other (770) from *Compilation of Air Pollutant Emission Factors, op. cit.*, p. 3-11, by using the highest fuel consumption rate in the range given and assuming a 50,000-ton tanker. One-way trips of 1,000 miles for domestic oil and 2,000 miles for imported oil are assumed; fuel consumption is then doubled to account for the return trip. Conversion factors are 0.56 barrels per ton for crude (average between foreign and domestic); 6.01 barrels per ton for residual fuel oil. *Petroleum Facts and Figures—1971 Edition, op. cit.*, p. 588.

[13] Component net efficiency=(% resource recovered)−(% energy input).

TABLE 14a

Component Efficiencies of Coal-Fired Electricity Systems

[In percent]

	Extraction		Processing	Transport	Conversion	Transmission	System [1]	
	Deep	Surface					Deep	Surface
Resource recovered [2]	[3] 57	[4] 80	[5] 92.1	[6] 90	[7] 38	[8] 91.2	18.0	25.3
Energy input [9]	10.8	10.8	10.1	11.9	0	0	.....	.....
Component net efficiency [13]	56.2	79.2	92.0	98.1	38	91.2	17.8	24.9

[1] System efficiency is the output energy of the last component divided by the total energy input to the system, including external energy.

[2] Percent of energy value of coal energy entering each component which remains after that component.

[3] Lowrie, Raymond L. 1968. *Recovery Percentage of Bituminous Coal Deposits in the United States. Part I. Underground Mines.* Washington, D.C.: U.S. Department of the Interior, Bureau of Mines, p. 1.

[4] Averitt, Paul. 1970. *Stripping Coal Resources of the United States—January 1, 1970.* U.S. Department of the Interior, Geological Survey Bulletin 1322. Washington, D.C.: Government Printing Office, pp. 7-8.

[5] Total 1969 raw coal production and percentage of raw coal wet cleaned, dry (pneumatically) cleaned, and unprocessed are shown in Figure A-1. U.S. Department of the Interior, Bureau of Mines. 1971. *Minerals Yearbook—1969.* Washington, D.C.: Government Printing Office, pp. 309, 347, 348. Total raw coal production includes processing plant wastes. Processing removes approximately 12 percent of the British thermal unit value of the coal, based on Leonard, Joseph W., and David R. Mitchell, eds. 1968. *Coal Preparation.* New York: American Institute of Mining, Metallurgical and Petroleum Engineers, p. 5-32.

[6] Approximately 1 percent of the coal is blown away during transport unless it is wetted. Delson, Jerome K., and Richard J. Frankel. April 1972. "Residuals Management in the Coal-Energy Industry." Manuscript to be published by Resources for the Future, Inc. Washington, D.C.: R.F.F., p. IV-45.

A large new powerplant is assumed to have a heat rate of 9,000 British thermal units per kilowatt-hour, equivalent to a 38 percent conversion efficiency. The best plants have achieved around 8,530 to 8,900, whereas the national average is around 10,500. Federal Power Commission. 1972. *The 1970 National Power Survey.* Part I. Washington, D.C.: Government Printing Office, pp. 1-5-6, 1-5-7.

[8] Power sold divided by power produced, 1969. Federal Power Commission. 1972. *Annual Report—1971.* Washington, D.C.: Government Printing Office, pp. 11, 13.

[9] Expressed as percent of energy content of the coal (or electricity) entering each stage. Based on 11,630 British thermal units per pound of coal, the 1969 average for coal burned at powerplants. National Coal Association. 1972. *Steam-Electric Plant Factors, 1971 Edition.* Washington, D.C.: N.C.A., p. 107.

[10] Data supplied by InterTechnology Corporation, Warrenton, Va.

[11] Assumes all coal is shipped by rail for an average of 300 miles. Actual 1965 average distance is 297 miles. National Coal Association. 1970. *Bituminous Coal Facts—1970.* Washington, D.C.: N.C.A., p. 91. Two-hundred ton-miles of cargo movement requires approximately 1 gallon of fuel with an energy content of 136,000 British thermal units per gallon. Rice, Richard A. "System Energy as a Factor in Considering Future Transportation." A paper presented at the American Society of Mechanical Engineers Winter Annual Meeting, November 29-December 3, 1970.

[13] Component net efficiency=(% resource recovered)−(% energy input).

On total, the rate of growth of energy demand can easily be reduced, provided that, on the whole, there will still be a growth, unless the very basis of our technological society changes. Table 15 shows the short-term possible actions for energy conservation,[43] and Appendix B shows the details of the efficiency of various energy systems producing electric energy.[44]

TABLE 15

Some Selected Policy Options in Energy-Environment Conservation

Policy Options	Impact			Public	mplementation
	Environmental	Economic	Social- Political	Acceptability	Possibility
More emphasis on mass transit –Improve and expand service –Reduce fares or no fares –Improve arterial mass transit –Better feeder services, i.e., dial-a-bus –Exclusive bus lanes –Provide fringe parking –Controlled entry to downtown cores –Make parking expensive in downtown cores –Pedestrian only oriented clusters –Develop better and more convenient forms of mass transit	High	Medium to High	High	Medium	Medium
Improve intercity passenger and freight services –Improve and expand service and network –Provide fringe parking –Ban subsidy on short flights by long flights –Encourage containerization and piggy-backing –Develop new and better passenger and freight handling systems	Medium to High	Medium to High	Low to High	Medium to High	Medium
Improve transportation efficiency –Improve automobile efficiency, i.e., better engines and drive trains, low loss tires, improved engine tuning –Improve urban design –Selective registration taxes on size, power, ancillary equipment, attachments –Develop energy efficiency standards for transportation –Encourage research to develop non-petroleum engines, advanced propulsion systems, advanced traffic control systems, etc.	High	High	Medium	Medium	Medium
Improve insulation of buildings to reduce heat loss in winter and heat gain in summer –Make improved and increased insulation mandatory under CMHC regulations –Make arrangements for better caulking and double glazing windows –Reduce excessive window areas –Provide tax incentives for adding insulation	High	Medium	Medium	Medium	Medium
Increase energy prices to reduce demand and achieve better efficiency –Initiate inverse rate structure –Ensure 'normal' investment return –Borrow money for capital investment at the market rate –Include environmental and social costs in the price of energy –Impose taxes and regulations	High	v	Medium	Low	Medium
Shift heavy load to off-peak hours –Restructure rates –Ban or restrict heavy use of energy during peak hours	Medium	Low	Medium	Low	Low
Provide centralized and efficient heating and air conditioning system to serve a number of buildings	High	Low	Medium	High	Medium
Limit energy which can be consumed by each household and commercial building annually	Medium	Low	Low	Low	Low
Establish minimum efficiencies for air-conditioners, furnaces and other appliances	Medium	Medium	Medium	High	High
Establish more rational lighting standards for homes and offices	Medium	Medium	Medium	High	High
Increase recycling and reuse of materials and products	High	Medium	Medium	Very High	High
Provide economic incentive to upgrade inefficient processes and equipment	Medium	Medium	Low	Medium	Medium
Impose fuel and/or energy tax to generate revenue for research to develop environmentally clean sources of energy, and to improve efficiencies in generation and utilization of energy	Very High	Medium	High	Low (tax increase) Very High (R&D)	Medium
Develop public information and education program to promote efficient utilization of energy	High	Low	High	Very High	High

2. Direct reduction of the environmental impact.

2.1 Extraction, processing and transportation stages.

About coal mining, there are obvious improvements to be made for miners' safety and appropriate working conditions. In the case of strip mining, regulations can specify the state in which the stripped land must be left, which can be quite costly in capital and water resources. For oil extraction, further studies need to be done to assess the exact leaks of oil dangers of underwater drilling. Concerning the transportation of oil, some international agreements should provide better possibilities of controlling oil tankers' operations in the high sea when they wash their tanks. A legislation on the maximum authorized size of tankers could be thought of too, because no one knows what would happen if a tanker with 500,00 tons of crude oil sank near a coastal area. Ways of improving pipe-line transmission and electric distribution lines design and siting (including new technologies like cryogenic transmission lines, or underground lines) are under study.[45]

2.2 Utilization stage

At this stage, where the most important environmental impact occurs, there are basically two ways to proceed: clear up the input fuel or treat and remove the wastes at the output.

2.2.1 Treatment of input fuel

Petroleum has a very wide range of sulfur content and a very simple way to reduce SO_x emissions is to use low sulfur oil. But fuel oil with less than 0.3% sulfur costs 35% more than with 2% sulfur, and 20% more than with 1% sulfur. For coal, the problem is the same, and low sulfur coal is in increasingly short supply, with increasing costs. An important new perspective could be the gasification of coal which would provide a full desulfurization in the process and, provided that technology of electricity generating systems is adapted (combined cycle gas turbine), would allow too, higher thermal

efficiency. But it is still too early to assess the real competitivity of such systems.[46] The other pollutants cannot economically be handled so far by input treatment.

2.2.2 Treatment of emissions. (Mainly for electricity generating plants)

Particulate emissions can be controlled by cyclones (devices which force the gas stream in a circular motion, trapping particulates by gravity force), filtration methods, electrostatic precipitators which can remove up to 99% of the total amount but which are quite energy consuming (5% of the capacity of the power plant), and scrubbers, the most thoroughly studied system, which can control SO_2 as well (injection of lime into the boiler, which absorbs SO_2, and the reacted material is removed in a wet scrubber or removed by reacting to form calcium sulfates in a scrubbing tower). Several variants of the scrubber process have been studied,[47] but on the whole, as the National Academy of Engineering said, "commercially proven technology for control of sulfur oxides from combustion processes does not exist."[48] No system is really superior to the others, for particulate removal (see Table 16)[49] nor for gaseous pollutants control.

TABLE 16

ADVANTAGES AND DISADVANTAGES
OF PARTICULATE CONTROL DEVICES

Device	Advantages	Disadvantages
Cyclones	➤Low Initial Cost ➤Simplicity of Construction and Operation ➤Applicability Over Broad Range of Temperatures	➤Power Requirements May Increase Over Time ➤Relatively Low Maximum Efficiency ➤Inability to Remove Small Particles
Filters	➤High Efficiency at All Loads (bags)	➤High Maintenance Cost ➤Require Highly Controlled Operating Conditions ➤Large Space Requirement

TABLE 16 (continued)

Device	Advantages	Disadvantages
Electrostatic Precipitators	➤Low Operating Cost and Power Requirements ➤High Efficiency ➤Can Operate at High Temp.	➤Require Highly Controlled Operating Conditions ➤High Initial and Maintenance Costs ➤Large Space Requirement
Scrubbers	➤May be Used as Cooling Devices ➤By-product Recovery Possible ➤Removal of Both Gaseous Pollutants and Particulates Possible ➤High Efficiency ➤Applicability for Wide Range of Operating Parameter	➤High Initial Cost ➤High Operating Cost and Power Requirements ➤Subject to Operating Problems ➤Large Volume of Sludge is Produced

The average increase in electricity costs to consumers is expected to be about 3 to 6%, due to SO_2 and particulate removal. For nitrogen oxides control, very little is known and scrubbing methods do remove them along with sulfur oxides.

For dissipating waste heat, the best known process is simply to withdraw water from a lake, stream or river, pass it through the condenser and return it heated to the source. One can, too, dissipate the heat in the air using wet cooling towers which evaporate water into the atmosphere, or dry cooling towers which reject warm air. Both systems are expensive, are huge unaesthetic structures and in both cases the meterological effects of cooling the air are unknown. Another solution is to develop beneficial uses for this waste heat.

2.2.3 Land use considerations. (for power plants)

An important parameter in the minimization of environmental impact is the one of location. At macro level, it is the question of the distance of the plant to the load center and to its fuel inputs, and the trade-offs in costs and environmental impact which are implied. At micro level, it is the choice of a site within the chosen area, according to meteorological,

topographical, geological and existing land use elements.[50]

2.2.4 Possible results and costs (for power plants)

Various cost evaluations have been made which of course would have to be adapted to other countires, give at least an order of magnitude of the costs which are implied. Table 17[51] shows that for coal and oil plants cost increases would be of 30 to 35%, 70 to 80% for air pollution removal, and a 5% cost increase for nuclear and natural gas plants (because natural gas is already a clear fuel and nuclear plants major problems cannot be addressed with end-of-the-pipe devices.

TABLE 17

Cost of Controls and Changes in Environmental Impacts of 1,000-Megawatt Electric Energy Systems Operating at a 0.75 Load Factor With a High Level of Environmental Controls[1]

(in percent)

System		Air		Water[2]		Land		Solid waste[3]	Total cost increase[5]
		Tonnage change	Cost increase	Tonnage change	Cost increase	Acreage change[4]	Cost increase	Tonnage change	
Coal	Deep-mined	−81.3	23	−96.2	4	+1	0	+159	28
	Surface-mined	−81.3	23	−92.4	4	−37	4	+29	31
Oil[6]	Onshore	−73.0	31	−38.8	5	0	0	0	36
	Offshore	−73.0	31	−38.8	5	0	0	0	36
	Imports	−39.4	28	−77.2	5	0	0	0	34
Natural gas		0	0	0	5	0	0	0	5
Nuclear		[7] −29.8	1	0	4	0	0	0	5

[1] See the Appendix for details.
[2] Costs of cooling tower construction and operation are considered with water controls.
[3] Solid waste costs are included in air and water pollution controls.
[4] Land impacts are reduced by reclamation but are increased for solid waste disposal.
[5] The total percentage cost increase may differ from the sum of the media percentage cost increases because of rounding.
[6] In the case of oil-fired systems, price increases for desulfurized oil are the primary cost effect.
[7] Radioactive emissions from the nuclear system are reduced by controls at the powerplant.

The details of the calculus and pollution control devices are given in Appendix C,[52] which breaks down the figures. Table 18[53] gives the costs per step for the energy system: generation (table 18a), transmission (18b) distribution (18c), right of way (18d), and for anti-pollution device or element (18e).

TABLE 18a

. Increased Generating Costs Due to Environmental Control Expenditures

Steam electric generation	Cost per kw Fossil[a]	Nuclear[b]
	(-------dollars-------)	
1. Tall stack	4.00	2.00
2. SO_2 removal, minus credit	8.00	–
3. Advanced electrostatic precipitator	2.00	–
4. Wet cooling tower, induced draft	4.00	5.00
5. Wet cooling tower, natural draft	5.50	3.25
6. Dry cooling tower, minus credit	18.00	7.00
7. Noise suppression	0.50	–
8. Monitoring devices	0.50	0.50
9. Improved architectural design and landscaping	3.00	4.00
10. Intake and discharge structures, improved design	3.00	4.00
11. General improved design standards	2.00	8.00
	(------mills/kwh------)	
12. Higher-cost fuel[c]	0.510 0.864 1.125	–
13. Operating cost of monitoring devices	0.012	0.020
14. Increased research	0.050	0.050

NOTE: These costs apply to both new and old plants.

[a] 1,300 mw unit size.

TABLE 18b

. Summary of Increased Electric Power Transmission Costs, Reflecting Environmental Control Expenditures

	End of decade 1970–1980	1980–1990	1990–2000
1. Investment cost, new, no allowance for environmental costs (*$/kw*)	68.00	53.30	45.50
2. Investment cost, weighted new and old, no allowance for environmental costs (*$/kw*)	74.00	65.20	57.80
3. Environmental cost to modify old equipment (*$/kw*)	10.00	10.00	10.00
4. Environmental cost component of new equipment (*$/kw*)	7.80	8.00	8.53
5. Sum of lines 2, 3, and 4	91.80	83.20	76.33
6. Incremental cost (line 5 minus $80) (*$/kw*)	11.80	3.20	–3.67
7. Annual incremental capital charge (line 6 at 15%) (*$/kw*)	1.77	0.48	–0.55
8. Total incremental cost (*mills/kwh*)	0.331	0.090	–0.103

NOTES: These calculations apply to a system having a 1970 peak of 10,000 mw and a net utility plant (original cost minus depreciation reserve) of $325/kw of maximum demand, and consisting of the following costs: generation, $140; transmission, $80; distribution, $85; miscellaneous, $20.

These judgments and calculations of the author are based in part on the following assumptions and considerations, each of which relates to the corresponding line in the table.

(1) New investment cost shown in line 1 declines by approximately 33 percent every 20 years due to technological improvement (including higher voltages).

(2) Demand doubles in the first decade, increases 75 percent in the second decade, and increases 60 percent in the third decade.

(3) Modification of old plant, shown in line 3, is based on the following estimated costs:

$1.33/kw/year in first decade
$0.55/kw/year in second decade
$0.46/kw/year in third decade

(4) Environmental cost of new equipment, shown in line 4, assumes the following increments to new equipment costs:

20 percent in first decade
35 percent in second decade
50 percent in third decade

(6) Calculated as the difference from new investment cost in 1970.

(8) Based on 5,350 hours per year. Note that the figures in this line reflect the combined effect of changes in power costs arising from environmental factors, on the one hand, offset to a limited extent by assumed technological improvements–hence reduced real costs–in transmission, on the other.

TABLE 18c

Summary of Increased Electric Power Distribution Costs, Reflecting Environmental Control Expenditures

	End of decade		
	1970-1980	1980-1990	1990-2000
1. Investment cost, new, no allowance for environmental costs (*$/kw*)	79.05	73.52	68.37
2. Investment cost, weighted new and old, no allowance for environmental costs (*$/kw*)	82.03	78.50	74.50
3. Environmental cost to modify old equipment (*$/kw*)	10.00	10.00	10.00
4. Environmental cost component of new equipment (*$/kw*)	13.84	14.20	14.10
5. Sum of lines 2, 3, and 4	105.87	102.70	98.60
6. Incremental cost (line 5 minus $85) (*$/kw*)	20.87	17.70	13.60
7. Annual incremental capital charge (line 6 at 15%) (*$/kw*)	3.13	2.65	2.04
8. Total incremental cost (*mills/kwh*)	0.585	0.495	0.381

NOTES: System characteristics are described in note to table 4a.

These judgments and calculations of the author are based in part on the following assumptions and considerations, each of which relates to the corresponding line in the table.

(1) New investment cost shown in line 1 declines by 7 percent every 10 years due to technological improvements (including higher distribution voltages).

(2) Demand doubles in the first decade, increases 75 percent in the second decade, and increases 60 percent in the third decade.

(3) Modification of old plant, shown in line 3, is based on the following estimated costs:

$1.33/kw/year in first decade
$0.55/kw/year in second decade
$0.46/kw/year in third decade

(4) Environmental cost of new equipment, shown in line 4, assumes following increments to new equipment costs:

35 percent in first decade
45 percent in second decade
55 percent in third decade

(6) Calculated as the difference from new investment cost in 1970.

(8) Based on 5,350 hours per year. Note that the figures in this line reflect the combined effect of changes in power costs arising from environmental factors, on the one hand, offset to a limited extent by assumed technological improvements—hence reduced real costs—in distribution, on the other.

TABLE 18d

Summary of Increased Costs of Rights-of-Way and Public Information due to Environmental Control Expenditures

	End of decade		
	1970-1980	1980-1990	1990-2000
Incremental costs (*mills/kwh*) for:			
1. Rights-of-way	0.017	0.017	0.017
2. Public information	0.020	0.020	0.020
Total	0.037	0.037	0.037

NOTES: The distinguishing characteristics of rights-of-way and public information components of electricity costs should be noted: a rights-of-way cost can be amortized over a period of years, while a public information charge cannot be amortized and has to be charged off in the year it is made.

Data on system characteristics, capital charge, and load factor appear in Table 4a.

These judgments and calculations of the author are based in part on the following assumptions and considerations, each of which relates to the corresponding line in the table.

(1) The calculation for the first decadal interval is based on a total system rights-of-way cost of $9 million per year, which reduces to an average of $0.60/kw/year or 0.017 mills/kwh. The estimates for the succeeding two decades were computed so as to equalize costs with the first decade.

(2) Based on a system public information cost during the first decade of $1.5 million per year, which reduces to $0.10/kw/year or 0.020 mills/kwh. Succeeding decades estimated as in line 1.

TABLE 18e

Summary of Total Increases in the Cost of Electric Power, Reflecting Environmental Control Expenditures

(mills/kwh)

	End of decade		
	1970-1980	1980-1990	1990-2000
1. Generation:			
Fossil fueled	0.791	1.249	1.547
Nuclear fueled	0.218	0.419	0.461
2. Transmission	0.331	0.090	0.103
3. Distribution	0.585	0.495	0.381
4. Miscellaneous (rights-of-way and public information)	0.037	0.037	0.037
Subtotal	1.962	2.290	2.323
5. Factor of ignorance (25 percent)	0.491	0.573	0.581
Total of above	2.453	2.863	2.904
Total (rounded)	2.50	2.90	3.00

3. New energy systems

There are many techniques under development for exploiting new energy resources, improving the efficiency of use of those already developed, and for reducing the environmental impact. Those which seem to offer the greatest promises for the short term include tapping geothermal energy and oil shale, gasifying coal and developing several advanced nuclear power systems. Long term promising technologies are nuclear fusion and solar energy, which hold promise of significantly freeing us from reliance on earth's limited fossil and nuclear fuel resources and whose environmental impact may be substantially less than alternative technologies.

Geothermal steam or superheated water is produced when the earth's heat energy is transferred to surface waters. When the pressure and temperature are adequate, the steam may be used in turbines for conversion of electricity. Exploitable sites have been developed in Japan, Italy, Iceland, New Zealand, and other places, but generally this energy resource is not economic. Few surveys of geothermical resources have been made so that it is impossible to assess the real potential of this new source. But it is probable that the environmental impact would be significant, since noxious gases are discharged with the water, which too is very loaded in salts: the temperature not being

very high. the system would not be very efficient, and a large amount of waste heat would be discharged. Exploitation of thermal energy of the terrestrial magma is a longer term possibility which feasibility is still unpredictable.

Oil shale containing more than 25 gallons of petroleum per ton of shal do exist in many parts of the world in huge amounts, and the technological framework considered applicable to commercial oil shale applications using surface mining techniques, is accurately developed. The problem is that very large surfaces of land would be disrupted, and large amounts of solid residual generated, with significant discharges of hydrogen sulfide.[54] Large amounts of water would be needed for shale oil upgrading.

In the nuclear area, there are too, potential developments, and in particular the Liquid Metal Fast Breeder Reactor (LMFBR) which is given to priority in research, and may become available for commercial application in the late 1980's. The specific feature of these reactors is that they produce more nuclear fuel than they consume, and are able to use 60% of the total energy of Uranium as opposed to 2% for the actual reactors, thus drastically diminishing the fuel needs. They will produce less waste heat, less radioactivity in the air, no (or almost no) Uranium mining and enrichment, but they will oblige the shipment, handling and management of fission products of much greater radioactivity, produced in ever increasing quantities, remaining highl dangerous practically forever (plutonium). Despite the potential problems the LMFBR holds promise as a relatively clean source of energy with a fuel supply that would last for centures.

A longer term possibility is the controlled thermo nuclear fusion: under extreme condition the nuclei of deuterium can fuse to make a heavier element releasing enormous quantities of energy which can then be converted in an almost infinite source of energy, since deuterium can be extracted at low cos from the sea. But the temperature needed for fusion is more than 100 millior

degrees, and the fusion has to be contained somehow in a magnetic field which would be used to convert the energy into electricity directly too. The technological and economic problems are great, a demonstration fusion power system might be built before the end of the century. The translation in an economical system would require many more billions of dollars and years of effort.

It has been quite long since it is known how to power an engine by solar energy or heat water. But it remains to show that the solar heat collecting devices are economic, and the geographical location is always a crucial factor. Solar cell converting solar energy directly into electricity need to be ameliorated to have better efficiency and be built at relatively low cost. Owing to the highly unfavorable economics of the solar cell produced electricit it is quite unlikely that solar energy will become anything else than a support energy for individual or very local purposes for many years.

CONCLUSION

The attainment of a sensible trade-off between energy growth and the environment is seriously hampered at present at the energy stage of analysis and decision making by ignorance, by lack of knowledge of the effects of various discharges in land, air and water, by the relative unavailability of economic methodologies to determine the value society puts on incremental improvements or worsening of environmental parameters due to different levels of pollution or to determine how regulations to curb pollution would affect prices, employment or location of different industries. We might take decision which may create irreversible enrivonmental damages or sacrifice acceptable development due to unreasonable or unnecessary environmental regulations.

But the problem is not only one for technicians, scientists, economists or administrators. It is ultimately a question of finding out what the people want and if what they want is feasible within technological, economic and administrative limits. And the ultimate answer can only be found in the political arena.

Finally, we can recall the UN Stockholm Conference on the human environment (1972) which declared that "it is essential to consider multiple choices in the planning and management of any energy economy" and adopted the following recommendation: "each nation should set up a national energy board to coordinate energy developments and utilization policies, staffed with highly qualified personnel, including some in the discipline relating to the adverse environmental effects of energy" that would already be, if implemented, a serious reason for hoping once again the genius of man will make him find his way to much higher degrees of human development.

FOOTNOTES

[1] See Gordon J. McDonald, "Energy and the Environment," in Sam Schurr, ed., Energy, Growth and the Environment, Johns Hopkins University press, 1973, p. 102.

[2] Source: Council on Environmental Quality, Washington, D.C., Energy and the Environment, Electric Power, August 1973, p. 4.

[3] For this discussion on energy consumption, see: Joel Darmstadter, "Energy Consumption," in Sam Schurr, ed., op. cit., p. 176.

[4] See J.S. Steinhart, "Energy use in the US Food System," in Science, 19 April 1974, pp. 307-316 *and*
E. Hirst, "Food Related Energy Requirements." in Science, 12 April 1974, pp. 134-138.

[5] Council on Environmental Quality, Environmental Quality, First Annual Report, 1970, p. 159.

[6] Naylor, T., International Journal of Agrarian Affairs, Oct. 1963.

[7] Source: Asit K. Biswas, Energy and the Environment, Planning and Finance Service, Report no. 1, Canada, 1973, p. 13.

[8] From Joel Darmstadter, op. cit., p. 206

[9] U.S. Department of the Interior, Surface Mining and our Environment, Washington, D.C., 1967, p. 117.

[10] Council on Environmental Quality, Environmental Quality, First Report, 1967, p. 107.

[11] Source: Asit K. Biswas, op. cit., p. 14.

[12] Joel Darmstadter, op. cit., p. 206.

[13] Ford Foundation Report, Time to Choose, 1974, Ballinger Publishing Co., p. 190.

[14] Source: OECD, Energy and the Environment, Paris, 1974, p. 45.

[15] Council on Environmental Quality, op. cit., p. 11.

[16] U.S. Health, Education and Welfare Department, Preliminary Air Pollution Survey of Vanadium, Raleigh, N.C., 1969, p. 29.

[17] Lave and Seskin, "Air Pollution and Human Health," Science, 1970, pp. 723-753.

[18] Source: Gordon J. McDonald. "Energy and the Environment" in Sam Schurr, ed., op. cit., p. 108.

[19] Federal Power Commission, Steam Electric Plant Construction Costs and Annual Production Expenses, 23rd Annual Supplement, 1970, p. xxxi.

[0] Source: Asit K. Biswas, op. cit., p. 18.

[21] Source: Council on Environmental Quality, Energy and the Environment, Electric Power, p. 14.

[22] Ibid, pp. 42, 43, 48, 49.

[23] Joel Darmstadter, op. cit., p. 216.

[24] David J. Rose, "Nuclear Electric Power," Science, 19 April, 1974, p. 355.

[25] "Nuclear Safety; Calculating the Odds of Disaster," Science, 6 Sept. 1974, p. 838.

[26] See A. R. Tamplin and T. B. Cochrane, Radiation Standards for Hot Particles, Natural Resources Defense Council, Washington, D.C., 1974, and D. J. Rose, op. cit.

[27] National Technical Information Service, An Assessment of Accident Risks in US Commercial Nuclear Power Plants, Washington, D.C., Atomic Energy Commission, August 1974.

[28] "EPA Cites Errors in AEC's Reactor Risk Study," Science, 13 Dec. 1974, p. 1008.

[29] David Rose, op. cit., p. 355.

[30] D.J. Rose and A.S. Kubo, Science, Vol. 182, p. 1205 (1973).

[31] OECD, op. cit., p. 46.

[32] C.B. Lave and L.C. Freeburg, Nuclear Safety, Vol. 14, p. 409 (1973) and C. Starr et.al., Nuclear News, Vol. 15, p. 37, (1972).

[33] Source: D.J. Rose, op. cit., p. 354.

[34] Source: Asit K. Biswas, op. cit., p. 10.

[35] Source: CEQ, Energy and the Environment, Electric Power, p. 57.

[36] See Neil Fabricant and Robert M. Hallmann, Towards a Rational Power Policy, Georges Brazillier, New York, 1971, p. 186.

[37] Source: Anna P. Carter, "Application of Input-Output Analysis to Energy Problems," Science, 19 April 1974, p. 329.

[38] See Charles A. Berg, "Energy Conservation through Effective Utilization," Science, 13 July 1973, p. 132, and G. A. Lincoln, "Energy Conservation," Science, 13 April, 1973, p. 157.

[39] Source: Council on Environmental Quality, Fifth Annual Report, 1974, p. 17.

[40] CEQ, Energy and Environment, op. cit., p. 40, 46, 55.

[41] N. Fabricant, op. cit., p. 77.

[42] G.A. Lincoln, op. cit., p. 160.

[43] Source: Asit K. Biswas, op. cit., p. 37.

[44] Source: Council on Environmental Qaulity, Energy and the Environment, pp. 41, 47, 56.

[45] Charles J. Cichetti, Alaskan Oil, Resources for the Future, Johns Hopkins University Press, 1972.

[46] A.M. Squires, "Clean Fuels from Coal Gasification," Science, 19 April, 1974, p. 340.

[47] J.T. Dunham, "High Sulfur Coal for Generating Electricity," Science, 19 April, 1974, p. 346.

[48] National Academy of Engineering, National Research Council, Abatement of Sulfur Oxides Emissions from Stationnary Combusion Sources, NTIS, Springfield, Va., 1970.

[49] Source: Ralph Stone & Co., Inc., Decision Maker's Guidebook for Industria Pollution Control, Feb. 1975, p. IV-6.

[50] Ralph Stone and Co., Inc., op. cit.

[51] Source: Council on Environmental Quality, op. cit., p. 19.

[52] Source: ibid, pp. 44-45, 50-51, 58.

[53] Source: Philip Sporn, "On Energy Growth and the Environment," in Sam Schurr, ed., op. cit., pp. 82-87.

[54] U.S. Department of the Interior, Draft Environmental Statement for the Proposed Oil Shale Leasing Program, Washington, D.C.

APPENDIX A

Annual Environmental Impacts of Uncontrolled Coal-Fired Electricity Systems Associated With a 1,000-Megawatt Powerplant With a Load Factor of 0.75

Impact		Extraction		Processing	Transport [1]	Conversion	Transmission	Total	
		Deep	Surface					Deep	Surface
Land [2]	Acres	[3] 9,120	[4] 14,010	[5] 161	[6] 2,213	[7] 696	[8] 17,188	29,378	34,268
Water	Tons	[9] 2,661	[9] 35,820	[10] 3,853	0	[11] 813	0	7,327	40,486
	Btu's	0	0	0	0	[12] 3.05×10^{13}	0	3.05×10^{13}	3.05×10^{13}
Air	Tons	[13] NA	[13] NA	[14] 4,714	[15] 26,270	[16] 352,217	0	383,201	383,201
Solid waste	Tons	[17] 97,141	[17] 2,762,000	[18] 454,092	0	[19] 50,800	0	602,033	3,266,892
Occupational health	Deaths	[20] 1.67	[20] 0.308	[21] 0.0238	[22] 2.30	[23] 0.012	NA	4.00	2.64
	Injuries	[20] 85	[20] 13.9	[21] 2.56	[22] 23.4	[23] 1.38	NA	112.3	41.2
	Workdays lost	[20] [24] 12,688	[20] 499	[21] 99.5	[22] 2,340	[23] 152.9	NA	15,280	3,091

NA=Not available.

[1] Impacts of coal transport are based on coal transport exclusively by rail for an average distance of 300 miles. See Table A-1, note 11. Annual coal transport for a 1,000-MWe powerplant is 0.10 percent of the total 1970 national ton-mileage. Transportation Association of America. July 1972. *Transportation Facts and Trends, Ninth Edition.* Washington, D.C.: T.A.A., p. 8.

[2] All land impacts are expressed as a time average of the amount of land in use over 30 years. Fixed land use is therefore taken as its full amount; average variable use is 15 times the annual incremental damage.

[3] Annual incremental land impact is 608 acres, including 607 acres affected by subsidence and less than 1 acre for storage of solid wastes. The subsidence rate is 0.1 acre per 500 tons produced. Delson, Jerome K. and Richard J. Frankel. April 1972. "Residuals Management in the Coal-Energy Industry." Manuscript to be published by Resources for the Future, Inc. Washington, D.C.: R.F.F., p. II-2a. The land disturbed by storage of underground mining wastes is based on a land use rate of 84,4[illegible] tons of waste per acre of waste bank. McNay, Lewis N. 1971. *Coal Refuse: [illegible] Environmental Hazard.* U.S. Department of the Interior, Bureau of Mines. Washington, D.C.: Government Printing Office, pp. 1, 5. This figure corresponds to waste banks averaging 35 feet high, assuming a density of 1.5 tons per cubic yard for the refuse. See note 17 for a discussion of tonnage produced.

[4] Annual incremental land impact is 934 acres. Derived from 308 acres per million tons mined. U.S. Bureau of Mines data for 1969. U.S. Senate Committee on Interior and Insular Affairs. December 1971. *The Issues Related to Surface Mining.* Serial No. 92-10. Washington, D.C.: Government Printing Office, p. 2.

[5] Fixed land use is 80 acres and annual incremental land use is 5.4 acres. For fixed land use, it is assumed that one processing plant is required for every million tons of raw coal processed. Based on data in U.S. Department of the Interior, Bureau of Mines. 1971. *Minerals Yearbook—1969.* Washington, D.C.: Government Printing Office, p. 347. Each processing plant is assumed to occupy 40 acres. See notes 3 and 18 for a discussion of the acreage affected by solid wastes.

[6] Total railroad track in 1969 was 365,000 miles. U.S. Bureau of the Census. 1971. *Statistical Abstract of the United States: 1971.* Washington, D.C.: Government Printing Office, p. 545. A right-of-way of 50 feet is assumed. Total land utilized is then multiplied by .0010. See note 1.

[7] Typical plant size for 3,000-MWe plants with fly ash controls is 1,050 acres, including 350 for ash storage and 40 for coal storage. Executive Office of the President, Office of Science and Technology, Energy Policy Staff. 1968. *Considerations Affecting Steam Power Plant Site Selection.* Washington, D.C.: Government Printing Office, pp. 11, 14. Land requirements for an uncontrolled 1,000-MWe powerplant are similar except that coal and ash storage acreages are reduced by factors of 3 and 15, respectively. See note 19 for the level of ash control.

[8] Based on estimated land right-of-way of 4 million acres. U.S. Department of the Interior and U.S. Department of Agriculture. 1970. *Environmental Criteria for Electric Transmission Systems.* Washington, D.C.: Government Printing Office, p. iii. This acreage is multiplied by .00130, the share of total 1970 U.S. electricity production represented by a 1,000-MWe plant. Federal Power Commission. 1972. *Annual Report—1971.* Washington, D.C.: Government Printing Office, p. 11.

[9] Comparison of aggregated figures here is deceptive, because they consist mostly of acid for deep mining and siltation for surface mining. Disaggregated figures, in tons, are:

	Deep	*Surface*
Sulfuric acid	2,129	166
Dissolved iron	532	42
Silt	0	35,612

These figures are based on an increment of 20,000 tons of sulfuric acid and 5,000 tons of dissolved iron from 1-year's U.S. coal production with runoff continuing for 15 years. Delson and Frankel, *op. cit.*, p. II-5. This drainage was then allocated to deep mines (95.4 percent) and surface mines (4.6 percent), according to data on active mines in Appalachian Regional Commission. 1969. *Acid Mine Drainage in Appalachia.* Washington, D.C.: A.R.C., p. 36. The drainage was further allocated to the 1,000-MWe powerplant by its share of the annual U.S. production, namely 0.74 percent of annual deep-mined production or 1.20 percent of surface-mined production. U.S. totals from *Minerals Yearbook—1969, op. cit.*, p. 309. Siltation was estimated at 3.0 tons per acre per year for 15 years. U.S. Department of the Interior, Geological Survey. 1970. *Influences of Strip Mining on the Hydrologic Environment of Parts of Beaver Creek Basin, Kentucky, 1955-66.* Professional Paper 427-C, Washington, D.C.: Government Printing Office, p. C2. Calculation based on 308 acres per million tons of surface-mined coal. See note 4.

[10] The discharge of blackwater solids from current plants is used as the basis for the "uncontrolled" plant because settling ponds are common practice; discharges would be about 250 times greater were there no control measures. Calculated from an estimate of 1968 nationwide discharges of 100,000 tons. Delson and Frankel, *op. cit.*, p. II-9. The fraction of coal mined in 1968 that is used in a 1,000-MWe plant is based on Figure A-1 and *Minerals Yearbook—1969, op. cit.*, p. 309. Siltation from processing waste banks is taken to be 42 tons per acre per year for 15 years, based on data in *Influences of Strip Mining on the Hydrologic Environment of Parts of Beaver Creek Basin, Kentucky, 1955-66, op. cit.*, p. C2. There is some acid drainage, but it is believed to be much smaller. See note 5 for acreage data.

[11] Although reliable data are not available, the following preliminary estimates were derived from Aynsley, Eric, and Meryl R. Jackson. May 1971. "Industrial Waste Studies: Steam Generating Plants."

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Unpublished draft prepared for the U.S. Environmental Protection Agency, Water Quality Office, Research Triangle Park, N.C., p. 67. Note that suspended solids from ash are assumed to be controlled to over 99 percent, and dissolved solids from ash ponds are not included. Water discharges, in tons, are:

Suspended solids: Ash	14
Suspended solids: Other	411
Nondegradable organics	55
BOD	2
Acid	68
Alkalis	9
Chlorine	22
Phosphates	25
Boron	205
Chromates	2
Total	813

[12] Based upon a powerplant efficiency of 38 percent, 62 percent of the British thermal units input is rejected heat. Of this, one-sixth is rejected with the stack gases. Delson and Frankel, *op. cit.*, p. II-13.

[13] Burning underground or surface coal seams have undetermined air emissions. Air pollution data from fuels needed to power mining equipment are not available (new mining equipment often runs on electricity rather than fossil fuels).

[14] Air emissions consist of coal dust from dry processing and from thermal drying of some wet processed coal. Emissions from current plants are used as the basis for an "uncontrolled" plant because cyclone dust collectors are common practice and pay for themselves in coal reclaimed. Delson and Frankel, *op. cit.*, p. IV-40. Calculated from estimate of 1968 emissions of 1 million tons, almost entirely from thermal drying, *ibid.*, p. II-9, times fraction of coal used in that year by a 1,000-MWe powerplant.

A significant quantity of air pollution occurs from the uncontrolled burning of coal waste banks. These are estimated below but are not included in the total because it is assumed that new processing plants would not have this problem. Nationwide emissions in 1968 are estimated in U.S. Department of Health, Education, and Welfare, National Air Pollution Control Administration. 1970. *Nationwide Inventory of Air Pollutant Emissions 1968.* Washington, D.C.: Government Printing Office. These emissions are multiplied by the fraction of 1968 coal production represented by a 1,000-MWe plant. *Minerals Yearbook—1969, op. cit.*, p. 300. Air pollution from burning waste banks related to a 1,000-MWe electrical plant, in tons, are:

Carbon monoxide	6,510
Particulates	2,180
Sulfur oxides	3,270
Hydrocarbons	1,090
Nitrogen oxides	1,090
Total	14,170

[15] Air emissions (570 tons) based on railroad consumption of diese fuel at the rate of 1 gallon per 200 ton-miles assuming 136,000 British thermal units per gallon. Rice, R. A. "System Energy as a Factor in Considering Future Transportation." A paper presented at the American Society of Mechanical Engineers winter annual meeting, November 29-December 3, 1970. Also assuming a 300-mile average movement of coal by rail and all coal for the 1,000-MWe powerplant sent by rail. Uncontrolled emissions are based on data from U.S. Environmental Protection Agency, Office of Air Programs. 1972. *Compilation of Air Pollutant Emission Factors.* Washington, D.C.: Government Printing Office, p. 3-7. Specific emissions, in tons, include:

Carbon monoxide	135
Particulates	48
Sulfur oxides	125
Hydrocarbons	96
Nitrogen oxides	145
Aldehydes	6
Organic acids	13
Total	570

In addition, 25,700 tons of coal is blown away during transport. See Table A-1, note 6.

[16] Emission factors are from *Compilation of Air Pollutant Emission Factors, op. cit.*, p. 1-3. They apply to a "general" pulverized-fuel furnace of over 100 million British thermal units per hour without control equipment. Ash content is estimated at 10 percent. Smith, W. S., and C. W. Gruber. 1966. *Atmospheric Emissions from Coal Combustion—An Inventory Guide.* Cincinnati: U.S. Department of Health, Education, and Welfare, Public Health Service, p. 12. Sulfur content is taken as 2.55 percent, the average for 1969, from Princiotta, Frank T. "Control of Sulfur Oxide Pollution from Power Plants." Paper prepared for the American Public Power Association, Engineering and Operations Workshop, March 11, 1972. Research Triangle Park, N.C.: U.S. Environmental Protection Agency, Control Systems Division. Air emissions from the powerplant, in tons, are:

Particulates	203,200
Sulfur oxides	124,500
Carbon monoxide	1,270
Hydrocarbons	381
Nitrogen oxides	22,860
Aldehydes	6
Total	352,217

An insignificant amount (equivalent to approximately 2.2 curies) of radioactivity is emitted annually from a 1,000-MWe coal-fired plant. This figure was derived from Martin, James E., Harvard, Ernest D., and Donald T. Oakley. 1969. "Comparison of Radioactivity from Fossil Fuel and Nuclear Powerplants." Washington, D.C.: U.S. Department of Health, Education, and Welfare.

[17] About 90 percent of the overburden from surface mining is redeposited on the site. This portion is excluded from the total. Nationwide estimates for solid wastes from 1966 coal production are 12.8 million tons for deep mining and 210 million tons of overburden wastes from surface mining. U.S. Department of the Interior. 1970. "Environmental Effects of Underground Mining and Mineral Processing." Unpublished report. Washington, D.C.: D.O.I., pp. 124, 126. Production figures for 1966 are from *Minerals Yearbook—1969, op. cit.*, pp. 300, 371.

[18] Of the extracted coal, 65.9 percent is processed, and 23 percent of that, or 459,257 tons, is waste. *Ibid.*, p. 347. Of this, 451 tons is blackwater solids and 4,714 is airborne, leaving 454,092 tons as solid waste. See notes 10 and 11.

[19] In note 16 it was estimated that 10 percent of the coal burned, 254,000 tons, is ash, 203,200 tons of which is emitted to the air as fly ash. The remainder is solid waste.

[20] The following 1970 death and injury rates were provided to the Council by Mary McNair, U.S. Department of the Interior, Bureau of Mines, Office of Technical Support, based upon Moyer, Forrest T., ed. 1971. *Injury Experience and Worktime in the Mineral Industries, 1969-1970.* Washington, D.C.: U.S. Department of the Interior, Bureau of Mines. For deep mines, there were 0.65 fatalities and 28.07 nonfatal injuries per million tons mined and 55 workdays lost per injury. For surface mines, there were 0.12 fatalities, 5.40 nonfatal injuries, and 36 workdays lost per injury.

[21] The death rate for processing operations is 0.0117 per million tons and the injury rate is 1.58 per million tons. Each injury averages 38.9 workdays lost. *Ibid.*, p. 29. Coal production statistics from *Minerals Yearbook—1969, op. cit.*, p. 300.

[22] National railroad death and injury statistics are from U.S. Bureau of the Census. 1971. *Statistical Abstract of the United States: 1971.* Washington, D.C.: Government Printing Office, p. 519. It is assumed that the average injury leads to a loss of 100 workdays. It should be noted that most railroad deaths occur at grade crossings. An additional major component of deaths is trespassers. Personal communication with the National Safety Council. Also see Table A-1, note 11.

[23] Olmstead, Leonard M. "17th Annual Steam Station Cost Survey." *Electrical World.* November 1, 1971, p. 46, based on 0.113 men per MWe. Injury data are from National Safety Council. 1971. *Accident Facts—1971 Edition.* Chicago: N.S.C., p. 35. One-half the combined deaths and permanent injuries are assumed to be fatal injuries. Permanent total disabilities are considered to represent 6,000 workdays lost, and other disabilities are estimated as 100 days lost.

[24] Pneumoconiosis workdays lost are attributed solely to complicated pneumoconiosis cases as determined by roentgenographic findings in 1964 field examinations. These cases are assumed to cost 6,000 workdays each. Based upon the average number of years each miner had worked, prevalence data are converted into estimated incidence rates. Lainhart, W. S., Doyle, H. N., Enterline, P. E., Henschel, A., and M. A. Kendrick. 1969. *Pneumoconiosis in Appalachian Bituminous Coal Miners.* Section IV. "Prevalence of Respiratory Symptoms in Two Appalachian Communities." Cincinnati: U.S. Department of Health, Education, and Welfare, Public Health Service, Bureau of Occupational Safety and Health. In *Hearings before the Subcommittee on Labor of the Committee on Labor and Public Welfare, United States Senate, Ninety-Second Congress, First and Second Sessions, on S. 2675, S. 2289, H.R. 9212.* 1972. Washington, D.C.: Government Printing Office, pp. 482, 486. Incidence rates are 3.47 simple cases per 1,000 man-years; 1.60 complicated cases per 1,000 man-years; and 2.14 suspect cases per 1,000 man-years. Productivity per workday data are from *Minerals Yearbook—1969, op. cit.*, p. 332. These data are based on coal shipments, reflecting cleaning losses, and are modified according to Table A-1. Two-hundred workdays per man-year are assumed, and 834 man-years are needed to supply coal for a 1,000-MWe powerplant. The number of workdays lost as a result of complicated pneumoconiosis is estimated at 8,010.

APPENDIX A

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Annual Environmental Impacts of Uncontrolled Oil-Fired Electricity Systems Associated With a 1,000-Megawatt Powerplant With a Load Factor of 0.75

Impact		Extraction		Processing	Transport			Conversion	Transmission	Total		
		Onshore	Offshore		Onshore	Offshore	Import			Onshore	Offshore	Import
Land	Acres	[1] 1,572	[2] 164	[3] 76	[4] 1,656	[4] 168	[5] 10	[6] 250	[7] 17,188	20,742	17,846	17,448
Water	Tons	[8] 111	[8] [9] 102	[10] 4,631	[11] 435	[11] 527	[11] 1,711	[12] 813	0	5,990	6,073	2,524
Air	Btu's	0	0	0	0	0	0	[13] 3.05×10^{13}	0	3.05×10^{13}	3.05×10^{13}	3.05×10^{13}
Solid waste	Tons	0	0	[14] 87,524	[15] 1,507	[15] 1,507	[15] 1,326	[16] 69,321	0	158,352	158,352	70,647
	Tons	0	0	0	0	0	0	0	0	0	0	0
Occupational health	Deaths	[17] 0.21	[17] 0.21	[18] 0.08	[19] 0.05	[19] 0.05	[19] 0.05	[20] 0.010	NA	0.35	0.35	0.06
	Injuries	[17] 21	[17] 21	[18] 5.6	[19] 4.5	[19] 4.5	[19] 4.5	[20] 1.15	NA	32.3	32.3	5.7
	Workdays lost	[17] 2,135	[17] 2,135	[18] 785	[19] 562	[19] 562	[19] 562	[20] 127.2	NA	3,609	3,609	689

NA=Not available.

[1] One thousand seventy-two onshore wells are required to supply a 1,000-MWe plant, based on average well production for the United States. U.S. Department of the Interior, Bureau of Mines. December 1971. *Mineral Industry Surveys: Crude Petroleum, Petroleum Products, and Natural-Gas-Liquids: 1970 (Final Summary)*. Pittsburgh: D.O.I., B.O.M., Table 3. Land area required for drilling rig and attendant equipment and supplies is estimated at 1 acre per well. InterTechnology Corporation, Warrenton, Va.

[2] One hundred sixty-four offshore wells are required to supply a 1,000-MWe plant, based on average well production of Gulf Coast offshore wells. U.S. Deprtment of the Interior, Bureau of Land Management. 197[illegible]. *Final Environmental Statement—Proposed 1972 Outer Continental Shelf Oil and Gas General Lease Sale, Offshore Eastern Louisiana*. Washington, D.C.: D.O.I., pp. 63, 132. Sea surface area required for equipment, considered a land impact, is estimated as in note 1.

[3] Land required for production facilities, administration, maintenance, storage, and surrounding "green belt," for a refinery of 51.75 million barrels per year capacity, is estimated at approximately 400 acres. Arthur D. Little, Inc., Cambridge, Mass.

[4] Land impact for pipeline transport is based on 1969 figures for total U.S. crude oil trunkline mileage (73,830) times the fraction of the total number of wells in the U.S. needed for a 1,000-MWe plant. American Petroleum Institute. 1971. *Petroleum Facts and Figures—1971 Edition*. Washington, D.C.: A.P.I., p. 215; and notes 1 and 2. A 62.5-foot right-of-way is assumed, averaged from data in Petroleum Extension Service and Pipeline Contractors Association. 1966. *A Primer of Pipe Line Construction*. Austin: Texas Education Agency.

[5] Terminal storage facilities of approximately 30 days' supply are necessary due to irregularities inherent in tanker shipments. For a terminal handling 2,190 million barrels per year, an estimated 2,000 acres is required. Arthur D. Little, Inc., Cambridge, Mass.

[6] Because of buffer zones, the land required for a 1,000-MWe plant is given as 150 to 350 acres in Executive Office of the President, Office of Science and Technology, Energy Policy Staff. 1968. *Considerations Affecting Steam Power Plant Site Selection*. Washington, D.C.: Government Printing Office, p. 11.

[7] See Table A-2, note 8.

[8] Quantity of oil emitted to waters from onshore oil production is the oil released by the incomplete separation of brine and oil at the wellhead. Based on production of 2.7 barrels of brine per barrel of crude oil and 16 percent of the brine disposed of in water bodies. National Petroleum Council. 1972. *Environmental Conservation: The Oil and Gas Industries*. Volume Two. Washington, D.C.: N.P.C., p. 147. Also based on 0.005 percent oil content in the brine, which is the Federal regulation applying to offshore drilling. *Final Environmental Statement—Proposed 1972 OCS Lease Sale, op. cit.* Conversion to tons from *Petroleum Facts and Figures—1971 Edition, op. cit.*, p. 588. Outer Continental Shelf data, calculated from water and accident data in *Final Environmental Statement—Proposed OCS Lease Sale, op. cit.*, pp. 133, 134, are used to estimate accidental [illegible]

[9] One other water impact that does occur but is not included on the summary table is pollution of waters by salts and suspended solids by the release of the brine to marine environments. Brine discharge to water bodies based on the above, 4.5 million barrels.

[10] Calculated from "achievable" effluent emission factors for topping and cracking plants divided by "achievable" reduction factors. U.S. Environmental Protection Agency. 1972. "The Industrial Waste Studies Program: Summary Report in the Petroleum Refinery Industry," S.I.C. 2911. Research Triangle Park, N.C., pp. 5, 6. Refinery water emissions, in tons, are:

Ammonia (as N)	52
BOD_5	390
Chromates	.3
COD	1,080
Oil	167
Phenols	87
Sulfides	52
Suspended solids	455
Dissolved solids	2,342

[11] Water pollution results from oil discharges. See Table A-4, note 6. Conversion to tons from *Petroleum Facts and Figures—1971 Edition, op. cit.*, p. 588. For prerefinery transport, oil loss is from barges for domestic oil (435 tons) and from tankers for imported oil (1,711 tons).

[12] See Table A-2, note 11.

[13] See Table A-2, note 12.

[14] See Table A-4, note 5, for hypothetical refinery. Given the output indicated in Figure A-2, we calculate input (assumed to be entirely crude oil) and total production. We calculate heat input from residual fuel oil and from natural and petroleum gas from *Mineral Industry Surveys: Crude Petroleum, Petroleum Products, and Natural-Gas-Liquids: 1970 (Final Summary), op. cit.*, Table 19. We calculate the refining capacity, storage capacity, and storage throughput from U.S. Environmental Protection Agency. 1972. *The Economics of Clean Air*. Washington, D.C.: E.P.A., p. 4-108:

Input (crude oil)	166.5 million barrels per year.
Output:	
Total	161.3 million barrels per year.
Residual fuel oil	0.39 million barrels per year.
Refinery capacity	189.7 million barrels per year.
Fuel oil burned	1.68 million barrels per year.
Gas burned	80.0 billion cubic feet per year.
Storage capacity	8.20 million barrels.
Storage throughput	71.8 million barrels per year.

The fraction attributable to residual fuel oil production is 6.65 percent.

Additional assumptions are that the fluid catalytic cracking process is used (representative of new refineries); that one-third of the crude undergoes vacuum distillation; that storage is 93 percent as finished products, 7 percent as crude; that hydrocarbon evaporation for crude and residual products is statistically similar; and that no floating roof storage is used. *The Economics of Clean Air, op. cit.*, pp. 4-105, 4-110.

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From these data, and from emission factors in U.S. Environmental Protection Agency. 1973. *Compilation of Air Pollutant Emission Factors.* Washington, D.C.: Government Printing Office, pp. 1-7, 9-3, 9-4, we calculate air emissions. Refinery air emissions, in tons, are:

Source	Particulates	SO_x	HC	CO
Process heat:				
Residual oil	47	558	8	0
Gas	54	0	81	0
Catalytic cracking	318	2,732	1,145	71,290
Blowdown	0	0	1,894	0
Vacuum distillation	0	0	226	0
Storage	0	0	7,224	0
Total	419	3,290	11,037	71,290

Source	NO_x	Aldehydes	Ammonia (as N)	Total
Process heat:				
Residual oil	161	2	0	776
Gas	619	8	0	76[illegible]
Catalytic cracking	325	99	281	76,193
Blowdown	0	0	0	1,894
Vacuum distillation	0	0	0	226
Storage	0	0	0	7,224
Total	1,105	109	281	87,52[illegible]

[14] See Table A-4, note 12, for assumptions and fuel consumption. For pre-refinery transport (domestic), pumps are assumed to be diesel engines with emission factors similar to those for heavy-duty trucks and buses. *Compilation of Air Pollutant Emission Factors, op. cit.*, p. 3-7. For post-refinery transport, barges (domestic oil) have diesel motors, whereas tankers (imports) are steamships. Emission factors in tons per gallon of fuel consumed are derived from "underway" columns in Tables 3-6 and 3-7, *ibid.*, p. 3-11. Air emissions for oil transport, in tons, are:

	Domestic			Import
	Pre-refinery	Post-refinery	Total	Post-refinery
Particulates	7	327	334	34
SO_x	14	246	260	885
CO	116	197	313	17
HC	19	146	165	17
NO_x	191	231	422	386
Aldehydes	2	11	13	[illegible]
Total	349	1,158	1,507	1,326

[16] Air emissions, assuming 1.5 percent sulfur in the fuel, are calculated from *Compilation of Air Pollutant Emission Factors, op. cit.*, p. 1-7. Powerplant air emissions, in tons, are:

Particulates	1,578
SO_x	46,438
CO	8
HC	395
NO_x	20,705
Aldehydes	197

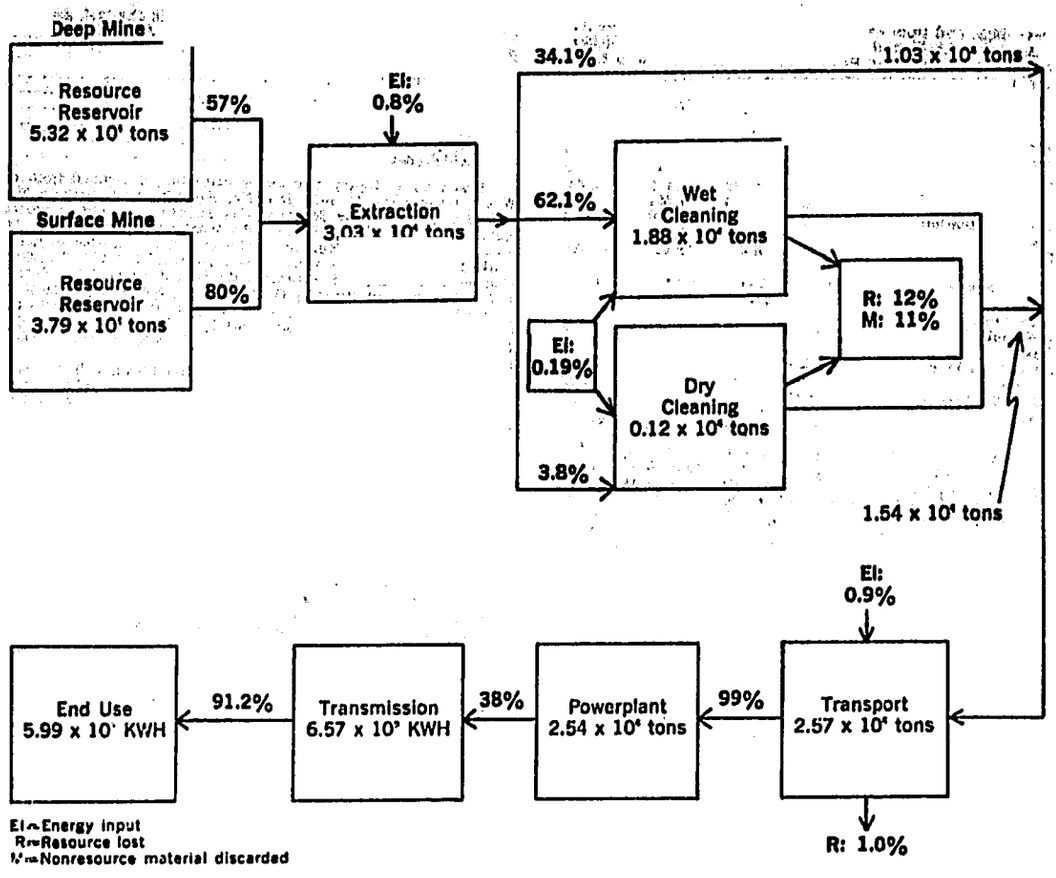
[17] Based on an injury rate for oil extraction developed from data in Watts, Gwendolyn M. 1972. *Disabling Work-Injury Experience of the Oil (All Activities) and the National Gas Industry (Excluding Distribution Activities) in the United States, 1970.* Washington, D.C.: U.S. Department of the Interior, Bureau of Mines; and on number of man-hours worked in oil extraction, which was developed from U.S. Bureau of the Census. 1971. *Statistical Abstract of the United States: 1971.* Washington, D.C.: Government Printing Office, pp. 219, 496. Rates of fatal injuries (1 death per 100 nonfatal injuries) and workdays lost due to nonfatal injuries (101 days lost per injury) are from U.S. Department of Labor, Bureau of Labor Statistics. 1971. *Injury Rates by Industry—1969.* Washington, D.C.: D.O.L., p. 18.

[18] Based on total man-hours worked, derived from U.S. Bureau of the Census. 1970. *Statistical Abstract of the United States: 1970.* Washington, D.C.: Government Printing Office, pp. 222, 656; and on injury rate statistics in *Injury Rates by Industry—1969, op. cit.*, p. 10.

[19] Based on 1969 occupational health data in Fish, George. 1970. *Disabling Work-Injury Experience of the Oil Industry (All Activities) and the Natural Gas Industry (Excluding Distribution Activities) in the United States, 1969.* Washington, D.C.: U.S. Department of the Interior, Bureau of Mines, p. 5; on the total work hours of marine transport in the oil industry, derived from National Petroleum Council. 1969. *People in the United States Oil and Gas Industries.* Washington, D.C.: N.P.C., p. 5; and on the share of all oil needed to fuel a 1,000-MWe powerplant for 1 year, derived from data in Figure A-2 and in U.S. Department of the Interior, Office of Oil and Gas. 1970. *1968 Petroleum Supply and Demand in the Free World.* Washington, D.C.: D.O.I. On first estimate, imports and domestic production are not separated.

[20] See Table A-2, note 23, using 0.009 men per MWe.

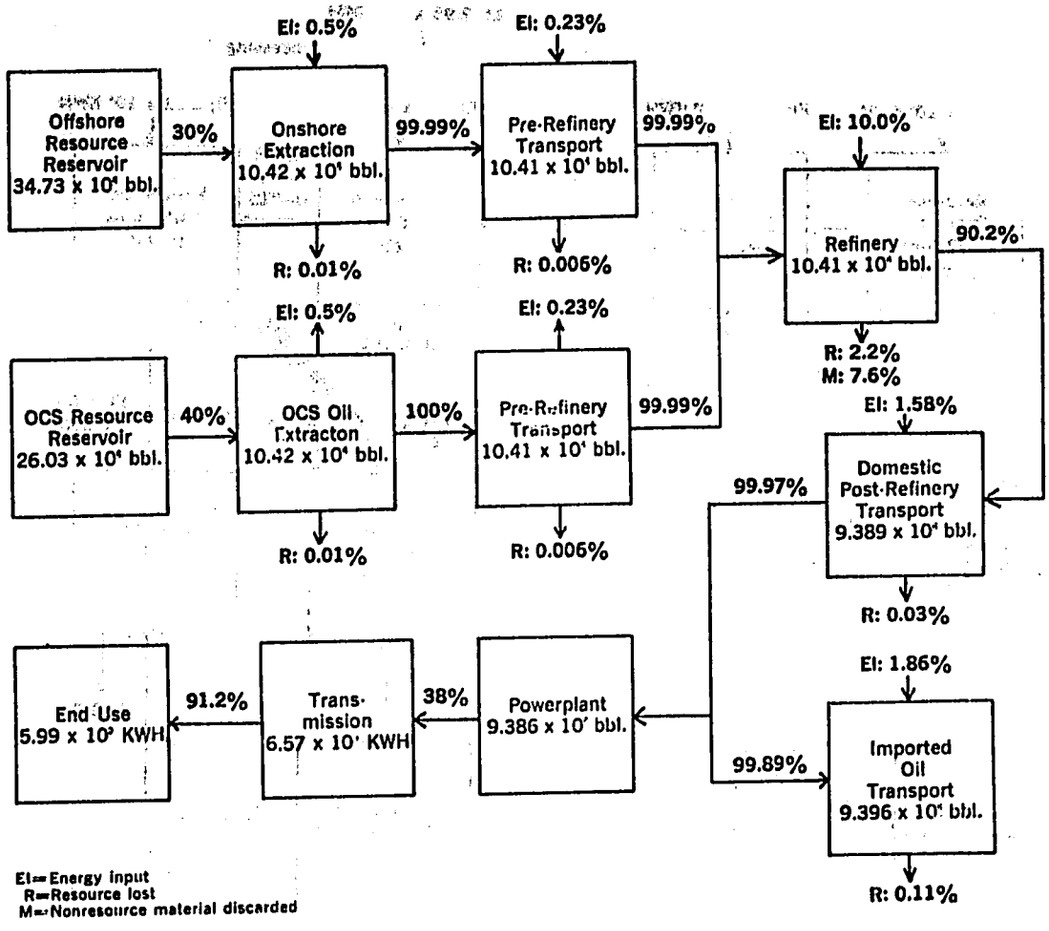
Coal-Fired Electricity System for a 1,000-Megawatt Powerplant Operating Annually at a 0.75 Load Factor



EI = Energy input
R = Resource lost
M = Nonresource material discarded

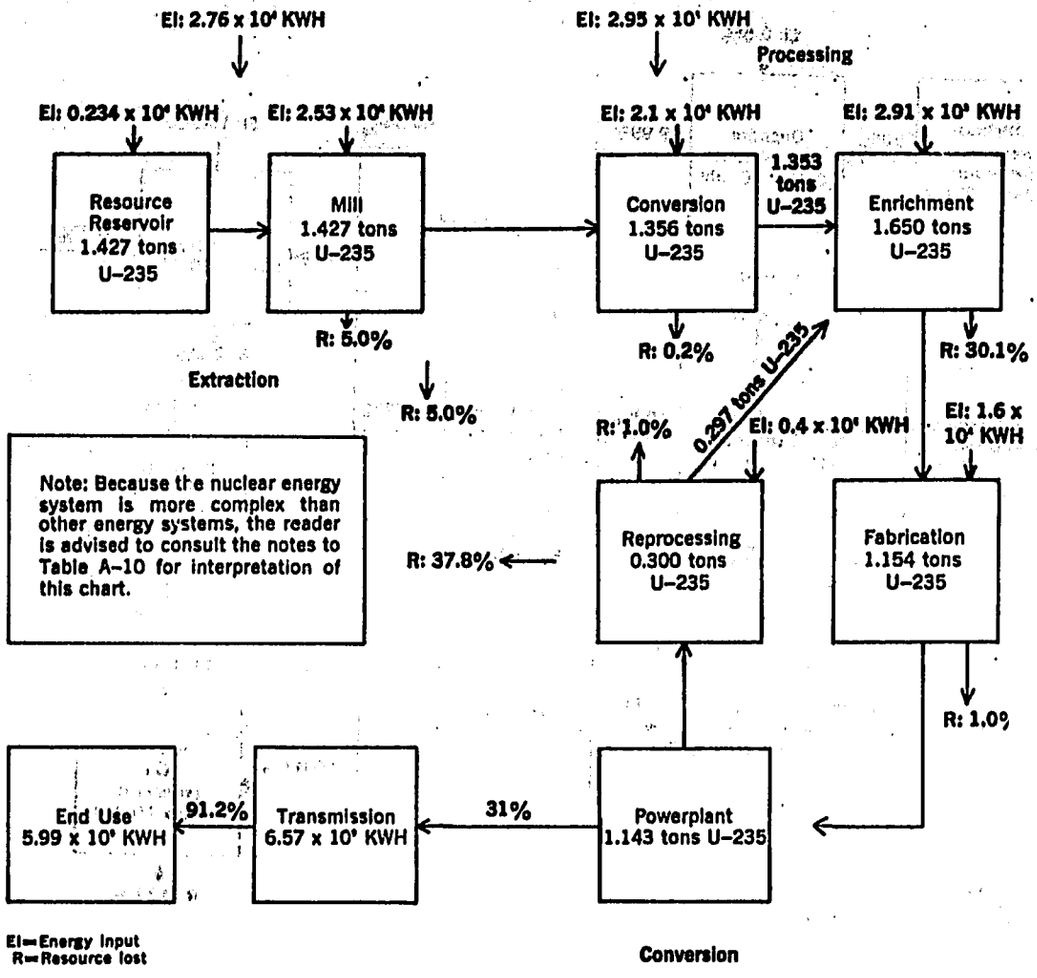
APPENDIX B

Residual Fuel Oil-Fired Electricity System for a 1,000-Megawatt Powerplant Operating Annually at a 0.75 Load Factor



APPENDIX B

Nuclear-Powered Electricity System for a 1,000-Megawatt Powerplant Operating Annually at a 0.75 Load Factor



APPENDIX C

Annual Environmental Impacts of Controlled Coal-Fired Electricity Systems Associated With a 1,000-Megawatt Powerplant With a Load Factor of 0.75 [1]

[Costs in thousands of dollars or mills per kilowatt-hour]

	Impact	Extraction		Processing	Transport	Conversion	Transmission	Total	
		Deep	Surface					Deep	Surface
Land	Acres	[2] 9,120	[3] 934	[4] 85	2,213	[5] 941	17,188	29,637	21,461
	Percent change	0	−94.3	−47.2	0	+35.2	0	+0.88	−37.4
	Costs								
	Annual total	0	1,868	10.8	0	0	0	10.8	1,878.8
	Mills per kilowatt-hour	0	.28	.002	0	0	0	.002	.282
Water	Tons	[6] 0	[7] 2,602	[7] 227	0	[8] 55	0	282	3,084
	Percent change	−100	−92.2	−94.1	0	−93.2	0	−96.2	−92.4
	Costs								
	Annual total	460	0	5.99	0	NA	0	465.99	5.99
	Mills per kilowatt-hour	.07	0	.001	0	NA	0	.071	.001
	Btu's	0	0	0	0	[9] 0	0	0	0
	Percent change	0	0	0	0	−100	0	−100	−100
	Costs								
	Investment	0	0	0	0	10,000	0	10,000	10,000
	Annual total	0	0	0	0	2,153.5	0	2,153.5	2,153.5
	Mills per kilowatt-hour	0	0	0	0	.328	0	.33	.33
Air	Tons	NA	0	[10] 59	26,270	[11] 45,175	0	71,501	71,501
	Percent change	NA	0	−98.7	0	−87.2	0	−81.3	−81.3
	Costs								
	Investment	NA	0	NA	0	40,000	0	40,000	40,000
	Annual total	NA	0	14	0	11,826	0	11,840	11,840
	Mills per kilowatt-hour	NA	0	.002	0	1.80	0	1.80	1.80
Solid waste [12]	Tons	[13] 101,316	[13] 2,762,325	[14] 462,373	0	[15] 691,000	0	1,558,000	4,219,000
	Percent change	+4.3	+0.01	+1.8	0	+1,057	0	+159	+29.1

NA = Not available.

[1] Costs of coal-fired powerplants are estimated at $180 per kilowatt, based on unpublished, updated data for Federal Power Commission, 1968 and 1969. *Hydroelectric Power Evaluation* and its *Supplement No. 1*. Washington, D.C.: Government Printing Office. The 14.8 percent annualization rate was developed using *Hydroelectric Power Evaluation, Supplement No. 1*, p. 3; and Board of Governors of the Federal Reserve System. "Bond and Stock Yields." *Federal Reserve Bulletin*. April 1973. Vol. 59, No. 4, p. A 34. Fuel is estimated at $0.35 per million British thermal units based on data in Federal Power Commission, Bureau of Power. February 1973. *Monthly Report of Cost and Quality of Fuels for Steam-Electric Plant*. Washington, D.C.: F.P.C., p. 2. Operation and maintenance costs are estimated at 0.39 mills per kilowatt-hour, based on data in "17th Steam Station Cost Survey." *Electrical World*. November 1, 1971, p. 46. Coal storage is set at 3 months, with the cost of capital taken as 10 percent. Electricity costs based on minimal controls, in mills per kilowatt-hour, are:

Powerplant	4.03
Coal	3.11
Coal storage	.08
Operation and maintenance	.39
Total	7.60

Incremental electricity costs with controls, in mills per kilowatt-hour are:

	Deep	Surface
Total costs of controls	2.13	2.41
Total costs with controls	9.79	10.07
Percent increase with controls	27.8	31.5

APPENDIX C

[1] Less than 1 acre is required for disposal of solid wastes from water pollution control.

[2] Complete reclamation is assumed after 1 year of mining. The Council estimates the cost at $2,000 per acre. U.S. Council on Environmental Quality, 1972. *Environmental Quality—1972*. Washington, D.C.: Government Printing Office, p. 275. Also see note 2.

[3] Fixed land use is the same as for the uncontrolled plant (80 acres) because land required for additional pollution control equipment is assumed to be negligible. For variable land use, it is assumed that the 3.4 acres of waste banks from solid wastes (see Table A-2, note 18) remains 1 year before reclamation, at a reclamation cost of $2,000 per acre.

[4] Annual incremental land use for disposal of solid waste generated by air pollution control is 15 acres and averages 15 years' duration. Based on 201,000 tons of dry ash averaging 33 cubic feet per ton and 742,000 tons of limestone sludge averaging 22 cubic feet per ton. Table A-2, note 16, with 99 percent control; and Federal Interagency Committee for Evaluation of State Implementation Plans, Sulfur Oxide Control Technology Panel. November 16, 1972. "Preliminary Draft of Final Report on Projected Utilization of Stack Gas Cleaning Systems by Steam Electric Plants." Washington, D.C., p. 58. Thirty-five-foot high waste banks are assumed. Costs are included in air pollution control costs. Cooling towers are estimated to occupy 10 acres. This cost is included under water impacts control.

[5] Acid drainage is assumed to be treated completely by adding lime and allowing it to settle in tanks or ponds. Cost, including capital, operating, and maintenance, is estimated at $0.185 per ton of coal deep mined. Delson, Jerome K., and Richard J. Frankel. April 1972. "Residuals Management in the Coal-Energy Industry." Manuscript to be published by Resources for the Future, Inc. Washington, D.C.: R.F.F., p. IV-25a. Siltation from surface mining is assumed to end with reclamation 1 year after mining. Cost for both acid and siltation control on surface-mined land is included in the land reclamation cost.

[6] Blackwater emissions can be completely prevented by sedimentation plus water recirculation, at a cost of approximately $0.003 per input ton. *Ibid.*, pp. II-3a, IV-37a. Waste banks are assumed reclaimed after 1 year at $2,000 per acre, as for surface-mined land, leading to cessation of siltation after 1 year.

[7] Aynsley, Eric, and Meryl R. Jackson. May 1971. "Industrial Waste Studies: Steam Generating Plants." Unpublished draft prepared for the U.S. Environmental Protection Agency, Water Quality Office. Research Triangle Park, N.C., p. 69, indicates that all effluents except nondegradable organics can be virtually eliminated. Cost data are being developed by the U.S. Environmental Protection Agency.

[8] Natural draft cooling towers have been estimated to cost from $6 to $9 per kilowatt. Federal Power Commission, "Problems in Disposal of Waste Heat from Steam-Electric Plants.' A staff study supporting the 1970 National Power Survey, p. 15. Our study uses $10 per kilowatt however, based upon unpublished supplemental data for *Hydroelectric Power Evaluation* and its *Supplement No. 1, op. cit.*

Operating costs are estimated at 0.05 mills per kilowatt-hour, with an additional 150 British thermal units per kilowatt-hour thermal loss cost resulting from the required energy input. National Economic Research Associates, Inc. 1972. *Possible Impact of Costs of Selected Pollution Control Equipment on the Electric Utility Industry and Certain Power Intensive Consumer Industries*. New York: N.E.R.A., p. III-3. Total costs assume the annualized capital cost rate at 11.8 percent. See note 1. The average cost of coal is estimated at $0.35 per million British thermal units, based on *Monthly Report of Cost and Quality of Fuels for Steam-Electric Plant, op. cit.*, p. 2.

[10] A system employing a wet scrubber and air recirculation, in addition to a cyclone, is used to control air emissions from thermal drying. Costs of the system are $0.037 per input ton of coal, and emissions are reduced to 0.1 ton of dust per 500 tons input coal. Delson and Frankel, *op. cit.*, pp. II-3a, IV-40a. Twenty percent of the mechanically cleaned coal is thermally dried. U.S. Department of the Interior, Bureau of Mines. 1971. *Minerals Yearbook—1969* Washington, D.C.: Government Printing Office, p. 351.

[11] Assumes wet limestone scrubber system for both SO_2 and particulate control. Removal efficiencies are taken at 85 percent for SO_2 and 99 percent for particulates. Princiotta, Frank T. "Control of Sulfur Oxide Pollution from Power Plants." A paper prepared for the American Public Power Association Engineering and Operations Workshop, March 14, 1972. Research Triangle Park, N.C.: U.S. Environmental Protection Agency, Control Systems Division, Table 8. Capital cost is estimated at $10 per kilowatt including settling pond, and annualized cost for a new 1,000-MWe unit burning 2.6 percent sulfur coal at 38 percent efficiency and a 0.75 load factor is estimated at 1.8 mills per kilowatt-hour. Developed from Burchard, John K., et al. 1972. "Some General Economic Considerations of Flue Gas Scrubbing for Utilities." Research Triangle Park, N.C.: U.S. Environmental Protection Agency, pp. 21, 22. Costs of solid waste disposal are included.

[12] Cost of disposal of the extra solid waste generated by air or water pollution controls is included in the air and water cost estimates.

[13] Additional solid wastes result from control of acid drainage. The addition of lime should precipitate 1.61 tons of calcium sulfate per ton of sulfuric acid and 1.46 tons of iron hydroxide per ton of iron, based on the atomic weights of the reagents. See Table A-2, note 9. Thus the additional solid waste generated is 4,205 tons for deep mining and 328 for surface mining. Note that gob and offsite overburden are still considered solid wastes, even though the reclamation process disposes of them satisfactorily.

[14] Additional solid wastes result from air and water pollution controls. See notes 7 and 10.

[15] See note 5 for additional solid wastes.

APPENDIX C

Annual Environmental Impacts of Controlled Oil-Fired Electricity Systems Associated With a 1,000-Megawatt Powerplant With a Load Factor of 0.75 [1]

[Costs in thousands of dollars or mills per kilowatt-hour]

Impact		Extraction		Processing	Transport			Conversion	Transmission	Total		
		Onshore	Offshore		Onshore	Offshore	Import			Onshore	Offshore	Import
Land	Acres	1,572	164	[2] 76	1,656	168	10	[3] 260	17,188	20,752	17,856	17,458
	Percent change	0	0	nil	0	0	0	+1	0	0	0	0
Water	Tons	111	102	[4] 3,063	435	527	[5] 520	[6] 55	0	3,664	3,747	575
	Percent change	0	0	−41	0	0	−60.6	−93.2	0	−38.8	−38.3	−77.2
	Costs											
	Investment	0	0	[7] 1,100	0	0	0	NA	0	1,100	1,100	0
	Annual operation and maintenance	0	0	110	0	0	0	NA	0	110	110	0
	Mills per kilowatt-hour	0	0	.026	0	0	0	NA	0	0.026	0.026	0
	Btu's	0	0	0	0	0	0	[8] 0	0	0	0	0
	Percent change	0	0	0	0	0	0	−100	0	−100	−100	−100
	Costs.											
	Investment	0	0	0	0	0	0	10,000	0	10,000	10,000	10,000
	Annual total	0	0	0	0	0	0	2,498	0	2,498	2,498	2,498
	Mills per kilowatt-hour	0	0	0	0	0	0	[9] .377	0	.377	.377	.377
Air	Tons	0	0	[9] 3,210	1,507	1,507	1,326	[10] 38,362	0	43,079	43,079	39,688
	Percent change	0	0	−96.3	0	0	0	−41.7	0	−72.8	−72.8	−43.8
	Costs											
	Investment	0	0	[11] 1,415	0	0	0	0	0	1,415	1,415	0
	Annual operation and maintenance	0	0	229	0	0	0	14,242	0	15,471	15,471	14,242
	Mills per kilowatt-hour	0	0	.067	0	0	0	2,168	0	2,355	2,355	2,168
Solid waste	Tons	0	0	[12] 213	0	0	0	0	0	213	213	0
	Percent change	0	0	+	0	0	0	0	0	+	+	0

NA=Not available.

[1] Costs of oil-fired powerplants are estimated at $150 per kilowatt based on unpublished, updated data for Federal Power Commission. 1968 and 1969. *Hydroelectric Power Evaluation* and its *Supplement No. 1*. Washington, D.C.: Government Printing Office. See Table A-3, note 1 for 14.8 percent annualization rate. Fuel is estimated at $0.45 per million British thermal units based on data in Federal Power Commission, Bureau of Power, February 1973. *Monthly Report of Cost and Quality of Fuels for Steam-Electric Plant*. Washington, D.C.: F.P.C., p. 3. Operation and maintenance costs are estimated at 0.21 mills per kilowatt-hour, based on data in "17th Steam Station Cost Survey." *Electrical World*, November 1, 1971, p. 46. Fuel storage is set at 1 month, with the cost of capital taken as 10 percent. Electricity costs based on minimal controls, in mills per kilowatt-hour, are:

Powerplant	3.38
Fuel	4.01
Fuel storage	.01
Operation and maintenance	.21
Total	7.67

The incremental electricity costs with controls, in mills per kilowatt-hour, are:

	Onshore	Offshore	Imports
Water discharges	.03	.03	0
Heat discharges	.38	.38	.38
Air emissions	2.36	2.36	2.17
Fuel storage	.02	.02	.02
Total costs of controls	2.79	2.79	2.57
Total costs with controls	10.46	10.46	10.21
Percent increase with controls	36.4	36.4	33.5

[2] Virtually no land is needed for added solid wastes disposal.

[3] See Table A-3, note 5 for the acreage needed for cooling towers.

[4] See Table A-3, note 10.

[5] The load-on-top system is about 80 percent effective in reducing oil discharges from tankers. Porricelli, Joseph D., Keith, Virgil F., and Richard L. Storch. "Tankers and the Ecology." *Transactions*. Vol. 79, 1971, pp. 2, 4, 7. The LOT system pays for itself.

[6] See Table A-3, note 8.

[7] Costs of control were estimated by InterTechnology Corporation, Warrenton, Va.

[8] See Table A-3, note 9. Costs are computed using $0.68 per millio British thermal units for residual fuel.

[9] Carbon monoxide boilers eliminate CO and 95 percent of the H from the catalytic cracking stage. U.S. Environmental Protectio Agency. 1972. *The Economics of Clean Air*. Washington, D.C.: E.P.A pp. 1-106, 107. Sulfur recovery plants and tail gas cleaning can reduc SO_2 from the cracking stage by 99.5 percent. *Ibid.*, p. 4-106. Electrostat precipitators can reduce particulates from the catalytic cracking stag by 67 percent. *Ibid.*, p. 4-107. Floating roofs on storage tanks can reduc emissions by 89 percent. *Ibid.*, p. 4-105. Blowdown emissions can b reduced by 98.3 percent with controls. U.S. Environmental Protectio Agency, Office of Air Programs. February 1972. *Compilation of A Pollutant Emission Factors*. Washington, D.C.: Government Printin Office, p. 9-3. Emissions from vacuum jets can be eliminated by contro *Ibid.*, p. 9-4. The purchase of 0.6 percent sulfur fuel oil is assumed, th reducing SO_2 from fuel oil combustion by 80 percent.

[10] Based on the use of 0.6 percent sulfur residual fuel costing $0.6 per million British thermal units. Based on data in *Monthly Report Cost and Quality of Fuels for Steam-Electric Plant*, *op. cit.*, p. 3.

[11] Costs based on data in *The Economics of Clean Air*, *op. cit.*, p. 4-11

[12] Electrostatic precipitators can reduce particulate emissions fro catalytic cracking by 67 percent. *The Economics of Clean Air*, *op. c* p. 4-107. See Table A-3, note 11.

APPENDIX C

Annual Environmental Impacts of a Controlled Light Water Reactor Nuclear Electricity System Associated with a 1,000-Megawatt Powerplant With a Load Factor of 0.75 [1]

[Costs in thousands of dollars or mills per kilowatt-hour]

	Impact	Extraction	Processing	Transport	Conversion	Transmission	Total
Land	Acres	785	9.12	0	[2] 314	17,188	18,314
	Percent change	0	0	0	+4.7	0	.1
Water	Tons	20,400	42.9	0	[3] 55	0	20,498
	Percent change	0	0	0	−93.2	0	−3.6
	Curies	1.9	2,348	0	332	0	2,682
	Percent change	0	0	0	0	0	0
	Btu's	[3] 0	[3] 0	0	[4] 0	0	0
	Percent change	−100	−100	0	−100	0	−100
	Cost						
	Investment	0	0	0	14,000	0	14,000
	Annual total	0	0	0	2,600	0	2,600
	Mills per kilowatt-hour	0	0	0	.39	0	.39
Air	Tons	nil	6,192	nil	0	0	6,192
	Percent change	0	0	0	0	0	0
	Curies	69.9	3.49×10^{6}	0	[5] 1.40×10^{3}	0	3.50×10^{6}
	Percent change	0	0	0	−99	0	−29.3
	Costs						
	Investment	0	0	0	4,000	0	4,000
	Annual total	0	0	0	614	0	614
	Mills per kilowatt-hour	0	0	0	.093	0	.093
Solid or stored waste	Tons	2.62×10^{6}	58	0	0	0	2.62×10^{6}
	Percent change	0	0	0	0	0	0
	Curies	1,125	1.4×10^{6}	0	31,500	0	1.4×10^{6}
	Percent change	0	0	0	0	0	0

[1] Note that the Atomic Energy Commission is developing cost and effectiveness data on reducing systemwide radioactive emissions. Using data from Federal Power Commission. 1969. *Hydroelectric Power Evaluation Supplement No. 1*. Washington, D.C.: Government Printing Office, pp. 10–12, inflated by 15 percent to cover cost rises since 1969, the construction cost of nuclear powerplants is estimated at $300 per kilowatt. Updated from *Ibid.* The annualization rate is based on Table A-3, note 1, with 0.55 mills per kilowatt-hour added for insurance. *Ibid.*, p. 3. Modifications, based on *Hydroelectric Power Evaluation* and its *Supplement No. 1, op. cit.*, are made to change the load factor to 0.75. In this way, operation and maintenance costs are determined to be $2,565,000 per year, or 0.44 mills per kilowatt-hour, and fuel costs are 1.79 mills per kilowatt-hour. Cooling towers are based on a 14.8 percent annualization rate. On this basis, the nuclear system with limited controls produces power at a cost of 9.24 mills per kilowatt-hour prior to transmission. The controlled systems produce power at 9.72 mills per kilowatt-hour, an increase of 5.19 percent.

[2] See Table A-3, note 5. Because nuclear units have over 60 porcen greater thermal discharge than fossil-fired powerplants, 14 acres is added for cooling towers, with the costs included in water control.

[3] See Table A-3, note 8.

[4] See Table A-3, note 9, for an analysis of cooling tower costs. The Council estimates the capital cost at $14 per kilowatt, based on over 60 percent greater thermal discharge of nuclear units but some economies of scale. Detailed annual cooling tower costs are:

Annual cost of investment	2,072,000
Operation and maintenance	328,500
Additional fuel	159,000
Total annual cost increase	2,559,500
Cost increase (mills per kilowatt-hour)	0.39

[5] Reducing powerplant radiation emissions by 99 percent is estimated to cost $4 million.

The Environmental Impact Statement As Practiced in the United States

Prepared for the

International Program in Environmental Aspects of Industrial Development

April 1975

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Chapel Hill
North Carolina

THE ENVIRONMENTAL IMPACT STATEMENT AS PRACTICED IN THE UNITED STATES

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Appendix A: The National Environmental Policy Act

Appendix B: The Guidelines of the Preparation of an Environmental Impact Statement.

Introduction

As a result of the growing concern about the quality of the environment--a concern rooted in the first conservation movement of the late nineteenth century and expressing itself in the 1960's in powerful organizations like the Sierra Club and through the political process--Congress passed The National Environmental Policy Act of 1969 (NEPA), a comprehensive national policy for "restoring, protecting and enhancing the quality of the environment."

The purpose of this paper is to describe the major tool for implementation of this policy, The Environmental Impact Statement review process, a process incorporating an environmental perspective in the decision making of federal agencies; and to discuss the efficiency, interest and difficulties linked with that tool by an evaluation of its first four years of application.

Overview of NEPA. Definition of the Environmental Impact Statement. (See Appendix A)

Basically, NEPA seeks better environment through better federal decision making by calling for the articulation of the reasons behind decisions, for the elaboration of the risks which proposed action entails, for discussion and consideration of alternatives as a test of soundness of the decision taken, for a wider review of the public interest, and for increased public participation. The two major aspects of NEPA are the creation of the Council on Environmental Quality and the Environmental Impact Statement review process.

In its Title II NEPA created the Council on Environmental Quality (CEQ) in the Executive Office of the President in order to "review and appraise the various programs and activities of the federal government in the light of the policy set forth in this Act," to "develop and recommend to the President national policies to foster and promote the improvement of environmental quality to meet the conservation, social, economic, health and other requirements and goals of the nation," and to provide for an annual progress report[1]

However, the originality of NEPA is its Title I, section 102, which is its action forcing procedure. This section requires all federal agencies of the United States to "insure that presently unquantified environmental amenities and values may be given appropriate consideration in decision making along with economic and technical considerations."

The means of achieving this is specified in section 102 (C) which requires the federal agencies to "include in every recommendation or

report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment" an environmental impact statement (EIS) prepared by the agency responsible for the recommendation for legislation or action. The EIS will be commented upon by "any federal agency which has jurisdiction, by law or special expertise, with respect to any environmental impact involved," and made available to the President, the CEQ and the public, and will "accompany the proposal through the existing agency review process."

Recognizing the far-reaching consequences of the Environmental Impact Statement procedure, Section 103 requires all agencies of the federal government to review their administrative regulations, current policies and procedures in order to ensure that they will permit full compliance with the purpose and nature of this new decision making process.

It is on this Environmental Impact Statement review process, the mechanism incorporating an environmental perspective into the decision making process of federal agencies, that we will now focus.

2. The CEQ Guidelines for the Preparation of Environmental Impact Statements (See Appendix B)

On August 1, 1973, the CEQ issued a revised set of guidelines for the preparation of EIS in order to translate section 102 of NEPA's broad language into more concrete terms incorporating much of NEPA's legal evolution in the courts and reflecting the experience gained and lessons learned during the three previous years.

2.1 Characterization of the Revised Guidelines

The proposed new guidelines emphasize that environmental consideration should be taken into account from the beginning of the decision making process,

enabling those responsible to increase the degree of public participation, itself the other major emphasis of the guidelines.

They encourage the use of program or generic impact statements to cover a number of related individual actions (policy impact statement), and they explicitly require agencies to discuss the secondary environmental impact of their actions, particularly on energy consumption, population concentration, and growth (sewers and highway construction, for example).

2.2 The Environmental Impact Statement Review Process (Summary of the guidelines, Appendix B)

i. Type of actions covered

"Major federal actions significantly affecting the quality of the human environment," are covered by Section 102(c) of NEPA. Action here means legislative and administrative action. Along with the requirement that the agencies continually review their policies, procedures and regulations to ensure full compliance with the purposes of NEPA, it is also required for them to develop specific criteria and methods for identifying those actions likely to require EIS, in consultation with CEQ.

In order to insure public information, those procedures must be regularly published and up-dated in the Federal Register. Along this line, agency procedures are required to include an early notice system for informing the public of the decision to prepare a draft environmental statement of proposed administrative action, and for soliciting comments that may be helpful in preparing the statement.

If the agency decides not to prepare an EIS, this information is to be published in the Federal Register with a notice setting forth the agency's reasons for such a decision.

ii. Preparing draft environmental statements; public hearings

Prior to the first significant point of decision in the agency review process, a point which must be defined in the agency's procedures for compliance with NEPA, a draft EIS should be prepared and circulated for comment from the CEQ, federal, state and local agencies. and the public. This must permit the agency decision makers and outside reviewers to give meaningful consideration to the environmental issues involved. To the fullest extent possible, whenever appropriate, public hearings should be held. The agency's procedure should indicate explicitly the kinds of decisions which utilize public hearings.

All comments received are carefully evaluated and considered in the decision process. A final EIS with substantive comments attached is then issued and circulated.

.ii. Content of an EIS

The information must be easily understandable to the non-specialist. The agency should indicate how the information has been obtained. Emphasis is put on the importance of a multi-disciplinary approach which would insure the integrated use of natural and social sciences for the preparation of the EIS as well as for the whole planning process.

The EIS itself covers the following points:

1. A description of the proposed action, a statement of its purpose and a description of the environment affected.
2. The relationship of the proposed action to land use plans, policies and controls for the affected area.
3. The probable impact of the proposed action on the environment, both direct and indirect (highway and sewer investments inducing local and population growth.)

4. Alternatives to the proposed action in any proposal which involves unresolved conflicts concerning alternative uses of available resources. Sufficient analysis of such alternatives and their environmental benefits, costs, and risks should accompany the proposed action through the agency review process in order not to prematurely foreclose options which might enhance environmental quality or have less detrimental effects.

5. Any probable adverse environmental effect which cannot be avoided.

6. A discussion of the extent to which the proposed action involves trade-offs between short-term environmental gains at the expense of long-term losses, or vice-versa, and the extent to which the proposed action forecloses future options.

7. Any irreversible and irretrievable commitments of resources that would be involved in the proposed action, should it be implemented.

8. An indication of what other interests and considerations of federal policy are thought to offset the environmental adverse effect of the proposed action.

iv. Review of draft EIS by federal, state, and local agencies and the public

Comments may be made on the draft EIS within 45 days. Such comments should emphasize the assessment of the environmental impact, the acceptability of that impact, and may recommend modifications to the proposed course of action.

Commenting entities are the federal agencies with jurisdiction, by law or special expertise, with respect to any environmental impact involved. The Environmental Protection Agency (EPA) has a duty to make comments regarding the compatibility of the action with the Clean Air Act and NEPA.

State and local agencies can comment, too, as can the public. Draft EIS should be made available to individuals and organizations on request; and its existence should be publicized in local newspapers, for example.

v. Preparation and circulation of final EIS

All substantive comments received on the draft should be attached to the final statement and should make a meaningful reference in the final EIS of any responsible opposing view not adequately discussed in the draft statement, and should indicate the agency's response to the issue raised.

vi. Transmittal of statements to the CEQ

Copies of the final EIS are made available to the CEQ and relevant commenting entities. No administrative action can be taken sooner than thirty days after this moment. The CEQ publishes weekly in the Federal Register the EIS received during the week that are available for public comments. We can notice here that CEQ does not approve or disapprove federal actions on the basis of EIS submitted to it, nor does it review all EIS. It is the Environmental Protection Agency (EPA), through its administrat that is required to review and comment in writing on all those actions subjec to NEPA impact statements, and to determine whether the action proposed in the statement is environmentally satisfactory. If it is found unsatisfactory EPA draws the attention of the CEQ to the problem so that the final decision will be made on a higher administrative level.

3. The Enforcement of NEPA; the Role of the Courts

Since NEPA, like many other reform legislation, is cast in terms of a general mandate and broad delegation of authority, it has been the responsibility of the courts to ensure that the legislation becomes a reality. This

is due to the specificity of the U.S. Judicial system which gives the courts the responsibility for interpreting statutes and other pieces of legislation. This is all the more important that the interpretations made by a court of appeals automatically acquires almost the power of law, because its interpretation has to be followed by all lower courts. (This system is specific to England and ex-British colonies.) It shows why it is important to review the major interpretations of the courts, all the more that, five years after its enactment, NEPA caused 500 law suits covering almost all possible controversies.

3.1 Standing

Since the mid 1960's, there has been a very noticeable expansion of the requirements for standing (to stand is to bring a law suit which is receivable by a court). The NEPA cases have still expanded the requirements creating new legal interests and grounds to sue, like the public's right to know, to participate and have the future generations protected. In other words, the courts have ruled that practically any citizen is allowed standing in NEPA cases. This is very important because it allowed environmentalists groups to sue and, as the courts interpreted NEPA rather strictly as we will see, it greatly increased the impact of NEPA on the actual decision making process of the federal agencies.

3.2 The Requirement of Strict Compliance

NEPA contends that "to the fullest extent possible, the policies, regulations. . ."[3] The phrase "to the fullest extent possible" has become the touchstone of NEPA interpretation; it has been given a forceful interpretation in the case of "Calvert Cliff's Coordinating Committee vs. The Atomic Energy Commission," which led to giving special vigor to the action-forcing provisions of NEPA. This case set the tone for many other court cases. In

other words, the courts have decided that section 102 of NEPA was subject to a strict standard of compliance and consequently many agencies have been ordered by the courts to re-do their EIS, resulting in the backlog of 110 nuclear power plants. In 102(B), NEPA uses the words " consideration of the environment," which have been interpreted in Calvert Cliff's in terms of a balancing or trading-off of environmental factors against economic and technical ones. Hence, the details of the manner in which an agency conducted its final decision making process will be subject to close judicial scrutiny under NEPA. The courts can review whether the decision gave sufficient weight to environmental values. However, subsequent cases showed that it doesn't mean a cost-benefit analysis is required; this leaves some room for subjective interpretation, as shown in another major court decision, "National Helium vs. Morton" which said that an EIS is acceptable if:

1. it discusses all of the five procedural requirements of NEPA,
2. it constitutes an "objective good faith" compliance with the demands of NEPA,
3. it contains a reasonable discussion of the subject matter involved in the five required areas.

The court insisted one should look for "adequacy and completeness of an EIS, not perfection."

3.3 Content of an Adequate EIS

The starting point is the statutory phrase "detailed statement." A first interpretation has been for the courts to declare that a statement's adequacy, in the end, is measured by its functional usefulness in decision making; an EIS should enable a decision maker to consider environmental factors in good faith. A second type of interpretation says that the EIS

is reasonably detailed if:

1. it is understandable and non-conclusory,
2. it refers to the full range of knowledge,
3. it discusses certain impacts which are typical of some types of action.

This has led the courts to require that the final EIS should include the comments and points of view even of those the agency disagrees violently with, provided they are based on scientific grounds. Courts have also required the detailed statements on "alternatives to the proposed action," one of them being to take no action at all. The statement should include a discussion of the environmental consequences of those alternatives. In the line of the strict compliance with NEPA, courts have rejected EIS which had not been circulated for comments. Furthermore, the comments must be meaningfully employed in the preparation of the final EIS, and be discussed.

In fact, the courts do review whether the agency acted within the scope of its authority, whether the decision reached was arbitrary, capricious, and whether the agency failed to consider all relevant factors in reaching its decision.

3.4 Conclusion

The courts have been vigorous in reviewing compliance by the federal bureaucracy with NEPA, and, even more, they have been the major architects of NEPA's requirements.

There are, of course, many other important interpretations made by the courts which we have not time to discuss here, but, what we have seen is enough to assert that, for better or for worse, NEPA and its action-forcing procedure, the EIS requirements have actually been, mainly through

the decisive action of the courts, forced into the heart of the federal agencies' decision making process. As it has been said, NEPA, as it operates today, is truly the stepchild of the judiciary.

4. NEPA in Practice

In five years, more than 6,000 EIS have been done; 85% of them by the Department of Transportation, the Corps of Engineers, the Departments of Agriculture, of the Interior, and the Atomic Energy Commission, ranging from the impact statement of the sale of oil and gas leases on the outer continental shelf,-to the one of a priority system for the allocation of low sulfur petroleum products and to the impact of the Washington D.C. mass transit system.

Let us look at the context and the concrete results of this massive application of the EIS procedure

4.1 Evolution of the Scope of NEPA

The 59 concerned federal agencies, including the CIA!, have developed their own procedures of decision making process to comply with NEPA, on the model of the guidelines of the CEQ discussed earlier. The agencies have conducted numerous training sessions, workshops and seminars to familiarize their staffs with the new procedures. Furthermore, since 1970, 21 states have adopted EIS requirements for state agencies similar to those set forth by NEPA. Some cities having legislative power, such as New York, have adopted acts similar to NEPA to regulate city agencies. Six states even require an economic impact statement added to the EIS, and some states require the EIS for private actions or investments, California being the state with the strongest provisions in that sense. This general trend of broadening the scope of NEPA has created some material problems of limited funds and staff allocated to implement the requirements, but one

can say that, even though integration of a state EIS into a state's decision making will take some time, the process has already begun.

4.2 Evolution of the practice of NEPA.

At the very beginning, most agencies thought the EIS requirement was not applicable to most of their programs, and that, anyway, it could be prepared by their administrative staffs as a finishing touch when the project went forward for final agency approval. The Trans-Alaska pipeline case gave reality and importance to NEPA, and focused the attention on the EIS process

From mid-1970 to mid-1973, there has been a transition period marked by the development of successive CEQ guidelines which helped each time reducing the uncertainty over NEPA requirements by integrating the rapidly expanding base of agency experience and codifying the major court decisions that were being handed down. In July 1971, in the "Calvert Cliff" case, one of the major NEPA decisions, the court declared that the procedures of the Atomic Energy Commission were unacceptable. This decision significantly broadened the range of issues which the agencies were required to consider, and led to increasing development of technical expertise, necessitated the development of new technical and cost benefit analysis concepts, and led to the adoption of new approaches to public hearings.

By 1973, the initial uncertainty and disruption had been more or less overcome. The promulgation of the revised CEQ guidelines, on August 1, 1973 showed the process for the integration of NEPA into agencies' operations. This accent is put on the development of policy impact statements as well as the integration, step by step since the early stages of the planning process of the EIS requirement, the involvement of the public, and the decision making

process, specifying the role of the draft EIS, the importance of the careful evaluation of the alternatives to the proposed action and the need to take the secondary impacts into account. The trend is now the expansion of the EIS process towards state agencies and the private sector operations.

3. The Concrete Results of NEPA

Rather than sudden spectacular material alteration of the federal programs, one has the subjective impression that NEPA has begun to cause some fundamental changes in the agencies' decision making process, so that the machinery for proper agency review of actions is in place, even if it has not yet been extensively used to achieve better substantive results. If NEPA's ultimate goal is a better environment through better federal decision making, then some steps in the right direction have already been done. This is not to say, of course, that no direct results have already ocurred. For example, over the past three years, there have been many modifications in nuclear plant design, including redesign of intake structures and major cooling systems, modifications of the thermal flume and the radiological and the chemical waste systems, rerouting of transmission lines, installation of fish screens, redesign of causeways and new studies of alternative cooling systems. Many reservoirs and stream channelization projects have been delayed, modified, or even abandoned. But, as CEQ's former Chairman, Russel Train put it, NEPA's implementation is iceberglike: the showy, controversial tip that involves public attention is complemented by the massive bulk of change that lies beneath the surface, hidden from view, but fundamentally altering the way the federal government responds to environmental problems. And here lies the hope of environmental improvement in the future and in the long run.

5. Learning from NEPA; Critique and Perspective

5.1 The Quality of the EIS; the Methodological Problem

Admittedly, the first EIS were of poor quality. There was little understanding of how to do environmental forecasting. This, in turn, reduced the benefits of the EIS process. Most of the first EIS were lengthy laundry lists: checking the potential impact on all kinds of plant and animal species with little attention to the secondary effects of the project under consideration (inducing industrial growth, for example), and little effort to synthesize the scattered impact findings.

The quality of the EIS has improved significantly since then, partly because the CEQ guidelines emphasize the notions of secondary impact and EIS as a continuing effort all along the decision making process; partly because the courts have sometimes ordered the agencies to do so and they ha had to quickly increase the manpower effort devoted to the preparation of the EIS; and partly because our scientific and methodological knowledge has increased. To be more specific about this point, environmental assessment consists of two separate processes: environmental impact analysis which involves identifying and forecasting environmental change, and describing the implications of such change, and impact evaluation which involves making trade-offs among impacts and arriving at a preference ordering of alternative actions.

Impact analysis consists mainly of identifying the scope of the problem both in spatial and temporal terms, identifying the basic elements concerned, and then taking explicitly into account the interrelationship between those elements, addressing the problem of "feedback-loops" and the fact that many causal linkages occur only over extremely long periods of time.

Impact evaluation raises the question of the relative roles of the decision makers and the "experts" because, at this stage, no judgement even those of the "experts"--can be value free. One has to decide what the relevant variables are, decide the "worth" of each impact and its "importance" in order to somehow aggregate those impacts and arrive at a final evaluation. If one adds to these "decisions" to be made, the facts of lack of data and knowledge and the need to assume linear relationships between factors, it will be seen that we are far from scientific judgement. There is plenty of room for improvement.

The Environmental Protection Agency is developing methodologies for analyzing the environmental aspects of different types of projects, along with the Institute for Ecology. Major efforts are made in the developing of a reference document containing the latest information on the environmental effects of every type of energy system.

These efforts and others like them will result in increased ability to prepare useful and accurate environmental forecasts. Nevertheless, the lack of accuracy of the methodologies and the lack of data are still a very real threat to the credibility of many EIS. This is likely to last for the next few years.

5.2 The Cost of NEPA

First of all, there is the expense of manpower. The Atomic Energy Commission, for example, invests two to five man years for each EIS. And the cost of this labor is very high, being highly skilled. Secondly, there are all kinds of costs related to the delaying of federal programs. Some studies are actually being done on the consequences of the EIS procedure on the cost of energy. Even though the price increase is a very small percent-

age of the total price, it still cannot be overlooked. More important, perhaps, increased delays increase the complexity and risk of inaccuracy of the whole planning process: planners have to prepare plans for a more distant time horizon if they add the EIS time to the planning and construction time. In the actual period where many parameters change so quickly and so suddenly, this might prove to be a grave handicap by decreasing the rapidity of response of a society to a problem. A third type of cost is organizational expense: such a change in the planning and decision making process of long established agencies has been quite disruptive in many cases decreasing the efficiency of work. Even though agencies have now adapted to the new system, there might be some traces of disruption and sterilizing internal conflict for long.

The response to this critique, based on the cost of NEPA, is that the reform of federal decision making which NEPA brings about will eventually save more time, money and bother than the NEPA procedure wastes. In short, it might well be that NEPA is "cost effective" because it brings careful analysis of the effects of government action and reduces the risk of ill-advised projects which can waste much more money than any EIS.

5.3 International Development

NEPA, and its action forcing procedure, the EIS, was the first law of its kind to be passed in the world. Now Australia and Canada have similar legislations. NEPA has also attracted a lot of attention in several European countries.

The question is whether other countries, and especially developing countries, could profit by EIS type of procedure. Whatever the answer, it is clear that the U.S. Judicial System is so particular that any procedure designed to improve the decision making process to better take the environ-

ment into account, would be very differently elaborated and enforced. Furthermore, any reflection about the usefulness of an EIS-type process must be based on an appraisal of the costs and benefits which would occur. As the same resources are not scarce in all countries, an EIS process might not be cost effective in all cases. In many countries the scarce resource is skilled manpower and capital, whereas in the U.S., it is the assimilative capacity of the environment.

Other consequences which might be of some importance are the international trade modifications. The United States has argued that it would not be fair for them to be less competitive in international markets because of the rigor of their environmental standards (Stockholm, 1972), and some countries have feared that they tie their "aid" to projects which have been through an EIS-type of process.*

Conclusion

In our opinion, the major interest of NEPA and its action forcing procedure, the EIS, is that it improves the decision making process:

i. by a systematic accounting of consequencies of a project and assessment of the general public needs and preferences;

ii. by enabling to appraise what are the trade-offs among the various conflicting objectives in the detailed review and evaluation of the various alternatives of the project;

iii. and, generally, by insuring that the final project fulfills and embodies as much as possible the set of priorities and objectives which a given society sees as best suited to increase its general welfare.

*Cf. the paper "Environmental Management, Economic Development and Social Welfare," Appendix B.

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NEPA is an example of a powerful procedural tool which has improved the decision making process by reducing the gap between the actual decisions on action or projects and the objectives of a society, which is usually the major inconsistency in that process. Whether a society chooses to emphasize the environment or something else is another matter. The important point is that, no matter what the emphasis is on, no matter where a society chooses to place its "optimal pollution point," an EIS like process is a useful means to reach it more consistently and rationally.

*Ibid.

Footnotes

1. The first, second, third, fourth and fifth Annual report of the Council on Environmental Quality, U. S. Government Printing Office, Washington, D.C. have already been published.

2. This chapter is inspired by Hugh J. Yarrington, "The National Environmental Policy Act," in Environment Reporter, monograph No. 17, vol. 4 no. 36, January 4, 1974, published by the Bureau of National Affairs, Inc. and Frederick R. Anderson, NEPA in the Courts, published by Resources for the Future, Inc., distributed by the Johns Hopkins University Press, Baltimore and London.

3. See NEPA, Appendix A.

4. Inspired by the Fifth Annual Report of the CEQ, U. S. Government Printing Office, chapter 4.

APPENDIX B

The National Environmental Policy Act of 1969, Public Law 91-190 January 1, 1970 (42 U.S.C. 4321-4347)

An Act to establish a national policy for the environment, to provide for the establishment of a Council on Environmental Quality, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Environmental Policy Act of 1969."

Purpose

SEC. 2. The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

Title I

Declaration of National Environmental Policy

SEC. 101. (a) The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding

technological advances and recognizing further the critical importance of restoring and maintaining environmental quality to the overall welfare and development of man, declares that it is the continuing policy of the Federal Government, in cooperation with State and local governments, and other concerned public and private organizations, to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans.

(b) In order to carry out the policy set forth in this Act, it is the continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources to the end that the Nation may—

(1) Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;

(2) Assure for all Americans safe, healthful, productive, and esthetically and culturally pleasuring surroundings;

(3) Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;

(4) Preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity, and variety of individual choice;

(5) Achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and

(6) Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

(c) The Congress recognizes that each person should enjoy a healthful environment and that each person has a responsibility to contribute to the preservation and enhancement of the environment.

SEC. 102. The Congress authorizes and directs that, to the fullest extent possible: (1) the policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with the policies set forth in this Act, and (2) all agencies of the Federal Government shall—

(A) Utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment;

(B) Identify and develop methods and procedures, in consultation with the Council on Environmental Quality established by title II of this Act, which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations;

(C) Include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on—

(i) The environmental impact of the proposed action,

(ii) Any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) Alternatives to the proposed action,

(iv) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

(v) Any irreversible and irretrievable commitments of resources

which would be involved in the proposed action should it be implemented.

Prior to making any detailed statement, the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to any environmental impact involved. Copies of such statement and the comments and views of the appropriate Federal, State, and local agencies, which are authorized to develop and enforce environmental standards, shall be made available to the President, the Council on Environmental Quality and to the public as provided by section 552 of title 5, United States Code, and shall accompany the proposal through the existing agency review processes;

(D) Study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources;

(E) Recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment;

(F) Make available to States, counties, municipalities, institutions, and individuals, advice and information useful in restoring, maintaining, and enhancing the quality of the environment;

(G) Initiate and utilize ecological information in the planning and development of resource-oriented projects; and

(H) Assist the Council on Environmental Quality established by title II of this Act.

SEC. 103. All agencies of the Federal Government shall review their present statutory authority, administrative regulations, and current policies and procedures for the purpose of determining whether there are any deficiencies or inconsistencies therein which prohibit full compliance with the purposes and provisions of this Act and shall propose to the President not later than July 1, 1971, such measurers as may be necessary to bring thier authority and policies into conformity with the intent, purposes, and procedures set forth in this Act.

SEC. 104. Nothing in section 102 or 103 shall in any way affect the specific statutory obligations of any Federal agency (1) to comply with criteria or standards of environmental quality, (2) to coordinate or consult with any other Federal or State agency, or (3) to act, or refrain from acting contingent upon the recommendations or certification of any other Federal or State agency.

SEC. 105. The policies and goals set forth in this Act are supplementary to those set forth in existing authorizations of Federal agencies.

Title II

Council on Environmental Quality

SEC. 201. The President shall transmit to the Congress annually beginning July 1, 1970, an Environmental Quality Report (hereinafter referred to as the "report") which shall set forth (1) the status and condition of the major natural, manmade, or altered environmental classes of the Nation, including, but not limited to, the air, the aquatic, including marine, estuarine, and fresh water, and the terrestrial environment, including, but not limited to, the forest, dryland, wetland, range, urban, suburban and rural environment; (2) current and foreseeable trends in the quality, management and utilization of such environments and the effects of those trends on the social, economic, and other requirements of the Nation; (3) the adequacy of available natural resources for fulfilling human and economic requirements of the Nation in the

light of expected population pressures; (4) a review of the programs and activities (including regulatory activities) of the Federal Government, the State and local governments, and nongovernmental entities or individuals with particular reference to their effect on the environment and on the conservation, development and utilization of natural resources; and (5) a program for remedying the deficiencies of existing programs and activities, together with recommendations for legislation.

SEC. 202. There is created in the Executive Office of the President a Council on Environmental Quality (hereinafter referred to as the "Council"). The Council shall be composed of three members who shall be appointed by the President to serve at his pleasure, by and with the advice and consent of the Senate. The President shall designate one of the members of the Council to serve as Chairman. Each member shall be a person who, as a result of his training, experience, and attainments, is exceptionally well qualified to analyze and interpret environmental trends and information of all kinds; to appraise programs and activities of the Federal Government in the light of the policy set forth in title I of this Act; to be conscious of and responsive to the scientific, economic, social, esthetic, and cultural needs and interests of the Nation; and to formulate and recommend national policies to promote the improvement of the quality of the environment.

SEC. 203. The Council may employ such officers and employees as may be necessary to carry out its functions under this Act. In addition, the Council may employ and fix the compensation of such experts and consultants as may be necessary for the carrying out of its functions under this Act, in accordance with section 3109 of title 5, United States Code (but without regard to the last sentence thereof).

SEC. 204. It shall be the duty and function of the Council—

(1) To assist and advise the President in the preparation of the Environmental Quality Report required by section 201;

(2) To gather timely and authoritative information concerning the conditions and trends in the quality of the environment both current and prospective, to analyze and interpret such information for the purpose of determining whether such conditions and trends are interfering, or are likely to interfere, with the achievement of the policy set forth in title I of this Act, and to compile and submit to the President studies relating to such conditions and trends;

(3) To review and appraise the various programs and activities of the Federal Government in the light of the policy set forth in title I of this Act for the purpose of determining the extent to which such programs and activities are contributing to the achievement of such policy, and to make recommendations to the President with respect thereto;

(4) To develop and recommend to the President national policies to foster and promote the improvement of environmental quality, to meet the conservation, social, economic, health, and other requirements and goals of the Nation;

(5) To conduct investigations, studies, surveys, research, and analyses relating to ecological systems and environmental quality;

(6) To document and define changes in the natural environment, including the plant and animal systems, and to accumulate necessary data and other information for a continuing analysis of these changes or trends and an interpretation of their underlying causes;

(7) To report at least once each year to the President on the state and condition of the environment; and

(8) To make and furnish such studies, reports thereon, and recommendations with respect to matters of policy and legislation as the President may request.

SEC. 205. In exercising its powers, functions, and duties under this Act, the Council shall—

(1) Consult with the Citizens' Advisory Committee on Environmental Quality established by Executive Order No. 11472, dated May 29, 1969, and with such representatives of science, industry, agriculture, labor, conservation organizations, State and local governments and other groups, as it deems advisable; and

(2) Utilize, to the fullest extent possible, the services, facilities and information (including statistical information) of public and private agencies and organizations, and individuals, in order that duplication of effort and expense may be avoided, thus assuring that the Council's activities will not unnecessarily overlap or conflict with similar activities authorized by law and performed by established agencies.

SEC. 205. Members of the Council shall serve full time and the Chairman of the Council shall be compensated at the rate provided for Level II of the Executive Schedule Pay Rates (5 U.S.C. 5313). The other members of the Council shall be compensated at the rate provided for Level IV of the Executive Schedule Pay Rates (5 U.S.C. 5315).

SEC. 207. There are authorized to be appropriated to carry out the provisions of this Act not to exceed $300,000 for fiscal year 1970, $700,000 for fiscal year 1971, and $1 million for each fiscal year thereafter.

Approved January 1, 1970.

APPENDIX D

Preparation of Environmental Impact Statements: Guidelines*

On May 2, 1973, the Council on Environmental Quality published in the FEDERAL REGISTER, for public comment, a proposed revision of its guidelines for the preparation of environmental impact statements. Pursuant to the National Environmental Policy Act (P.L. 91-190, 42 U.S.C. 4321 et seq.) and Executive Order 11514 (35 FR 4247) all Federal departments, agencies, and establishments are required to prepare such statements in connection with their proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The authority for the Council's guidelines is set forth below in § 1500.1. The specific policies to be implemented by the guidelines is set forth below in § 1500.2.

The Council received numerous comments on its proposed guidelines from environmental groups, Federal, State, and local agencies, industry, and private individuals. Two general themes were presented in the majority of the comments. First, the Council should increase the opportunity for public involvement in the impact statement process. Second, the Council should provide more detailed guidance on the responsibilities of Federal agencies in light of recent court decisions interpreting the Act. The proposed guidelines have been revised in light of the specific comments relating to these general themes, as well as other comments received, and are now being issued in final form.

The guidelines will appear in the Code of Federal Regulations in Title 40, Chapter V, at Part 1500. They are being codified, in part, because they affect State and local governmental agencies, environmental groups, industry, and private individuals, in addition to Federal agencies, to which they are specifically directed, and the resultant need to make them widely and readily available.

Sec.

1500.1 Purpose and authority.
1500.2 Policy.
1500.3 Agency and OMB procedures.
1500.4 Federal agencies included; effect of the act on existing agency mandates.
1500.5 Types of actions covered by the act.
1500.6 Identifying major actions significantly affecting the environment.
1500.7 Preparing draft environmental statements; public hearings.
1500.8 Content of environmental statements.
1500.9 Review of draft environmental statements by Federal, Federal, State, and local agencies and by the public.
1500.10 Preparation and circulation of final environmental statements.
1500.11 Transmittal of statements to the Council; minimum period for review, requests by the Council.

*38 Fed. Reg. 20550-20562, August 1, 1973.

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1500.12 Legislative actions.
1500.13 Application of section 102(2)(C) procedure to existing projects and programs.
1500.14 Supplementary guidelines; evaluation of procedures.

Sec.

Appendix I Summary to accompany draft and final statements.

Appendix II Areas of environmental impact and Federal agencies and Federal State agencies with jurisdiction by law or special expertise to comment thereon.

Appendix III Offices within Federal agencies and Federal-State agencies for information regarding the agencies' NEPA activities and for receiving other agencies' impact statements for which comments are requested.

Appendix IV State and local agency review of impact statements.

AUTHORITY: National Environmental Act (P.L. 91-190, 42 U.S.C. 4321 et seq.) and Executive Order 11514.

§ 1500.1 Purpose and authority.

(a) This directive provides guidelines to Federal departments, agencies, and establishments for preparing detailed environmental statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment as required by section 102(2)(C) of the National Environmental Policy Act (P.L. 91-190, 42 U.S.C. 4321 et. seq.) (hereafter "the Act"). Underlying the preparation of such environmental statements is the mandate of both the Act and Executive Order 11514 (35 FR 4247) of March 5, 1970, that all Federal agencies, to the fullest extent possible, direct their policies, plans and programs to protect and enhance environmental quality. Agencies are required to view their actions in a manner calculated to encourage productive and enjoyable harmony between man and his environment, to promote efforts preventing or eliminating damage to the environment and biosphere and stimulating the health and welfare of man, and to enrich the understanding of the ecological systems and natural resources important to the Nation. The objective of section 102(2)(C) of the Act and of these guidelines is to assist agencies in implementing these policies. This requires agencies to build into their decisionmaking process, beginning at the earliest possible point, an appropriate and careful consideration of the environmental aspects of proposed action in order that adverse environmental effects may be avoided or minimized and environmental quality previously lost may be restored. This directive also provides guidance to Federal, State, and local agencies and the public in commenting on statements prepared under these guidelines.

(b) Pursuant to section 204(3) of the Act the Council on Environmental Quality (hereafter "the Council") is assigned the duty and function of reviewing and appraising the programs and activities of the Federal Government, in the light of the Act's policy, for the purpose of determining the extent to which such programs and activities are contributing to the achievement of such policy, and to make recommendations to the President with respect thereto. Section 102(2)(B) of the Act directs all Federal agencies to identify and develop methods and procedures, in consultation with the Council, to insure that unquantified environmental values be given appropriate consideration in decisionmaking along with economic and technical considerations; section 102(2)(C) of the Act directs that copies of all environmental impact statements be filed with the Council; and section 102(2)(H) directs all Federal agencies to assist the Council in the performance of its functions. These provisions have been supplemented in sections 3(h) and (i) of Executive Order 11514 by directions that the Council issue guidelines to Federal agencies for preparation of environmental impact statements and such other instructions to agencies and requests for reports and information as may be required to carry out the Council's responsibilities under the Act.

§ 1500.2 Policy.

(a) As early as possible and in all cases prior to agency decision concerning recommendations or favorable reports on proposals for (1) legislation significantly affecting the quality of the human environment (see §§ 1500.5(i) and 1500.12) (hereafter "legislative actions") and (2) all other major Federal actions significantly affecting the quality of the human environment (hereafter "administrative actions"), Federal agencies will, in consultation with other appropriate Federal, State and local agencies and the public assess in detail the potential environmental impact.

(b) Initial assessments of the environmental impacts of proposed action should be undertaken concurrently with initial technical and economic studies and, where required, a draft environmental impact statement prepared and circulated for comment in time to accompany the proposal through the existing agency review processes for such action. In this process, Federal agencies shall:

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(1) Provide for circulation of draft environmental statements to other Federal, State, and local agencies and for their availability to the public in accordance with the provisions of these guidelines; (2) consider the comments of the agencies and the public; and (3) issue final environmental impact statements responsive to the comments received. The purpose of this assessment and consultation process is to provide agencies and other decisionmakers as well as members of the public with an understanding of the potential environmental effects of proposed actions, to avoid or minimize adverse effects wherever possible, and to restore or enhance environmental quality to the fullest extent practicable. In particular, agencies should use the environmental impact statement process to explore alternative actions that will avoid or minimize adverse impacts and to evaluate both the long- and short-range implications of proposed actions to man, his physical and social surroundings, and to nature. Agencies should consider the results of their environmental assessments along with their assessments of the net economic, technical and other benefits of proposed actions and use all practicable means, consistent with other essential considerations of national policy, to restore environmental quality as well as to avoid or minimize undesirable consequences for the environment.

§ 1500.3 Agency and OMB procedures.

(a) Pursuant to section 2(f) of Executive Order 11514, the heads of Federal agencies have been directed to proceed with measures required by section 102 (2)(C) of the Act. Previous guidelines of the Council directed each agency to establish its own formal procedures for (1) identifying those agency actions requiring environmental statements, the appropriate time prior to decision for the consultations required by section 102 (2)(C) and the agency review process for which environmental statements are to be available, (2) obtaining information required in their preparation, (3) designating the officials who are to be responsible for the statements, (4) consulting with and taking account of the comments of appropriate Federal, State and local agencies and the public, including obtaining the comment of the Administrator of the Environmental Protection Agency when required under section 309 of the Clean Air Act, as amended, and (5) meeting the requirements of section 2(b) of Executive Order 11514 for providing timely public information on Federal plans and programs with environmental impact. Each agency, including both departmental and subdepartmental components having such procedures, shall review its procedures and shall revise them, in consultation with the Council, as may be necessary in order to respond to requirements imposed by these revised guidelines as well as by such previous directives. After such consultation, proposed revisions of such agency procedures shall be published in the FEDERAL REGISTER no later than October 30, 1973. A minimum 45-day period for public comment shall be provided, followed by publication of final procedures no later than forty-five (45) days after the conclusion of the comment period. Each agency shall submit seven (7) copies of all such procedures to the Council. Any future revision of such agency procedures shall similarly be proposed and adopted only after prior consultation with the Council and, in the case of substantial revision, opportunity for public comment. All revisions shall be published in the FEDERAL REGISTER.

(b) Each Federal agency should consult, with the assistance of the Council and the Office of Management and Budget if desired, with other appropriate Federal agencies in the development and revision of the above procedures so as to achieve consistency in dealing with similar activities and to assure effective coordination among agencies in their review of proposed activities. Where applicable, State and local review of such agency procedures should be conducted pursuant to procedures established by Office of Management and Budget Circular No. A-85.

(c) Existing mechanisms for obtaining the views of Federal, State, and local agencies on proposed Federal actions should be utilized to the maximum extent practicable in dealing with environmental matters. The Office of Management and Budget will issue instructions, as necessary, to take full advantage of such existing mechanisms.

§ 1500.4 Federal agencies included; effect of the Act on existing agency mandates.

(a) Section 102(2)(C) of the Act applies to all agencies of the Federal Government. Section 102 of the Act provides that "to the fullest extent possible: (1) The policies, regulations, and public laws of the United States shall be interpreted and administered in accordance

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with the policies set forth in this Act," and section 105 of the Act provides that "the policies and goals set forth in this Act are supplementary to those set forth in existing authorizations of Federal agencies." This means that each agency shall interpret the provisions of the Act as a supplement to its existing authority and as a mandate to view traditional policies and missions in the light of the Act's national environmental objectives. In accordance with this purpose, agencies should continue to review their policies, procedures, and regulations and to revise them as necessary to ensure full compliance with the purposes and provisions of the Act. The phrase "to the fullest extent possible" in section 102 is meant to make clear that each agency of the Federal Government shall comply with that section unless existing law applicable to the agency's operations expressly prohibits or makes compliance impossible.

§ 1500.5 Types of actions covered by the Act.

(a) "Actions" include but are not limited to:

(1) Recommendations or favorable reports relating to legislation including requests for appropriations. The requirement for following the section 102 (2) (C) procedure as elaborated in these guidelines applies to both (i) agency recommendations on their own proposals for legislation (see § 1500.12); and (ii) agency reports on legislation initiated elsewhere. In the latter case only the agency which has primary responsibility for the subject matter involved will prepare an environmental statement.

(2) New and continuing projects and program activities: directly undertaken by Federal agencies; or supported in whole or in part through Federal contracts, grants, subsidies, loans, or other forms of funding assistance (except where such assistance is solely in the form of general revenue sharing funds, distributed under the State and Local Fiscal Assistance Act of 1972, 31 U.S.C. 1221 et. seq. with no Federal agency control over the subsequent use of such funds); or involving a Federal lease, permit, license certificate or other entitlement for use.

(3) The making, modification, or establishment of regulations, rules, procedures, and policy.

§ 1500.6 Identifying major actions significantly affecting the environment.

(a) The statutory clause "major Federal actions significantly affecting the quality of the human environment" is to be construed by agencies with a view to the overall, cumulative impact of the action proposed, related Federal actions and projects in the area, and further actions contemplated. Such actions may be localized in their impact, but if there is potential that the environment may be significantly affected, the statement is to be prepared. Proposed major actions, the enviornmental impact of which is likely to be highly controversial, should be covered in all cases. In considering what constitutes major action significantly affecting the environment, agencies should bear in mind that the effect of many Federal decisions about a project or complex of projects can be individually limited but cumulatively considerable. This can occur when one or more agencies over a period of years puts into a project individually minor but collectively major resources, when one decision involving a limited amount of money is a precedent for action in much larger cases or represents a decision in principle about a future major course of action, or when several Government agencies individually make decisions about partial aspects of a major action. In all such cases, an environmental statement should be prepared if it is reasonable to anticipate a cumulatively significant impact on the environment from Federal action. The Council, on the basis of a written assessment of the impacts involved, is available to assist agencies in determining whether specific actions require impact statements.

(b) Section 101(b) of the Act indicates the broad range of aspects of the environment to be surveyed in any assessment of significant effect. The Act also indicates that adverse significant effects include those that degrade the quality of the environment, curtail the range of beneficial uses of the environment, and serve short-term, to the disadvantage of long-term, environmental goals. Significant effects can also include actions which may have both beneficial and detrimental effects, even if on balance the agency believes that the effect will be beneficial. Significant effects also include secondary effects, as described more fully, for example, in § 1500.8(a)(iii)(B). The significance of a proposed action may also vary with the setting, with the result that an action that would have little impact in an urban area may be significant in a rural setting or vice versa. While a precise definition of environmental "significance," valid in all contexts, is not possible, effects to be considered in assessing significance in-

clude, but are not limited to, those outlined in Appendix II of these guidelines.

(c) Each of the provisions of the Act, except section 102(2)(C), applies to all Federal agency actions. Section 102(2)(C) requires the preparation of a detailed environmental impact statement in the case of "major Federal actions significantly affecting the quality of the human environment." The identification of major actions significantly affecting the environment is the responsibility of each Federal agency, to be carried out against the background of its own particular operations. The action must be a (1) "major" action, (2) which is a "Federal action," (3) which has a "significant" effect, and (4) which involves the "quality of the human environment." The words "major" and "significantly" are intended to imply thresholds of importance and impact that must be met before a statement is required. The action causing the impact must also be one where there is sufficient Federal control and responsibility to constitute "Federal action" in contrast to cases where such Federal control and responsibility are not present as, for example, when Federal funds are distributed in the form of general revenue sharing to be used by State and local governments (see § 1500.5(ii)). Finally, the action must be one that significantly affects the quality of the human environment either by directly affecting human beings or by indirectly affecting human beings through adverse effects on the environment. Each agency should review the typical classes of actions that it undertakes and, in consultation with the Council, should develop specific criteria and methods for identifying those actions likely to require environmental statements and those actions likely not to require environmental statements. Normally this will involve:

(i) Making an initial assessment of the environmental impacts typically associated with principal types of agency action.

(ii) Identifying on the basis of this assessment, types of actions which normally do, and types of actions which normally do not, require statements.

(iii) With respect to remaining actions that may require statements depending on the circumstances, and those actions determined under the preceding paragraph (C)(4)(ii) of this section as likely to require statements, identifying: (*a*) what basic information needs to be gathered; (*b*) how and when such information is to be assembled and analyzed; and (*c*) on what bases environmental assessments and decisions to prepare impact statements will be made. Agencies may either include this substantive guidance in the procedures issued pursuant to § 1500.3(a) of these guidelines, or issue such guidance as supplemental instructions to aid relevant agency personnel in implementing the impact statement process. Pursuant to § 1500.14 of these guidelines, agencies shall report to the Council by June 30, 1974, on the progress made in developing such substantive guidance.

(d) (1) Agencies should give careful attention to identifying and defining the purpose and scope of the action which would most appropriately serve as the subject of the statement. In many cases, broad program statements will be required in order to assess the environmental effects of a number of individual actions on a given geographical area (e.g., coal leases), or environmental impacts that are generic or common to a series of agency actions (e.g., maintenance or waste handling practices), or the overall impact of a large-scale program or chain of contemplated projects (e.g., major lengths of highway as opposed to small segments). Subsequent statements on major individual actions will be necessary where such actions have significant environmental impacts not adequately evaluated in the program statement.

(2) Agencies engaging in major technology research and development programs should develop procedures for periodic evaluation to determine when a program statement is required for such programs. Factors to be considered in making this determination include the magnitude of Federal investment in the program, the likelihood of widespread application of the technology, the degree of environmental impact which would occur if the technology were widely applied, and the extent to which continued investment in the new technology is likely to restrict future alternatives. Statements must be written late enough in the development process to contain meaningful information, but early enough so that this information can practically serve as an input in the decision-making process. Where it is anticipated that a statement may ultimately be required but that its preparation is still premature, the agency should prepare an evaluation briefly setting forth the reasons for its determination that a statement is not yet necessary. This evaluation should be periodically updated, particularly when significant new information becomes available concerning the

potential environmental impact of the program. In any case, a statement must be prepared before research activities have reached a stage of investment or commitment to implementation likely to determine subsequent development or restrict later alternatives. Statements on technology research and development programs should include an analysis not only of alternative forms of the same technology that might reduce any adverse environmental impacts but also of alternative technologies that would serve the same function as the technology under consideration. Efforts should be made to involve other Federal agencies and interested groups with relevant expertise in the preparation of such statements because the impacts and alternatives to be considered are likely to be less well defined than in other types of statements.

(e) In accordance with the policy of the Act and Executive Order 11514 agencies have a responsibility to develop procedures to insure the fullest practicable provision of timely public information and understanding of Federal plans and programs with environmental impact in order to obtain the views of interested parties. In furtherance of this policy, agency procedures should include an appropriate early notice system for informing the public of the decision to prepare a draft environmental statement on proposed administrative actions (and for soliciting comments that may be helpful in preparing the statement) as soon as is practicable after the decision to prepare the statement is made. In this connection, agencies should: (1) maintain a list of administrative actions for which environmental statements are being prepared; (2) revise the list at regular intervals specified in the agency's procedures developed pursuant to § 1500.3(a) of these guidelines (but not less than quarterly) and transmit each such revision to the Council; and (3) make the list available for public inspection on request. The Council will periodically publish such lists in the FEDERAL REGISTER. If an agency decides that an environmental statement is not necessary for a proposed action (i) which the agency has identified pursuant to § 1500.6(c)(4)(ii) as normally requiring preparation of a statement, (ii) which is similar to actions for which the agency has prepared a significant number of statements, (iii) which the agency has previously announced would be the subject of a statement, or (iv) for which the agency has made a negative determination in response to a request from the Council pursuant to § 1500.11(f), the agency shall prepare a publicly available record briefly setting forth the agency's decision and the reasons for that determination. Lists of such negative determinations, and any evaluations made pursuant to §-1500.6 which conclude that preparation of a statement is not yet timely, shall be prepared and made available in the same manner as provided in this subsection for lists of statements under preparation.

§ 1500.7 Preparing draft environmental statements; public hearings.

(a) Each environmental impact statement shall be prepared and circulated in draft form for comment in accordance with the provisions of these guidelines. The draft statement must fulfill and satisfy to the fullest extent possible at the time the draft is prepared the requirements established for final statements by section 102(2)(C). (Where an agency has an established practice of declining to favor an alternative until public comments on a proposed action have been received, the draft environmental statement may indicate that two or more alternatives are under consideration.) Comments received shall be carefully evaluated and considered in the decision process. A final statement with substantive comments attached shall then be issued and circulated in accordance with applicable provisions of §§ 1500.10, 1500.11, or 1500.12. It is important that draft environmental statements be prepared and circulated for comment and furnished to the Council as early as possible in the agency review process in order to permit agency decisionmakers and outside reviewers to give meaningful consideration to the environmental issues involved. In particular, agencies should keep in mind that such statements are to serve as the means of assessing the environmental impact of proposed agency actions, rather than as a justification for decisions already made. This means that draft statements on administrative actions should be prepared and circulated for comment prior to the first significant point of decision in the agency review process. For major categories of agency action, this point should be identified in the procedures issued pursuant to § 1500.3(a). For major categories of projects involving an applicant and identified pursuant to § 1500.6(c)(c)(ii) as normally requiring the preparation of a statement, agencies should include in their procedures provisions limiting actions which an applicant is permitted to take prior to completion

and review of the final statement with respect to his application.

(b) Where more than one agency (1) directly sponsors an action, or is directly involved in an action through funding, licenses, or permits, or (2) is involved in a group of actions directly related to each other because of their functional interdependence and geographical proximity, consideration should be given to preparing one statement for all the Federal actions involved (see § 1500.6(d)(1)). Agencies in such cases should consider the possibility of joint preparation of a statement by all agencies concerned, or designation of a single "lead agency" to assume supervisory responsibility for preparation of the statement. Where a lead agency prepares the statement, the other agencies involved should provide assistance with respect to their areas of jurisdiction and expertise. In either case, the statement should contain an environmental assessment of the full range of Federal actions involved, should reflect the views of all participating agencies, and should be prepared before major or irreversible actions have been taken by any of the participating agencies. Factors relevant in determining an appropriate lead agency include the time sequence in which the agencies become involved, the magnitude of their respective involvement, and their relative expertise with respect to the project's environmental effects. As necessary, the Council will assist in resolving questions of responsibility for statement preparation in the case of multi-agency actions. Federal Regional Councils, agencies and the public are encouraged to bring to the attention of the Council and other relevant agencies appropriate situations where a geographic or regionally focused statement would be desirable because of the cumulative environmental effects likely to result from multi-agency actions in the area.

(c) Where an agency relies on an applicant to submit initial environmental information, the agency should assist the applicant by outlining the types of information required. In all cases, the agency should make its own evaluation of the environmental issues and take responsibility for the scope and content of draft and final environmental statements.

(d) Agency procedures developed pursuant to § 1500.3(a) of these guidelines should indicate as explicitly as possible those types of agency decisions or actions which utilize hearings as part of the normal agency review process, either as a result of statutory requirement or agency practice. To the fullest extent possible, all such hearings shall include consideration of the environmental aspects of the proposed action. Agency procedures shall also specifically include provision for public hearings on major actions with environmental impact, whenever appropriate, and for providing the public with relevant information, including information on alternative courses of action. In deciding whether a public hearing is appropriate, an agency should consider: (1) The magnitude of the proposal in terms of economic costs, the geographic area involved, and the uniqueness or size of commitment of the resources involved; (2) the degree of interest in the proposal, as evidenced by requests from the public and from Federal, State and local authorities that a hearing be held; (3) the complexity of the issue and the likelihood that information will be presented at the hearing which will be of assistance to the agency in fulfilling its responsibilities under the Act; and (4) the extent to which public involvement already has been achieved through other means, such as earlier public hearings, meetings with citizen representatives, and/or written comments on the proposed action. Agencies should make any draft environmental statements to be issued available to the public at least fifteen (15) days prior to the time of such hearings.

§ 1500.8 Content of environmental statements.

(a) The following points are to be covered:

(1) A description of the proposed action, a statement of its purposes, and a description of the environment affected, including information, summary technical data, and maps and diagrams where relevant, adequate to permit an assessment of potential environmental impact by commenting agencies and the public. Highly technical and specialized analyses and data should be avoided in the body of the draft impact statement. Such materials should be attached as appendices or footnoted with adequate bibliographic references. The statement should also succinctly describe the environment of the area affected as it exists prior to a proposed action, including other Federal activities in the area affected by the proposed action which are related to the proposed action. The interrelationships and cumulative environmental impacts of the proposed action and other related Federal projects shall be presented in the statement. The amount of detail provided in such descriptions should be commensurate with the extent and expected impact of the

action, and with the amount of information required at the particular level of decisionmaking (planning, feasibility, design, etc.). In order to ensure accurate descriptions and environmental assessments, site visits should be made where feasible. Agencies should also take care to identify, as appropriate, population and growth characteristics of the affected area and any population and growth assumptions used to justify the project or program or to determine secondary population and growth impacts resulting from the proposed action and its alternatives (see paragraph (a)(i)(3)(ii), of this section). In discussing these population aspects, agencies should give consideration to using the rates of growth in the region of the project contained in the projection compiled for the Water Resources Council by the Bureau of Economic Analysis of the Department of Commerce and the Economic Research Service of the Department of Agriculture (the "OBERS" projection). In any event it is essential that the sources of data used to identify, quantify or evaluate any and all environmental consequences be expressly noted.

(2) The relationship of the proposed action to land use plans, policies, and controls for the affected area. This requires a discussion of how the proposed action may conform or conflict with the objectives and specific terms of approved or proposed Federal, State, and local land use plans, policies, and controls, if any, for the area affected including those developed in response to the Clean Air Act or the Federal Water Pollution Control Act Amendments of 1972. Where a conflict or inconsistency exists, the statement should describe the extent to which the agency has reconciled its proposed action with the plan, policy or control, and the reasons why the agency has decided to proceed notwithstanding the absence of full reconciliation.

(3) The probable impact of the proposed action on the environment.

(i) This requires agencies to assess the positive and negative effects of the proposed action as it affects both the national and international environment. The attention given to different environmental factors will vary according to the nature, scale, and location of proposed actions. Among factors to consider should be the potential effect of the action on such aspects of the environment as those listed in Appendix II of these guidelines. Primary attention should be given in the statement to discussing those factors most evidently impacted by the proposed action.

(ii) Secondary or indirect, as well as primary or direct, consequences for the environment should be included in the analysis. Many major Federal actions, in particular those that involve the construction or licensing of infrastructure investments (e.g., highways, airports, sewer systems, water resource projects, etc.), stimulate or induce secondary effects in the form of associated investments and changed patterns of social and economic activities. Such secondary effects, through their impacts on existing community facilities and activities, through inducing new facilities and activities, or through changes in natural conditions, may often be even more substantial than the primary effects of the original action itself. For example, the effects of the proposed action on population and growth may be among the more significant secondary effects. Such population and growth impacts should be estimated if expected to be significant (using data identified as indicated in § 1500.8(a)(1)) and an assessment made of the effect of any possible change in population patterns or growth upon the resource base, including land use, water, and public services, of the area in question.

(4) Alternatives to the proposed action, including, where relevant, those not within the existing authority of the responsible agency. (Section 102(2)(D) of the Act requires the responsible agency to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources"). A rigorous exploration and objective evaluation of the environmental impacts of all reasonable alternative actions, particularly those that might enhance environmental quality or avoid some or all of the adverse environmental effects, is essential. Sufficient analysis of such alternatives and their environmental benefits, costs and risks should accompany the proposed action through the agency review process in order not to foreclose prematurely options which might enhance environmental quality or have less detrimental effects. Examples of such alternatives include: the alternative of taking no action or of postponing action pending further study; alternatives requiring actions of a significantly different nature which would provide similar benefits with different environmental impacts (e.g., nonstructural alternatives to flood control programs, or mass transit alternatives to highway construction); alternatives related to different designs

or details of the proposed action which would present different environmental impacts (e.g., cooling ponds vs. cooling towers for a power plant or alternatives that will significantly conserve energy); alternative measures to provide for compensation of fish and wildlife losses, including the acquisition of land, waters, and interests therein. In each case, the analysis should be sufficiently detailed to reveal the agency's comparative evaluation of the environmental benefits, costs and risks of the proposed action and each reasonable alternative. Where an existing impact statement already contains such an analysis, its treatment of alternatives may be incorporated provided that such treatment is current and relevant to the precise purpose of the proposed action.

(5.) Any probable adverse environmental effects which cannot be avoided (such as water or air pollution, undesirable land use patterns, damage to life systems, urban congestion, threats to health or other consequences adverse to the environmental goals set out in section 101 (b) of the Act). This should be a brief section summarizing in one place those effects discussed in paragraph (a) (3) of this section that are adverse and unavoidable under the proposed action. Included for purposes of contrast should be a clear statement of how other avoidable adverse effects discussed in paragraph (a) (2) of this section will be mitigated.

(6) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. This section should contain a brief discussion of the extent to which the proposed action involves tradeoffs between short-term environmental gains at the expense of long-term losses, or vice versa, and a discussion of the extent to which the proposed action forecloses future options. In this context short-term and long-term do not refer to any fixed time periods, but should be viewed in terms of the environmentally significant consequences of the proposed action.

(7) Any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented. This requires the agency to identify from its survey of unavoidable impacts in paragraph (a) (5) of this section the extent to which the action irreversibly curtails the range of potential uses of the environment. Agencies should avoid construing the term "resources" to mean only the labor and materials devoted to an action. "Resources" also means the natural and cultural resources committed to loss or destruction by the action.

(8) An indication of what other interests and considerations of Federal policy are thought to offset the adverse environmental effects of the proposed action identified pursuant to paragraphs (a) (3) and (5) of this section. The statement should also indicate the extent to which these stated countervailing benefits could be realized by following reasonable alternatives to the proposed action (as identified in paragraph (a) (4) of this section) that would avoid some or all of the adverse environmental effects. In this connection, agencies that prepare cost-benefit analyses of proposed actions should attach such analyses, or summaries thereof, to the environmental impact statement, and should clearly indicate the extent to which environmental costs have not been reflected in such analyses.

(b) In developing the above points agencies should make every effort to convey the required information succinctly in a form easily understood, both by members of the public and by public decisionmakers, giving attention to the substance of the information conveyed rather than to the particular form, or length or detail of the statement. Each of the above points, for example, need not always occupy a distinct section of the statement if it is otherwise adequately covered in discussing the impact of the proposed action and its alternatives—which items should normally be the focus of the statement. Draft statements should indicate at appropriate points in the text any underlying studies, reports, and other information obtained and considered by the agency in preparing the statement including any cost-benefit analyses prepared by the agency, and reports of consulting agencies under the Fish and Wildlife Coordination Act, 16 U.S.C. 661 et seq., and the National Historic Preservation Act of 1966, 16 U.S.C. 470 et seq., where such consultation has taken place. In the case of documents not likely to be easily accessible (such as internal studies or reports), the agency should indicate how such information may be obtained. If such information is attached to the statement, care should be taken to ensure that the statement remains an essentially self-contained instrument, capable of being understood by the reader without the need for undue cross reference.

(c) Each environmental statement should be prepared in accordance with the precept in section 102(2)(A) of the Act that all agencies of the Federal Government "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and decisionmaking which may have an impact on man's environment." Agencies should attempt to have relevant disciplines represented on their own staffs; where this is not feasible they should make appropriate use of relevant Federal, State, and local agencies or the professional services of universities and outside consultants. The interdisciplinary approach should not be limited to the preparation of the environmental impact statement, but should also be used in the early planning stages of the proposed action. Early application of such an approach should help assure a systematic evaluation of reasonable alternative courses of action and their potential social, economic, and environmental consequences.

(d) Appendix I prescribes the form of the summary sheet which should accompany each draft and final environmental statement.

§ 1500.9 Review of draft environmental statements by Federal, Federal-State, State, and local agencies and by the public.

(a) *Federal agency review.* (1) *In general.* A Federal agency considering an action requiring an environmental statement should consult with, and (on the basis of a draft environmental statement for which the agency takes responsibility) obtain the comment on the environmental impact of the action of Federal and Federal-State agencies with jurisdiction by law or special expertise with respect to any environmental impact involved. These Federal and Federal-State agencies and their relevant areas of expertise include those identified in Appendices II and III to these guidelines. It is recommended that the listed departments and agencies establish contact points, which may be regional offices, for providing comments on the environmental statements. The requirement in section 102(2)(C) to obtain comment from Federal agencies having jurisdiction or special expertise is in addition to any specific statutory obligation of any Federal agency to coordinate or consult with any other Federal or State agency. Agencies should, for example, be alert to consultation requirements of the Fish and Wildlife Coordination Act, 16 U.S.C. 661 et seq., and the National Historic Preservation Act of 1966, 16 U.S.C. 470 et seq. To the extent possible, statements or findings concerning environmental impact required by other statutes, such as section 4(f) of the Department of Transportation Act of 1966, 49 U.S.C. 1653(f), or section 106 of the National Historic Preservation Act of 1966, should be combined with compliance with the environmental impact statement requirements of section 102(2)(C) of the Act to yield a single document which meets all applicable requirements. The Advisory Council on Historic Preservation, the Department of Transportation, and the Department of the Interior, in consultation with the Council, will issue any necessary supplementing instructions for furnishing information or findings not forthcoming under the environmental impact statement process.

(b) *EPA review.* Section 309 of the Clean Air Act, as amended (42 U.S.C. § 1857h-7), provides that the Administrator of the Environmental Protection Agency shall comment in writing on the environmental impact of any matter relating to his duties and responsibilities, and shall refer to the Council any matter that the Administrator determines is unsatisfactory from the standpoint of public health or welfare or environmental quality. Accordingly, wherever an agency action related to air or water quality, noise abatement and control, pesticide regulation, solid waste disposal, generally applicable environmental radiation criteria and standards, or other provision of the authority of the Administrator is involved, Federal agencies are required to submit such proposed actions and their environmental impact statements, if such have been prepared, to the Administrator for review and comment in writing. In all cases where EPA determines that proposed agency action is environmentally unsatisfactory, or where EPA determines that an environmental statement is so inadequate that such a determination cannot be made, EPA shall publish its determination and notify the Council as soon as practicable. The Administrator's comments shall constitute his comments for the purposes of both section 309 of the Clean Air Act and section 102(2)(C) of the National Environmental Policy Act.

(c) State and local review. Office of Management and Budget Circular No. A-95 (Revised) through its system of State and areawide clearinghouses provides a means for securnig the views of

State and local environmental agencies, which can assist in the preparation and review of environmental impact statements. Current instructions for obtaining the views of such agencies are contained in the joint OMB–CEQ memorandum attached to these guidelines as Appendix IV. A current listing of clearinghouses is issued periodically by the Office of Management and Budget.

(d) *Public review:* The procedures established by these guidelines are designed to encourage public participation in the impact statement process at the earliest possible time. Agency procedures should make provision for facilitating the comment of public and private organizations and individuals by announcing the availability of draft environmental statements and by making copies available to organizations and individuals that request an opportunity to comment. Agencies should devise methods for publicizing the existence of draft statements, for example, by publication of notices in local newspapers or by maintaining a list of groups, including relevant conservation commissions, known to be interested in the agency's activities and directly notifying such groups of the existence of a draft statement, or sending them a copy, as soon as it has been prepared. A copy of the draft statement should in all cases be sent to any applicant whose project is the subject of the statement. Materials to be made available to the public shall be provided without charge to the extent practicable, or at a fee which is not more than the actual cost of reproducing copies required to be sent to other Federal agencies, including the Council.

(e) *Responsibilities of commenting entities.* (1) Agencies and members of the public submitting comments on proposed actions on the basis of draft environmental statements should endeavor to make their comments as specific, substantive, and factual as possible without undue attention to matters of form in the impact statement. Although the comments need not conform to any particular format, it would assist agencies reviewing comments if the comments were organized in a manner consistent with the structure of the draft statement. Emphasis should be placed on the assessment of the environmental impacts of the proposed action, and the acceptability of those impacts on the quality of the environment, particularly as contrasted with the impacts of reasonable alternatives to the action. Commenting entities may recommend modifications to the proposed action and/or new alternatives that will enhance environmental quality and avoid or minimize adverse environmental impacts.

(2) Commenting agencies should indicate whether any of their projects not identified in the draft statement are sufficiently advanced in planning and related environmentally to the proposed action so that a discussion of the environmental interrelationships should be included in the final statement (see § 1500.8(a)(1)). The Council is available to assist agencies in making such determinations.

(3) Agencies and members of the public should indicate in their comments the nature of any monitoring of the environmental effects of the proposed project that appears particularly appropriate. Such monitoring may be necessary during the construction, startup, or operation phases of the project. Agencies with special expertise with respect to the environmental impacts involved are encouraged to assist the sponsoring agency in the establishment and operation of appropriate environmental monitoring.

(f) Agencies seeking comment shall establish time limits of not less than forty-five (45) days for reply, after which it may be presumed, unless the agency or party consulted requests a specified extension of time, that the agency or party consulted has no comment to make. Agencies seeking comment should endeavor to comply with requests for extensions of time of up to fifteen (15) days. In determining an appropriate period for comment, agencies should consider the magnitude and complexity of the statement and the extent of citizen interest in the proposed action.

§ 1500.10 Preparation and circulation of final environmental statements.

(a) Agencies should make every effort to discover and discuss all major points of view on the environmental effects of the proposed action and its alternatives in the draft statement itself. However, where opposing professional views and responsible opinion have been overlooked in the draft statement and are brought to the agency's attention through the commenting process, the agency should review the environmental effects of the action in light of those views and should make a meaningful reference in the final statement to the existence of any responsible opposing view not adequately discussed in the draft statement, indicating the agency's response to the issues raised. All substantive comments received on the draft (or summaries thereof where response has

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been exceptionally voluminous) should be attached to the final statement, whether or not each such comment is thought to merit individual discussion by the agency in the text of the statement.

(b) Copies of final statements, with comments attached, shall be sent to all Federal, State, and local agencies and private organizations that made substantive comments on the draft statement and to individuals who requested a copy of the final statement, as well as any applicant whose project is the subject of the statement. Copies of final statements shall in all cases be sent to the Environmental Protection Agency to assist it in carrying out its responsibilities under section 309 of the Clean Air Act. Where the number of comments on a draft statement is such that distribution of the final statement to all commenting entities appears impracticable, the agency shall consult with the Council concerning alternative arrangements for distribution of the statement.

§ 1500.11 Transmittal of statements to the Council; minimum periods for review; requests by the Council.

(a) As soon as they have been prepared, ten (10) copies of draft environmental statements, five (5) copies of all comments made thereon (to be forwarded to the Council by the entity making comment at the time comment is forwarded to the responsible agency), and ten (10) copies of the final text of environmental statements (together with the substance of all comments received by the responsible agency from Federal, State, and local agencies and from private organizations and individuals) shall be supplied to the Council. This will serve to meet the statutory requirement to make environmental statements available to the President. At the same time that copies of draft and final statements are sent to the Council, copies should also be sent to relevant commenting entities as set forth in §§ 1500.9 and 1500.10(b) of these guidelines.

(b) To the maximum extent practicable no administrative action subject to section 102(2)(C) is to be taken sooner than ninety (90) days after a draft environmental statement has been circulated for comment, furnished to the Council and, except where advance public disclosure will result in significantly increased costs of procurement to the Government, made available to the public pursuant to these guidelines; neither should such administrative action be taken sooner than thirty (30) days after the final text of an environmental statement (together with comments) has been made available to the Council, commenting agencies, and the public. In all cases, agencies should allot a sufficient review period for the final statement so as to comply with the statutory requirement that the "statement and the comments and views of appropriate Federal, State, and local agencies * * * accompany the proposal through the existing agency review processes." If the final text of an environmental statement is filed within ninety (90) days after a draft statement has been circulated for comment, furnished to the Council and made public pursuant to this section of these guidelines, the minimum thirty (30) day period and the ninety (90) day period may run concurrently to the extent that they overlap. An agency may at any time supplement or amend a draft or final environmental statement particularly when substantial changes are made in the proposed action, or significant new information becomes available concerning its environmental aspects. In such cases the agency should consult with the Council with respect to the possible need for or desirability of recirculation of the statement for the appropriate period.

(c) The Council will publish weekly in the FEDERAL REGISTER lists of environmental statements received during the preceding week that are available for public comment. The date of publication of such lists shall be the date from which the minimum periods for review and advance availability of statements shall be calculated.

(d) The Council's publication of notice of the availability of statements is in addition to the agency's responsibility, as described in § 1500.9(d) of these guidelines, to insure the fullest practicable provision of timely public information concerning the existence and availability of environmental statements. The agency responsible for the environmental statement is also responsible for making the statement, the comments received, and any underlying documents available to the public pursuant to the provisions of the Freedom of Information Act (5 U.S.C., 552), without regard to the exclusion of intra- or interagency memoranda when such memoranda transmit comments of Federal agencies on the environmental impact of the proposed action pursuant to § 1500.9 of these guidelines. Agency procedures prepared pursuant to § 1500.3(a) of these guidelines shall implement these public information requirements and shall include arrangements for availability of

environmental statements and comments at the head and appropriate regional offices of the responsible agency and at appropriate State and areawide clearinghouses unless the Governor of the State involved designates to the Council some other point for receipt of this information. Notice of such designation of an alternate point for receipt of this information will be included in the Office of Management and Budget listing of clearinghouses referred to in § 1500.9(c).

(e) Where emergency circumstances make it necessary to take an action with significant environmental impact without observing the provisions of these guidelines concerning minimum periods for agency review and advance availability of environmental statements, the Federal agency proposing to take the action should consult with the Council about alternative arrangements. Similarly where there are overriding considerations of expense to the Government or impaired program effectiveness, the responsible agency should consult with the Council concerning appropriate modifications of the minimum periods.

(f) In order to assist the Council in fulfilling its responsibilities under the Act and under Executive Order 11514, all agencies shall (as required by section 102(2)(H) of the Act and section 3(i) of Executive Order 11514) be responsive to requests by the Council for reports and other information dealing with issues arising in connection with the implementation of the Act. In particular, agencies shall be responsive to a request by the Council for the preparation and circulation of an environmental statement, unless the agency determines that such a statement is not required, in which case the agency shall prepare an environmental assessment and a publicly available record briefly setting forth the reasons for its determination. In no case, however, shall the Council's silence or failure to comment or request preparation, modification, or recirculation of an environmental statement or to take other action with respect to an environmental statement be construed as bearing in any way on the question of the legal requirement for or the adequacy of such statement under the Act.

§ 1500.12 Legislative actions.

(a) The Council and the Office of Management and Budget will cooperate in giving guidance as needed to assist agencies in identifying legislative items believed to have environmental significance. Agencies should prepare impact statements prior to submission of their legislative proposals to the Office of Management and Budget. In this regard, agencies should identify types of repetitive legislation requiring environmental impact statements (such as certain types of bills affecting transportation policy or annual construction authorizations).

(b) With respect to recommendations or reports on proposals for legislation to which section 102(2)(C) applies, the final text of the environmental statement and comments thereon should be available to the Congress and to the public for consideration in connection with the proposed legislation or report. In cases where the scheduling of congressional hearings on recommendations or reports on proposals for legislation which the Federal agency has forwarded to the Congress does not allow adequate time for the completion of a final text of an environmental statement (together with comments), a draft environmental statement may be furnished to the Congress and made available to the public pending transmittal of the comments as received and the final text.

§ 1500.13 Application of section 102(2)(C) procedure to existing projects and programs.

Agencies have an obligation to reassess ongoing projects and programs in order to avoid or minimize adverse environmental effects. The section 102(2)(C) procedure shall be applied to further major Federal actions having a significant effect on the environment even though they arise from projects or programs initiated prior to enactment of the Act on January 1, 1970. While the status of the work and degree of completion may be considered in determining whether to proceed with the project, it is essential that the environmental impacts of proceeding are reassessed pursuant to the Act's policies and procedures and, if the project or program is continued, that further incremental major actions be shaped so as to enhance and restore environmental quality as well as to avoid or minimize adverse environmental consequences. It is also important in further action that account be taken of environmental consequences not fully evaluated at the outset of the project or program.

§ 1500.14 Supplementary guidelines; evaluation of procedures.

(a) The Council after examining environmental statements and agency procedures with respect to such statements will issue such supplements to these guidelines as are necessary.

(b) Agencies will continue to assess their experience in the implementation of the section 102(2)(C) provisions of the Act and in conforming with these guidelines and report thereon to the Council by June 30, 1974. Such reports should include an identification of the problem areas and suggestions for revision or clarification of these guidelines to achieve effective coordination of views on environmental aspects (and alternatives, where appropriate) of proposed actions without imposing unproductive administrative procedures. Such reports shall also indicate what progress the agency has made in developing substantive criteria and guidance for making environmental assessments as required by § 1500.6(c) of this directive and by section 102(2)(B) of the Act.

Effective date. The revisions of these guidelines shall apply to all draft and final impact statements filed with the Council after January 28, 1974.

RUSSELL E. TRAIN,
Chairman.

APPENDIX I—SUMMARY TO ACCOMPANY DRAFT AND FINAL STATEMENTS

(Check one) ( ) Draft. ( ) Final Environmental Statement.

Name of responsible Federal agency (with name of operating division where appropriate). Name, address, and telephone number of individual at the agency who can be contacted for additional information about the proposed action or the statement.

1. Name of action (Check one) ( ) Administrative Action. ( ) Legislative Action.

2. Brief description of action and its purpose. Indicate what States (and counties) particularly affected, and what other proposed Federal actions in the area, if any, are discussed in the statement.

3. Summary of environmental impacts and adverse environmental effects.

4. Summary of major alternatives considered.

5. (For draft statements) List all Federal, State, and local agencies and other parties from which comments have been requested. (For final statements) List all Federal, State, and local agencies and other parties from which written comments have been received.

6. Date draft statement (and final environmental statement, if one has been issued) made available to the Council and the public.

APPENDIX II—AREAS OF ENVIRONMENTAL IMPACT AND FEDERAL AGENCIES AND FEDERAL STATE AGENCIES [1] WITH JURISDICTION BY LAW OR SPECIAL EXPERTISE TO COMMENT THEREON [2]

AIR

Air Quality

Department of Agriculture—
- Forest Service (effects on vegetation)

Atomic Energy Commission (radioactive substances)
Department of Health, Education, and Welfare
Environmental Protection Agency
Department of the Interior—
- Bureau of Mines (fossil and gaseous fuel combustion)
- Bureau of Sport Fisheries and Wildlife (effect on wildlife)
- Bureau of Outdoor Recreation (effects on recreation)
- Bureau of Land Management (public lands)
- Bureau of Indian Affairs (Indian lands)

National Aeronautics and Space Administration (remote sensing, aircraft emissions)
Department of Transportation—
- Assistant Secretary for Systems Development and Technology (auto emissions)
- Coast Guard (vessel emissions)
- Federal Aviation Administration (aircraft emissions)

Weather Modification

Department of Agriculture—
- Forest Service

Department of Commerce—
- National Oceanic and Atmospheric Administration

Department of Defense—
- Department of the Air Force

Department of the Interior
- Bureau of Reclamation

WATER RESOURCES COUNCIL

WATER

Water Quality

Department of Agriculture—
- Soil Conservation Service
- Forest Service

Atomic Energy Commission (radioactive substances)
Department of the Interior—
- Bureau of Reclamation
- Bureau of Land Management (public lands)
- Bureau of Indian Affairs (Indian lands)
- Bureau of Sports Fisheries and Wildlife
- Bureau of Outdoor Recreation
- Geological Survey
- Office of Saline Water

Environmental Protection Agency
Department of Health, Education, and Welfare

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[1] River Basin Commissions (Delaware, Great Lakes, Missouri, New England, Ohio, Pacific Northwest, Souris-Red-Rainy, Susquehanna, Upper Mississippi) and similar Federal-State agencies should be consulted on actions affecting the environment of their specific geographic jurisdictions.

[2] In all cases where a proposed action will have significant international environmental effects, the Department of State should be consulted, and should be sent a copy of any draft and final impact statement which covers such action.

Ref: Jack B. Carmichael. Environmental Considerations in the Planning and Evaluation of Development Projects; monograph published by the Organization of American States, Washington. 1974.
Case Study: Ecological Survey of the Menta River in the Country of Farmington.

I. Introduction: The major motivation for this survey is that a proposal is pending to locate the first pulp and paper mill in Farmington in the vicinity of Temer Falls on the Menta River.

Pulp and paper mills produce substantial volumes of chemical-laden effluents which can poison the water for biota or human users and degrade its quality for other industrial or agricultural users. A French newspaper recently called the paper mills "the veritable cancers of the Swedish environment."

The ecological survey reported here originated from the consciousness of the government of Farmington that the overall economic benefits of such an industrial plant might be reduced if there is a negative pollutional impact on the environment in the Menta River Basin. Thus it was deemed desirable to assess the present ecological balance of the river environment and the impact which pollutants could exert on it.

The following terms of reference were established for the survey:

i. A chemical, physical, and biological analysis of Menta River water and water life will be carried out from Temer Falls to the mounth of the Menta 157 km. away. A similar analysis will be carried out at Lake Constan in the vicinity of where it receives the Menta discharge.

ii. There will be a survey of all vegetation on the river shores.

iii. To the extent possible, a census will be carried out of those wildlife which are dependent on the river for water.

iv. The present pattern of human consumption of Menta River water will be determined, along with estimates of present and future requirements for such uses.

v. Other projected water needs presently contemplated in the development of the watershed will be considered

II. Methodology

A. The Aerial Survey.

A limited aerial survey was carried out over the entire course of the Menta River from Temer Falls to Lake Constan.

B. Ground Surveys.

Ground surveys were concentrated on selected parts of the river. Sixteen study areas (stations) were surveyed along the course of the Menta. Two stations were upstream from the proposed site of the pulp and paper plant (the vicinity of Temer Falls). Thirteen stations were downstream from the falls, and one was located in Lake Constan. Since hydrobiological techniques and measurements require several hours work, an average of two stations were studied per day by a two man scientific team. Six stations were chosen near major bridges or ferries. The rest were in the rural hinterlands with difficult access by land rover.

Vegetation profiles were taken at each station in both parallel and perpendicular directions to the bank. Plant species were identified. Land use practices were noted and the density of livestock and humans was estimated. Birds and other animals were observed but there was no trapping of small riverbank mammals.

The following water quality measurements were carried out at the field stations:

1. Temperature (measured by a bulb type thermometer or thermister probe).

2. Dissolved oxygen content (measured by probe as percent saturation).

3. Specific conductivity (measured with a portable conductivity bridge). For practical purposes, this is equivalent to total dissolved solids See Appendix B, p. A-8.

4. pH, or hydrogen ion concentration (measured by a colorimeter).

5. Total alkalinity was measured by titration.

For background, see Appendix B, Explanations of Common Water Quality Parameters.

The following biological samplings were carried out:

1. Invertebrate bottom fauna, usually collected from stones situated in rapids.

2. Fish were caught using a 20 mm mesh gill net and were preserved in 4% formalin.

Hydrological analyses included streamflow and velocity data. Existing data records were utilized.

III. The Menta River Environment

A. The Basin.

The Menta River drains an area of 15,000 km. which includes plateau areas and rolling hills. The river flows through the northern part of Constan Swamp to enter Lake Constan about three miles south of Constan City

The Menta has a drainage area of 9000 km^2 below the propsed pulp and paper mill site in the vicinity of Temer Falls. Three important tributaries enter the Menta between the falls and the mouth. The average flow of the Menta is 3 billion m^3/year.

B. Nature of the River Channel.

Where the river leaves the foothills of its source the channel has a gradient of approximately 1% (10 m per km.) This decreases to about 0.6% in the vicinity of Temer Falls. Below the falls, the gradient decreases to about 0.3% 70 km. from the mouth. By the time the river has reached the swamp prior to entering the lake the gradient has decreased to 0.06%. The flow gradient of the channel changes frequently in short reaches throughout the course of the river.

Generally the flow is fast and highly turbulent with a high capacity for reaerating organic wastes. Even between major rapids the river has a high velocity. Standing waves are common and the aeration is great.

The river becomes sluggish only in the lower alluvial section near the mouth.

At Temer Falls, when the river is at mean annual flow of 1500 cfs, the average velocity is 3 feet/sec. When the discharge of the river declines to 200 cfs, the average velocity is only 1 foot/sec. Flows of 200 cfs or less occur on 12 days in an average year.

C. Geology.

At Temer Falls the river begins a southwesterly course for many miles over granite outcroppings. Below the first major tributary, the Menta flows through banks of siltstone, pebbles, and sand.

The Menta flows in a mature valley with many rapids. There are unmistakable signs of rejuvenation due to earth movements in the escarpment which runs along the valley. In most parts of the surveyed areas the river flows swiftly over rocky beds which are being cut deeper.

D. Soils.

Just below Temer Falls the Menta flows through an area of well drained red loamy soil. Further downstream there is a section of black to grey clays which is gradually replaced by brown clay loams. Both show signs of impeded drainage. Near the mouth of the river there are sandy soils.

E. Rainfa

The average annual rainfall amounts to about 1000 mm at the river mouth and 1500 mm at Temer Falls. The rainfall is seasonal. Roads and lands are dried out and dusty during the four months of the dry weather

F. Population.

The Menta River below Temer Falls flows through a countryside inhabited by 100-200 persons/km^2 on both sides of the river. Thus 32,000-64,000 people populate the lands within 1000 m from the river.

G. Most of the course of the river is flanked with traditional subsistence agriculture, mostly maize. There is a 20 km. stretch of mostly

rangeland. The tributaries in the mountains flow through forests.

IV. Results of the Field Studies

A. The Aerial Survey.

The Menta River has a very low flow at the end of the dry season. The Temer Falls appeared like small trickles in an empty stream bed. The river was observed to be between 30-40 m wide during most of its 160 km to the lake. There are 75 major curves as the river winds its course. Ten rapids were evident and many islands.

More than a dozen large fish weirs wer built across the river, some 100 km. above the mouth. This is evidence for large scale fishing and fish migration up the river.

The Menta flows through a man-altered environment. No riverine forest exists at all. Human settlements, fields, and pasture lands often extend right to the river bank itself.

Most of the population in the river area is located on higher elevated areas several hundred meters away from the river. This pattern is presumable due to floods and mosquitos.

At the mouth of the river many fishing nets, boats, and traps were observed. The yellowish color of the Menta is recognizable and distinct for at least 500 meters into the lake.

B. The Ground Survey at the Stations.

To illustrate the kinds of data gathered, results from selected stations are reported.

Station 3

The location is 500 m below the Temer Falls bridge, 157 km above the river mouth. Altitude at this point is 1,450 m.

The area around Temer Falls is densely populated. Building and road construction is going on and there is a mining of sand from the river bank near the bridge. There is very little undergrowth and generally thinned out vegetation. This is due to heavy grazing pressure and the daily move-

ments of cattle.

Cultivation is frequently carried out up to the edge of the river bank. In most cases a strip no wider than 10-50 meters is left uncultivated. Some natural vegetation is found along these strips, but is heavily grazed by livestock. Soil along the river at this point is silt and sand with few alluvial deposits. There is a rather high rate of soil erosion.

Eighteen different species of bottom fauna were identified. Micronecta (21 samples), chironomidial (18 samples), and ecdyonuridae (10 samples) were the most abundent. The wide variety of species indicates an undisturbed natural environment and an absence of pollutants.

Water analyses were carried out from the bank. Data are shown in Table 1 following the discussions of the stations. The waters were completely oxygenated, had a nearly neutral pH of 7.3, and showed a very low concentration of dissolved salts. No evidence of pollutants was observed.

One hour of fishing with a 20 mm mesh net of 33 m length and 1.5 m depth yielded a total of 5 fish of 3 different species ranging in size from 7.9 to 12.9 cm.

On the left bank of the river there were many large boulders and pools of water which were separated from the river. Persons from th nearby village were draining water from the pools in order to catch fish Another group of women worked to separate a side bay from the main river by constructing a mud dam. Other women used pots and bowls to drain the water from this artificially created pool. At the end, two dozen people jumped into the empty pool to hunt for fish. What a joy when five 20 cm. catfish and 4 10 cm. tilapias were caught!

Station 8

The location of the station is at Kaplan Bridge, 60 km. downstream from the proposed pulp and paper mill. The neighborhood of the

bridge is overgrazed, burnt, and poor in tree cover. Just below the bridge there is a succession of sugar cane fields which border the bank.

Three years from now a large sugar factory will be completed. This factory will require large amounts of river water for its operation.

The fishing net was set for one hour. Four catfish ranging from 10.2 to 16.1 cm. and 4 tilapias ranging from 8.3 to 12.9 cm. were caught.

To the human eye the Menta is unchanged from its appearance at Station 3-no larger, no dirtier, no cleaner. Water analyses (see Table 1) showed the waters were 95% saturated in oxygen, contained few dissolved salts, and had a nearly neutral pH of 7.4. The yellowish color of the Menta is apparently due strictly to the sediment loading.

Twelve species of bottom fauna were observed from the samplings. Ecdyonuridae (12 samples) and macronema sp. B. (10 samples) were the most abundent. This diversity of species again confirms the lack of pollutants in the river.

Station 9

This station is located at the juncture of the Elio River with the Mensa, 70 km. downstream from the paper mill site and 10 km. downstream from the proposed future site of the sugar factory.

Here the most natural and scenic area of the surveyed area of the Mensa was found. The river flows through a narrow valley with steep hills rising on the left bank. The stream flow is swift through rapids of granite boulders.

Few people were observed. A family was seen washing themselves in the river. The man explained that they lived some two km. away but came often to bath. He said that they liked the good water of the Menta ver much.

Two large wooden fish wiers were the only permanent signs of human activity. A zone of 150 meters width is untouched along both banks. Obviously there is no high grazing pressure. More indigenous vegetation is

found here than at any other study area along the Menta. including some beautiful archids. Furthermore, the only colony of the white-necked pratincole known to exist in Farmington is found here on the rocks in the river.

A dozen common plant species identified included wild apple trees, wild date palm, and a wild reed widely utilized for handicraft work.

Because of the well preserved natural environment, this area is important from a scientific and an educational point of view.

Water analyses again revealed a supersaturation of oxygen. The pH of 7.6 is very slightly more alkaline that upstream. The increase is probably due to natural causes-changes in soil characteristics, for example. Data are shown in Table 1.

Eleven species of bottom fauna were collected. Most abundant were Ecdyonuridae (12) and Macronema sp. B. (10).

Station 15

This station was located in the mouth of the Menta River, 157 km. from Temer Falls and the proposed paper mill and 97 km. downstream from the future sugar factory. The elevation at this point is 1,130 m.

The Menta here is a 40 meter wide stream with a maximum dept of 4 meters. It is yellowish in color, similar to the color of the upper reaches of the river. The mouth of the river is almost devoid of any kind of water plants. For that reason, it flows with quite a strong current into Lake Constan.

Some two km. from the mout'. of the river the lake abounds in aquatic vegetation, especially papyrus. Wild reed, antelope grass, water lettuce and nettles are other common plant species found here.

The mouth of the Menta is full of fish. Many fish were caught withing 5 minutes after placement of the net. Mullet, catfish, and tilapias abound. Several kingfishers were observed fishing at the mouth of the Menta.

Water quality data were obtained from midstream. The river was found to be 90% saturated with oxygen and a pH of 7.7. These and the other

water quality data indicated a very slight lessening of water quality in the mouth of the Menta compared to the upstream reaches. Water quality here would be classified as very good based on these limited analyses.

Table 1-Water Quality Analyses at the Stations

	Station 3	Station 8	Station 9	Station 15
Day	3/25	3/27	3/30	4/2
Time	13:00	17:30	11:45	14:30
Temp., °C	22.8	24.2	25.2	27.2
% Oxygen Saturation	106	95	103	90
pH	7.3	7.4	7.6	7.7
Specific conductance, micromhos/cm.	135	137	140	150
Alkalinity, meq/l.	1.5	1.5	1.55	1.6

These data reveal an unpolluted stream which is easily able to assimilate the present small waste loading that is received from the human population and animal population. The slight increase in specific conductance probably indicates an increase in ions due to materials in the increased sediment loading as one moves downstream.

IV. Water Pollutional Aspects of the Mill

According to the information received by World Wide Paper Mills Ltd., the output of their proposed sulfate pulp mill will be 125 tons of Kraft pulp per day. At full capacity the factory will have a water demand of 20 cfs. This is 10% of the low flow which occurs on 12 days of an average year. Much of the industrial water will be recycled for use within the plant.

The major portion of the pollution from paper making originates in the pulping process. When the wood is received, the bark is removed and the wood is reduced to chips by grinding. Chips are then converted to pulp after a chemical preparation, called cooking. In the kraft process, the wood chips are cooked in either batch or continuous digesters with a mixture of caustic soda and sodium sulfide.

The wastewater produced from this process contains suspended solids, dissolved solids, color, odor, specific chemical residues, and, in general, a high loading of wastes which will consume the oxygen of the waterway. (See Appendix A-2, An Explanation of Common Water Quality Parameters)

The requirement of oxygen for degradation of the wastes is called the biochemical oxygen demand. It is a good single measure of the pollutional loading of these wastes. An organic waste loading to a stream is gradually assimilated through oxidation by the bacteria present. Oxygen must be provided so that the bacteria can grow and oxidize the waste materials. A waste loading on the stream thus depletes the oxygen present in the stream. High concentrations of dissolved oxygen are therefore a good indication of a healthy river, whereas low concentrations are an indication of a polluted river. Dissolved oxygen is essential to stream life. Total consumption of the dissolved oxygen by wastes results in a dead river.

On the average, the kraft pulping operation is known to produce about 40 lbs. of BOD in the effluent per ton of pulp produced. Thus the total BOD generated by the World Wide Paper Mills plant will be about 5000 lbs of BOD/day

A water pollution expert has recently completed estimates of effects of given BOD loadings at Temer Falls on the levels of dissolved oxygen at Station 8, Kaplan Bridge. This is the site of the proposed future sugar plant. Results of the calculations appear in Table 2.

Table 2. Effects of Pollutional Loadings at Temer Falls on Dissolved Oxygen Levels at Kaplan Bridge (calculated through measurements of the reaeration capacity of the river).

# of lbs. of B.O.D./day	Calculated Dissolved Oxygen, % saturation mean annual flow 1500 cfs.	low flow for 12 days of ave. year 200 cfs.
500	96%	90%
1000	90%	80%
5000	70%	50%
10.000	40%	10%

A pollutional loading of 500 lbs/day can be assimilated by the stream with no effects upon the present uses.

A pollutional loading of 1000 lbs/day would render the river unfit for drinking at least at far as Kaplan Bridge. The river would be unsuitable for use by the sugar plant during the 12 or so days of low flow in a given year.

A pollutional loading of 5000 lbs/day would render the river unfit for drinking and unsuitable for use by the sugar plant without pretreatment. Some damage to the biota of the stream would occur during the periods of low flow.

A pollutional loading of 10,000 lbs/day would cause the effects listed above but would still permit the survival of many species of fish except during periods of low flow. Severe damage to the biota would occur and few if any fish would survive. Fish populations could be expected to remain depressed for substantial periods of time following periods of low flow in the river. Effects of this level of pollutional loading would remain substantial all the way to the mouth of the river. Some effects on the

ecology of Lake Constan would be expected.

As mentioned, the pollutional loading of the untreated wastes from the pulp mill will be 4000 lbs/day. World Wide would like to consider doubling the capacity of the plant in ten years, which would increase the effluent loading to 8,000 lbs./day.

Various means are available to treat these wastes. More efficie treatment methods are more costly.

Primary treatment involves allowing the wastes to settle in earthen basins prior to discharge. This treatment removes about 50% of the BOD loading at a cost of about 50c /ton of kraft pulp produced.

Secondary treatment involves oxidation in storage lagoons for extended periods of time. This treatment removes about 75% of the BOD and costs about $1/ton of kraft pulp produced.

Secondary treatment by mechanical treatment plant involves oxidation of the wastes by mechanical agitation in a reactor. This treatment removes about 90 % of the BOD and costs about $2/ton of kraft pulp produced.

Tertiary treatment involves secondary treatment by mechanical plant followed by lime addition and filtration through activated charcoal. This treatment removes about 95% of the BOD and costs about $4/ton of kraf pulp produced.

The company expects to realize a profit of $20/ton of pulp produced, and has indicated that a profit reduction of 5% is all it wishes to sacrifice due to pollution abatement costs.

Ref: Jack B. Carmichael, Environmental Considerations in the Planning and Evaluation of Development Projects; monograph published by the Organization of American States, Washington, D.C., 1974.

Case Study: Hydroelectric Project for the Country of Odi

Project Description

The Odi hydroelectric project will develop power from El Rio Caballo. A rockfill dam 85 m high by 800 m crest length will be constructed. The project will also consist of a spillway, intakes and pressure tunnels, surface powerhouse with two 70 MW turbogenerator units, and a switchyard connecting to a double circuit 115 Kv line to Odiville, capital of Odi.

The dam will form a reservoir with the following dimensions at its maximum operating level: Surface area of 150 km^2; length of 40 km. upstream from the dam site: storage of 1.5 billion m^3 within the operating limits of 15 m vertical drawdown plus 0.75 billion m^3 reserve storage.

The entire watershed of El Rio Caballo and its tributaries suffers a severe six month dry season. Reservoir levels will therefore fluctuate greatly and a 15 meter drawdown is anticipated during the dry season.

Justification for the Project

During the past ten years, energy consumption in Odi has increased annually by 10%. The forecasted annual growth rate for electricity demand is also 10% through 1985. There is at present sufficient installed generator capacity in Odi to meet the demand only until 1975.

The completion of this hydroelectric project in El Rio Caballo plus two other planned power generation projects in other parts of Odi will enable the country to meet its projected power needs through the late 1980's.

The project will provide employment of unskilled labor for up to 1500 people per year during the construction period of the project.

Environmental Impact Assessment

Human Ecology

The major impact of this project will be on peoples who must be relocated. For background reading on this subject, see the paper "The pro-

blem of population resettlement in reservoir projects in Africa. Cultural and human ecological factors and the need for adequate resettlement planning." Ten thousand people live in the area to be flooded and will be forced to abandon their homes. An adequate resettlement plan has not been developed. Such a plan will be necessary and must include the components of relocation, employment, and community development.

Watershed Management and Sedimentation

The problem of expected sediment buildup in the reservoir is the environmental impact expected to be next largest in magnitude. Quantitative studies of erosion and siltation in this portion of El Rio Caballo watershed are absent, but a high siltation rate into the new reservoir is expected. An existing dam in the same region in Odi is receiving sediment at a rate which will fill the reservoir in 20 years. A watershed management/reforestation plan is necessary to monitor and reduce erosion and siltation and improve the resources of the project area.

Vegetation

There are neither rare plants nor especially valuable tracts of vegetation in the area to be flooded.

An expected large impact will be growth of aquatic vegetation in the reservoir and an adequate program of control will be required.

Animals

No rare animals exist in the area. Various mammals may be trapped by the project flooding. A contingency plan is needed for their rescue and transport to new habitats.

There is a plan to develop a substantial commercial and sport fishery in the new reservoir. The reservoir is expected to become a popular habitat for waterfowl.

Archaeology

The Government of Odi has reported no known archaeological sites within the affected area. However the area is poorly known archaeologically.

Through a cultural exchange program, the government of Odi plans to bring in visiting archaeologists to help inventory the area and develop contingency plans to protect any valuable artifacts which are unearthed.

Public Health

The waters which will drain into the new reservoir presently carry a heavy loading of raw sewage. Reducing the quantity of raw sewage entering the reservoir will reduce the incidence of fecal-oral transmitted diseases, such as hepatitis.

The project is expected to lead to an increase in malaria. This should be checked through a program of vector habitat destruction, chemotherapy, and isolation of victims.

Waterweeds should be controlled to reduce disease vector habitats.

Detailed Environmental Analysis

A. Human Ecology

The benefits of a development project are usually assessed at the national level. However, benefits should extend to a maximum number of individual citizens as well. People are a country's most valuable resource.

Necessary considerations for the Resettlement Plan for the Odi Hydroelectric Project are the following:

1. A complete census of people displaced by the project should include an inventory of work skills.

2. Relocation

a. Suitable areas must be obtained and plots assigned as soon as possible. All the families of this area need a backyard in which to raise chickens and harvest fruit trees. An objective should be to allow time for the clearing and planting of the backyard so that food trees are bearing by the time the move occurs.

b. There are compelling reasons for a formal resettlement pro-

gram organized by the government of Odi. There may not be enough plots available privately for sale or lease to accomodate all the displaced people. Furthermore, the value of these plots would rise in value due to scarcity, putting them above the amounts paid to the displaced citizens for indemnification. The region is already overpopulated, and natural resources are scarce. Many plots will not yield enough timber to construct buildings.

c. A formal relocation program is therefore essential. Every family unit should receive a plot of sufficient size to support the family.

d. Expert planning assistance is needed from a sociological community development specialist and an agricultural extension expert. Some input from an economist, a watershed management expert, and an ecologist may also be necessary.

3. Employment.

Immediate employment opportunities should be offered the displaced persons either on the dam construction project or the recommended environmental protection program of erosion control and reforestation.

4. Unplanned land use.

In an overpopulated region, people may be expected to concentrate near a development project. Impoverished squatters will begin to arrive and settle in the area to be flooded in the hope of receiving some indemnification. This is already occurring at the Odi site, where squatters have established a settlement just outside the boundaries of the construction camp.

a. The government of Odi should impose a moratorium on, or require permission to be sought for, all property transactions inthe area.

b. A plan should be developed to integrate unplanned arrivals into the work programs of reservoir site preparation and reforestation.

B. Watershed Management and Sedimentation Control

1. Stream protection for the tributaries.

A program is recommended for revegetation of banks and construction

of rock barriers, revetments, and other necessary measures to reduce erosion and siltation in the tributaries.

2. Reduction of sheet erosion on slopes.

Slopes which drain into the watershed or directly into the reservoir often show substantial erosion. Stone walls constructed in fields within the project area frequently show one meter or more accumulation of soil on the uphill side after a year or two.

3. Drainage areas susceptible to gully erosion should receive special attention. Gullied road cuts should be stabilized by means or vines or grasses

4. The government of Odi should acquire a 100 meter strip of land surrounding the reservoir. This land should be managed for watershed protection.

5. Reforestation is an effective means of watershed protection. Trees capable of tolerating severe dry seasons should be planted and maintained. A rational sustainable harvesting plan should be established.

6. The government of Odi should establish a regionally administered extension program to reduce burning, overgrazing, shifting agriculture, and other bad practices in the watershed.

C. Construction Activities

1. Borrow areas for aggregate, rock fill, sand, and other construction materials are nearby. Transport roads will not significantly contribute to environmental degradation of the area. Use of the borrow locations will not destroy any special environmental features. Customary industrial protection measures for noise and dust pollution control must be complied with. Otherwise no problems are envisioned.

2. Engineering environmental protection plans.

a. There should be a plan for restoration in the borrow area and minimizing erosion.

b. The topsoil is a scarce and valuable resource in the project area. All topsoil scraped off during construction should be stored for replacement or reuse.

c. When practicable, quarries or sand pits should be exploited as fish ponds or recreational areas.

3. Clearing most of the area to be flooded is strongly recommended. Another reservoir built 20 years ago in Odi was not cleared of trees beforehand. These trees are still present, show little signs of decay, are a hazard to navigation, interfere with fishing, and increase susceptibility to build-up of waterweeds.

D. Project Operation

1. Drawdown schedules should be developed in conjunction with fisheries experts. Many fish depend on shallows at the waters edge for food, shelter, or reproduction. Drawdown at an unpropitious time could kill all reproductive stages of certain fish species.

2. The reservoir will regulate flows downstream and reduce the frequency of flooding in the lower Caballo Valley. Flow augmentation will vary from 70 cu. m./sec. to 140 cu. m./sec. during the dry season. These well regulated flows should be exploited for irrigation of fertile valley land.

E. Vegetation

1. Terrestri

There is no undisturbed natural vegetation in the project area. In an earlier era, the area was forested. Much of the area to be be flooded is planted in sugarcane, maize, and sorgum. There is some rotational pasture land.

Near the proposed reservoir site there are some small and isolated patches of vegetation which contain a higher density of trees and more species

of trees than the project area. These patches can provide seeds for the reforestation program and should be carefully conserved and protected.

2. Aquatic.

A heavy growth of waterweeds should be expected and a control program should be planned from the earliest stages. The water hyacinth (Eichhornia crassipes) is the most waterweed found in this area and will be the greatest threat. Cattle cannot control this plant even though they feed upon it, because they generally eat only the tops.

The waterweed second in abundance in the project area is water lettuce (pistia stratiotes). Floating tern (salvinia auriculata) has been observed in heavy abundance at other reservoirs in Odi and may be expected in this new reservoir. Hornwort (ceratophyllum demersum) is an inconspicuous plant because it floats beneath the surface of the water. However, the dense, rootless spheres of the hornwort can accelerate the deoxygenation of a water body. These waterweeds have occurred in dense growth in two other reservoirs in similar geographical regions of Odi. A heavy growth in this project should also be anticipated.

The several adverse effects of heavy growths of waterweed are listed below:

a. Floating aquatic plants increase the surface area from which water is lost from a reservoir. If such plants cover wide areas, evapotranspiration can cause a serious loss of water, especially in the seasonally dry climate of the project area.

b. Dense mats of waterweeds mechanically interfere with fishing and navigation and occasionally also interfere with the turbine intakes.

c. Waterweed mats contribute to a decline in water quality through reducing the amounts of light and oxygen that can enter the water and by consuming already present dissolved oxygen

d. A serious health problem is also attendant with mats of waterweed. Surfaces of the mats provide ideal habitats for malarial mosquitos, for example. Roots of the water hyacinth are a habitat for the snails which carry schistosomiasis. This disease has already been reported in Odi, and snails in the same subfamily as the disease carriers have been found in water hyacinth roots in two other reservoirs of Odi.

Therefore a plan should be developed to control waterweeds over an indefinite duration. The government of Odi suggested control through herbicides in its original project proposal. This should not be accepted. Means of mechanical control and removal, habitat manipulation by drawdown, and biological control by fish and insects should be evaluated and incorporated first.

F. Animals

1. Terrestrial.

Population pressures and the destruction of all large forest areas have caused the migration or the extinction of large mammals in this project area of Odi. Presently some racoon, weasel, paca, agouti, coati, and grison are thought to occur within the project area.

Although the project will not endanger any particular mammal, the fauna of the region is generally depleted. Substantial efforts should be made to preserve existing fauna. No hunting or trading in hide or flesh of wild animals should be permitted. Also, all animals trapped by rising waters should be rescued and sent to predestined habitats.

There are relatively few species and numbers of birds presently in the project area due to the absence of wet forest. The existing species are not rare, but should be protected, in part because of benefits in controlling insect pests.

2. Aquatic.

There are many lakes throughout Odi and the country abounds in water-

fowl. Several species of duck and egret are especially abundent. The new reservoir is likely to develop into a fine stopover for migratory birds.

Migratory fish are already prevented from passing up El Rio Caballo by the presence of another dam. The new project will not change this situation.

A great benefit could accrue to peoples of the region by developing the reservoir into a warm water fishery. Fish is a staple in the local diet, and current fishing yields from El Rio Caballo are decreasing. The government of Odi has envisioned creation of a fishery with an annual production of 500,000 kg of fish and employment of 400 men. These estimates seem overoptomistic, but potential exists for a good fishery.

A large and newly created reservoir will often have an initial burst of fish productivity followed by a decline. The process of maintaining a viable and productive fishery over a long time period is a biologically and technically complicated procedure. A surprisingly large fish breeding program is required along with lengthy pilot investigations.

Fish which are presently common to Odi and which could be expected to thrive in the new reservoir include the Tilapias, catfish (Galeichthys guatemalensis), the mullet (mugil), and the chimbola, or top minnow (molliensia sphenops). The top minnow is very abundent and well distributed throughout Odi. Apart from being a reasonable food source, this species can serve a valuable role in mosquito control.

<u>Specific recommendations regarding the establishment of a commercial fishery</u>

1. A fish culture station should be immediately established at the reservoir site by the Ministry of Agriculture of Odi.

2. The personnel of the fish culture station should advise on the clearing operation in order to optimize future fishing.

3. The fishery station personnel should be involved in a program of restoration of the lake margin, including reforestation.

4. The station should establish a limnological research program to include studies of algae and invertebrates, especially shrimp.

5. The fish program should emphasize game fish. Work with top feeders for insect control, vegetarians for waterweed control, bottom feeders and snail feeders should all be encouraged. The many lakes in Odi can provide the breeding stock for this project.

G. Public Health

Diseases expected to increase due to the project if no precautions are taken include hepatitis, malaria, schistosomiasis, and Chagas' disease.

1. Hepatitis.

A recent outbreak of infectious viral hepatitis is causing concern in the National Health Service of Odi. About 10,000 cases are reported annually in the country. Fecal contamination of drinking water is usually responsible for this disease. There is reason for concern over possible future epidemics in the project area because the waste waters from the city of Las Montañas (pop. 400,000) drain directly into the projected reservoir. According to the National Health Service of Odi, these wastewaters are raw and untreated.

2. Malaria.

Malaria is presently endemic to the project area. Although the country reports 50,000 annual cases, there are few deaths. The larva of the Amopheles mosquito vector is aquatic. The creation of the proposed reservoir will increase the breeding habitat of this mosquito. Special preventative measures may be called for.

3. Schistosomiasis.

Presently there are only a few cases of schistosomiasis in Odi. The

disease was unreported before 1970.

The disease vector is an aquatic snail through the parasitic blood fluke is passed on to humans. The snails flourish in the roots of the water hyacinth. Since there are snails of the same subfamily flourishing in other waters of Odi, there is legitimate concern that the Schistosomiasis vector would flourish if introduced.

4. Chagas' disease.

Chagas' disease is a potential and not an actual problem in the project area. About 300 cases are annually reported in Odi. The vector is the blood-sucking triatomine bug. The use of mud, adobe, and thatch must be restricted in the project area in order not to afford habitat to the bug.

Public health recommendations

1. The National Malaria Control Service of Odi should assign a small permanent detachment to the new reservoir project. This detachment can collaborate with other groups to reduce and destroy breeding sites and encourage programs to stock larval-eating fish. The unit should stock free chemotherapeutics and be prepared to offer free treatment to a sizable number of cases

2. A full Public Health Clinic might be justified for the project area, of which the Malaria Unit would be a part. Clinical staff would be on the alert for symptoms of all four of the major diseases and would provide free care to anyone.

H. Archaeology

According to the Ministry of Cultural Affairs of Odi, there are no known archaeological, historic, or otherwise noteworthy sites in the project area. However, the area is poorly known archaeologically. Through a cultural exchange program, the government of Odi plans to bring in visiting archaeologists to help inventory the area and develop contingency plans in case valuable artifacts are unearthed.

A valuable ruins of an ancient community at Aguas Calientes lies just outside the area to be flooded. The government of Odi has developed a plan to protect and inventory this area.

I. Scenic and Aesthetic Qualities of the Reservoir

The new reservoir will have a prolonged 15 meter drawdown during the dry season. This will expose unattractive and probably pungent mudbanks. The drawdown will make access to the water difficule. However, the seasonally exposed banks will be beneficial in establishing a waterfowl sanctuary.

Water quality in the reservoir is expected to improve with the better watershed management practices, but the reservoir will be at least initially turbid in some parts.

There are other rivers in this area of Odi with attractions similar to that which will be flooded. No noteworthy waterfalls, gorges, unusual geological formations, or caves are likely to be affected by the project.

The presence of a clean lake amid the rugged mountains of the area will enhance the attractiveness of the region.

J. Tourist Potential

There are many large and medium sized natural lakes in the country of Odi. The addition of another large lake will not add greatly to the attraction of tourists. The proposed fishery development will ensure much sport fishing opportunity.

The government of Odi should carefully designate sites for picnics, camping, bathing, and (non-power) boating. These activities should be managed so as to be compatible with water quality control, watershed management, power generation, and good health conditions.

Ref: Jack B. Carmichael, Environmental Considerations in the Planning and Evaluation of Development Projects; monographs published by the Organization of American States, Washington, D.C., 1974.

Case Study: Iron Ore Project in the Country of Edel

Project Summary

The project involves the exploitation of large quantities of high grade iron ore in the interior of the country at a site called La Tierra de Fierro. The ore will then be transported by rail to a terminal to be located at the ocean port of Baja Linda. There it will be transferred onto large half-million ton combination oil/ore boats for transportation to the world markets.

Environmental Impact Summary

The area which stands to suffer the greatest environmental impact unless proper precautions are taken is the Bay of Baja Linda. Baja Linda is a largely unspoiled bay of great esthetic beauty. The small town of the same name is located on the bay. The attraction of the bay causes the population of Baja Linda to swell from 3000 permanent residents to 15,000 during the summer months. The Bay of Baja Linda also supports an important shellfish and finfish commercial fishery.

Studies of the currents and tides show that the bay does not readily flush itself of impurities. Accumulation of oil and other discharged pollutants is likely to occur. If the oil/ore boats clean their holds with detergents, the discharged mixture of oil/detergent/water could prove toxic to large areas of shellfish and begin a process of ecological deterioration of the bay.

Other environmental impacts considered at Baia Linda were the proposed 2 km. rail trestle which would cross the bay to an island-based marine ore loading terminal, and the total impact of the project on tourism development.

Environmental impacts associated with the mining site and rail transport of the ore are considered to be less severe. These are discussed in detail in the text.

Alternatives to Mitigate Environmental Impacts at Baja Linda

The following agreements to mitigate environmental impacts at Baja

Linda were achieved through negotiations with the borrower (the Govt. of Edel):

1. A safe procedure was established for handling the slops (the oil/detergent/water mixture) from the ships' holds.
2. An improved navigation system for the oil/ore boats was designed to prevent accidents.
3. A contingency plan with standby equipment was established to better preserve the esthetic qualities of the bay.
4. A plan was established for dust control from the ore.
5. Plans for solid wastes handling and sewage treatment at the ore terminal were developed.

Detailed Project Description

The Government of Edel requested a loan from the ~~World Bank~~ to finance a project fo mine and export 10 million tons of iron ore per year from a large deposit in the interior of the country at a site called La Tierra de Fierro. Once extracted, the ore would be shipped by rail about 200 kms. to the seaport of Baja Linda. A new marine terminal would be constructed on an island in the bay to receive the ore and transfer it to ocean-going vessels. The terminal design would enable it to handle vessels up to a half-million tons.

Transfer of the ore from the mine to the terminal will be provided by the state-owned railway system, Los Ferrocarriles de Edel.

The iron reserves in La Tierra de Fierro are high grade and substantial. The deposit to be mined contains 500 million tons of ore with an average iron content of 70%. Other deposits nearby contain another 500 million tons of ore. The deposit has very little overburden and is well suited to the planned open pit operation.

Economic justification for the project is substantial. World iron ore prices are firm, after an earlier depressed period during the 1960's.

World iron ore demand is expected to require an increase in annual production of 40 million tons each year throughout the 1970's.

The Government of Edel has already obtained long term sales contracts for 90% of the initial iron ore output of the project. An expected return to the Government of 20% has been calculated at a sales of 10 million tons per annum. Even under the adverse conditions of increased operating costs and price erosion the economic return should not decrease below 12%.

The average net foreign exchange benefits to the Govt. of Edel are expected to range between US$50 millions and $75 millions annually.

A. The Mining Plan

The orebody at La Tierra de Fierro is massive and outcropping. Thus it is well suited to open-pit mining and has a quite favorable stripping ratio. Conventional hillside open-pit mining methods will be used. Ore and waste will be drilled, blasted, and loaded by shovels into trucks for haulage to the processing plant or waste dumping sites. The mining will occur over 3 shifts operating 6 days per week. About 12 million tons of crude ore will be extracted to produce 10 million tons of salable ore

B. Ore Preparation

The ore preparation plant will consist of primary crushibg, screening, secondary crushing, final screening and washing, and hydraulic classification facilities. The plant will be designed to process 15 million tons of crude ore per year with provisions for future expansion.

About 80-85% of the ore mined will emerge from processing as salable ore. The remainder, consisting of very fine material, will be stored in hopes of developing a future market.

C. Overland Transport

The ore will be transported the 200 km. to the port of Baia Linda via a commercial railway system which presently exists and is operated by the government railways, Los Ferrocarriles de Edel.

D. Ore Transfer

Transfer of the ore will occur at an ocean terminal to be constructed on a small island about 1 km. off the coast in Baja Linda. The site was selected from various alternatives after weighing the various technical and economic factors, including feasibility of transport.

The terminal will receive and unload unit trains of iron ore, provide stockpiling facilities, and load oceangoing vessels of up to a half million tons. Linkage with the mainland will be through a railroad trestle 2000 meters long.

The ore transfer operation has been designed to be easily expandable to double the present annual capacity.

Environmental Impact Analysis

A. The Mine Site

1. Dust created by mining operations at La Tierra de Fierro is not expected to cause major problems. Blasting will cause considerable dust and flying rock for brief periods. The blasting will occur so infrequently, however, that the impact is expected to be negligible. Drills will be equipped with dust collectors and will be essentially dust free. Dust will be caused by traffic on haul roads. This will be minimized by sprinkling. The main access roads and roads around office areas will be paved.

Dust from transfer operations will also be minimized. The mined ore will be transferred by truck from the mine to the crushing plant. The plant will be equipped with dust collectors connected to hoods at the feeder and crusher. If necessary, water sprays will be used on the feeder discharge and ore conveyer. Water sprays will be used to control dust on the open piles of ore stored after crushing.

2. Tailings from the processing operation require proper disposal. These tailings will consist of a slurry of fine hematite sand and slimes. The slurry will be thickened by passing through a cyclone and the reclaimed

water will be reutilized in the process. The final slurry will be stored in a pond formed by damming up a valley behind the plant. The plan is to recycle pond water to the processing plant. To accomplish this, a synthetic polyelectrolyte flocculant will be utilized to clarify the pond waters. Overflows will then be passed through a filtering dam prior to reuse.

3. Processed ore will be stored in an area with a system of underdrains. Drainage water will flow to the process water reservoir. Piles in storage for long periods in the dry season will be sprinkled periodically. Bucket wheel excavators will dig into the pile and mix the underlying damp material with any dry surface material. The bucket wheel excavavators will discharge to conveyors, bins, shuttle conveyors, and to a continuously moving train.

4. Erosion in the mining and processing areas will be minimized by fitting lined ditches into the top and base of cuts. Cuts will be designed to minimize the area exposed to surface water. Sediment carried by the runoff and drain streams will be deposited by siltation in the process water reservoir.

5. Reforestation will also be employed to control erosion at the mining site and to minimize the visual impact of the mining operation.

6. The nearby city of El Fierro Grande is located on the opposite side of the mountain from the mining operation. Thus the inhabitants will not directly view the mining operation.

7. Sanitary wastes from the various facilities will receive treatment in an aerated sewage treatment plant designed for 1000 people.

8. The water supply system will be constructed for the project. A reservoir will accumulate natural runoff behind a dam to be constructed below the plant.

B. Ore Transport Overland

1. Noise will be a major problem. The roar of 3000 hp locomotives, signal whistles, screaming of loaded ore cars on curves, and the rumble of empty cars returning will frequently exceed the 80 db. level commonly set as tolerable.

When the ore processing plant operates at capacity, twelve trains

daily of 100 cars each will be required. Los Ferrocarriles de Edel have proposed welded track and muffled locomotives to lessen the noise. Even so, the passage of trains at night would disturb the sleep of persons in villages along the right of way.

2. A hazard to pedestrians will be introduced if trains are restricted to daylight hours to eliminate disturbance to sleep. The tracks run along the coast for the last 100 km. before Baja Linda and many people cross these tracks to visit coastal beaches.

3. Some new railroad construction will be required. Unless controlled, erosion associated with construction could be a major problem.

4. Ore dust can fly from the open cars unless kept moist. Sprinkler systems should be installed enroute.

C. Ore Terminal Site-Baja Linda

A sketch of the site appears on the following page.

1. Presently the Baja Linda area is undeveloped. Ecological investigators described it as the most beautiful they had seen.

2. The most serious existing environmental problem is erosion. This is especially true on the low hillsides of deep lateral soil which have been cleared for pasture. Road cuts and natural washouts from these areas are highly visible.

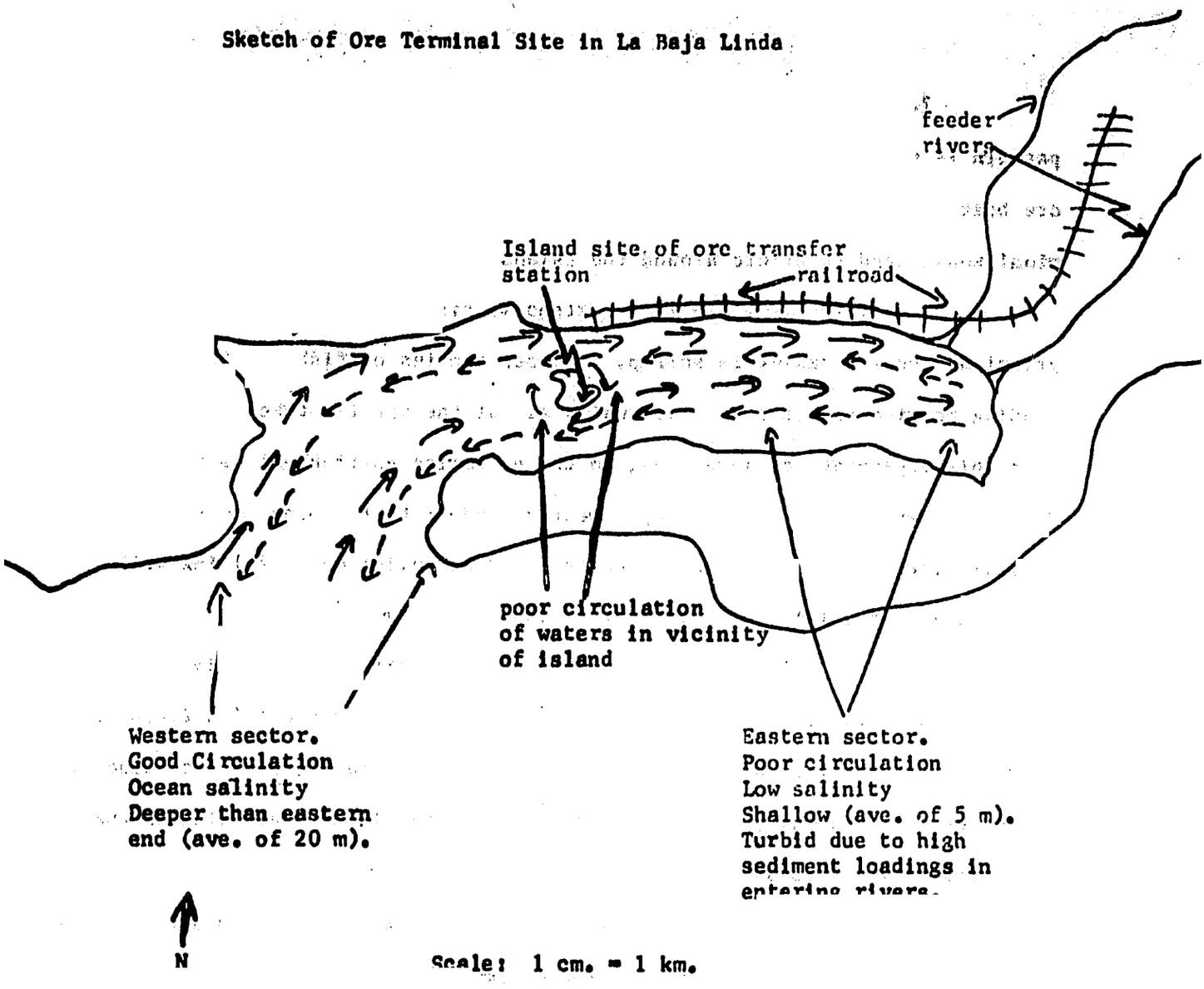
3. Slash and burn agriculture is practiced but is not intensive. Few environmental problems are presented.

4. The natural vegetation is lush. There exists a variety of species and the growth is dense.

5. There are many lovely sandy beaches with clean white and tan sands.

6. Population density is low and the homes blend pleasantly with the natural environment.

Sketch of Ore Terminal Site in La Baja Linda



Scale: 1 cm. = 1 km.

7. The tide flows in the bay have been measured. The circulation pattern is poor around the island which is to serve as the terminal for the ore boats. Any waterborne wastes or pollutants eminating from the ore terminal would tend to circle around the island and would not be well dispersed.

8. Presently there is an extensive fishery in La Baja Linda. The principal species caught is shrimp. A dozen species of fish are taken, including corvina and catfish. Virtually all of the species taken are known to be highly dependent, as juveniles, on the estuarine environment of the bay. Probably they migrate to the deeper western end or to the ocean to spawn. Habitat alteration in the shallow eastern end by pollution or filling will reduce the productivity of the bay for fish and shrimp.

About 200 metric tons of shrimp are harvested annually from tl eastern end of La Baja Linda. The worth of this catch is about $US 250,000. This figure, plus the value of the fish caught commercially, plus the value of the estuary as a nursery area indicate that this bay is of real value to the commercial fishing industry of the country of Edel.

9. An extensive biological sampling program was carried out throughout the bay to establish the major biotic communities of the project area and their floral and faunal components. For example, 53 species of mollusks were identified.

This sampling has established ecological conditions before the construction and operation of the ore terminal so that benchmarks exist. Changes due to project-caused pollution can be quantitatively related to these earlier conditions.

10. The tourism potential of Baja Linda is great. The attractiveness of the area is such that the town of Baja Linda increases from 3000 permanent residents to a summer population of 15,000.

Environmental recommendations regarding the ore terminal facility

1. The site for the ore terminal has been recommended to be based at the southern portion of the island so that it will not be visible from shore A further recommendation is that no alteration be made on the northeast side of the island by forest cutting or blasting.

2. The face of the excavation on the south side of the island should be provided with broad terraces. These will prevent erosion and encourage natural regrowth of vegetation. The aesthetic advantage will be to help soften the visual impact of the ore terminal transfer site.

3. No signs advertising the project should be permitted except those required by law.

4. The 2 km. railroad trestle will be an eyesore. The trestle and terminal facilities should be painted appropriate soft colors to blend with the sea (trestle) and the island background (terminal).

One possible advantage of the trestle will be to serve as a catwalk for fishermen. This may add to the recreational potential of the area.

5. A plan should be developed to provide solutions to the anticipated water supply and sewage disposal problems that will accompany the increased population in the Baja Linda area due to the project construction. It is specifically recommended that the Government of Edel begin planning now to install a new water treatment plant and a secondary level sewage treatment plant.

6. The Government of Edel should assign an environmental inspector to the project. Such as inspector would have authority to order measures to prevent environmental degradation and, if necessary, to order work halted until remedial measures are taken.

7. The greatest potential for project environmental impact is from oil spills.

a. The possibility for oil discharges within Baja Linda will exist even if prohibited by law. The harbor of Baja de Oro, for example, is located in the adjoining country of Spar. This harbor receives heavy industrial traffic and is now grossly polluted by oil discharges which occur in flagrant violation of existing law.

b. The oil/ore boats have a procedure of washing the oil from bulkheads with water and detergent when switching cargos from oil to ore. At least 10 tons of "slurry" or "slop" is produced from each of the several holds of the vessel. Total discharges of more than 100 tons can be expected.

c. Possibilities for construction of shore facilities to reclaim the oil should be investigated. Alternatively, a law requiring discharge of slop far out at sea should be rigidly enforced.

d. The detergents used in hold cleaning are extremely toxic to marine organisms and special precautions should be taken to prevent detergent from entering the waters of Baja Linda.

e. A large oil spill in Baja Linda could have disasterous effects upon the ecology of the bay and on the commercial fishery. The problem would be compounded because pollution from the ore terminal would tend to circle the island and not be well dispersed. Effects from a spill would thus linger over a long time period.

8. Planning should include a modern shoreside facility for solid wastes disposal. Furthermore, close policing will be required to prevent the too common practice of shipside disposal of solid wastes.

9. If a future market is developed for the fine spoil from the mining operation, this should be pelletized at the mine site. Extreme dust problems would be otherwise be associated with shipping and processing these fines.

Ref: Jack B. Carmichael. Environmental Considerations in the Planning and Evaluation of Development Projects; monograph published by the Organization of American States, Washington, D.C., 1974.
Case Study: Nickel Ore Mining and Refinery Project in the Country of Teleroy.

Project Summary

The State-owned mining corporation of Teleroy, Corporacion de Explotacion de las Minas, has proposed a project to mine and refine one million tons per year of ore containing an average of 1.5% nickel. The ore will be mined from a mountainside on the northeastern side of El Lago Capitan in southern Teleroy. The site is about a mile to the north of the processing site and 4000 feet up into the mountains. The mined ore will be trucked down the hill to the processing site.

The refinery will be built on the lakeshore adjacent to the mine. A port will be constructed to receive supplies and export the refined nickel. A 60 MW oil-fired power plant will be constructed to provide both steam and power for the plant. Another major construction associated with the project will be a residential area of 200 homes for plant supervisors.

The ore processing will proceed by crushing the ore followed by rotary drying to 25% moisture. Roasting at 1700 °F with sulfur and in the presence of air selectively reduces the iron and produces NiS. The reduced ore is smelted in an electric furnace at 2700 °F. The floating slag is skimmed, cooled with water, and disposed. The settled matte contains about 25% nickel. It is transferred in 30 ton batches to a top blown rotary converter with blown air and a sand flux. Another slag is produced. This time the slag sinks and the converter matte is separated by skimming. This converter matte contains about 75% nickel. It is water cooled, granulated, dried, and packaged for shipment. The processing of a ton of ore yields about 50 pounds of final product.

Environmental Impact Summary

Environmental impacts can occur at the mining site, the refinery, a sand mining operation on the shores of El Lago Capitán, the port, and the new village.

El Lago Capitán is an unpolluted lake of about 500 km^2 with an average depth of 15 m. The greatest potential for project environmental impact is deterioration of this lake from a variety of sources. These include wastewater discharge from the refinery, siltation from the sand mining operation and the mine site, accidental spillage at the port, and effluent discharge from the new village.

The refining operation is pyrometallurgical and does not produce liquid process wastes. However a total of 30,000 gallons per minute of coolin water will be discharged with a 20°F temperature differential over ambient. Also 9,000 gallons per minute of various processing waters will be produced. Some water quality impacts can be expected from the thermal discharge and the (relatively small amounts of) pollutants in the process waters.

The sand mining operation will produce 200 tons of sand per day and is calculated to produce 50 tons per day of silt. This is expected to have a substantial local impact to the southeastern area of El Lago Capitán. Another source of siltation in the lake could occur from erosion at the mine site but is expected to be minimal.

arge amounts of oil will be transported to the port. Sizeable leaks or spills would have a substantial and lasting impact upon El Lago Capitán.

A package secondary treatment plant will be installed to serve the new village. The effluent will be discharged into a stream which drains into ~~a nearby swamp rather than directly into~~ the lake.

The impact upon the air environment will be due to the 30 tons of sulfur as SO_2 which will be discharged from the power plant and the converter at the ore processing plant. Filtration and electrostatic precipitation will

remove essentially all the particulate matter from exhaust gases of the power plant and the processing operations.

Good methods of controlling erosion and restoration of the mining area will insure that little environmental damage will occur there.

Procedures to Mitigate Environmental Impacts

The following agreements were reached with the government of Teleroy to mitigate various impacts of the nickel ore mining and refining project.

1. An emergency system of boom containment and absorbers will be in place at dockside to restrict and collect any oil spills which might occur.

2. A lagoon will be constructed for the sand washing operation to prevent siltation of the southeastern end of the lake.

3. Process waters discharged from the ore processing and refinery operation will pass through a settling tank prior to discharge to the lake. Suspended solids will settle and oil will float on the surface and can be removed by skimming. Little cooling will occur due to the short residence time.

4. Two air sampling stations will be located to the east and west of the plant to insure that ground levels of SO_2 are not excessive. (If these show that excessive concentrations of SO_2 are present, additional treatment facilities should be considered for this plant and should definitely be required for any plant expansions).

5. A water sampling station will be placed at the discharge of the cooling and process waters. Analysis should include temperature, suspended solids, oils, and metals such as Fe, Ni, and Zn.

Disagreements over Impact Mitigation Procedures

There is a disagreement over the need to mitigate the thermal effects of the cooling water discharge. The discharge will undoubtedly cause a substantial localized temperature rise. However the Corporación de Explotacion

de las Minas has disputed the claim that the discharge will cause a temperature rise sufficient to disrupt the ecology of a substantial area of the lake. The recommendation that heat be dissipated through a diffuser pipeline with perforated openings has not been accepted on the gorunds that it is not necessary. The matter remains to be resolved.

Detailed Environmental Analysis

A. The Mine Site

The ore is a silicate of iron and magnesium containing an average of 1.5% nickel. This ore will be surface mined to depths of 10 to 30 meters. The average depth will be 20 meters and will consist of about equal layers of ore and overburden. This overburden will be spoiled, and the spoil from one bench will be replaced into a previously mined out bench. The benching of the mine area will start at the bottom and mined out sections will be replaced from above. This is a substantial environmental protection action designed to preserve the mine area in as close to its original state as possible.

The other major environmental measure at the mine site will be that topsoil will be separated and redistributed on top of the spoil following the mining operation. The plan is to plant a commercial crop on the regenerated land after the mine has been abandoned.

Some loss of topsoil, expecially silt, will occur during periods of heavy rainfall. This will increase the sediment loading in the clear mountain stream that runs down the mountain. Sediment may, on occasion, reach the lake. Periodic increases in turbidity in the lake would present an unsightly condition and interfere with fishing operations. If a heavy rainfall occurs at a time when topsoil has been freshly excavated and is unprotected, a substantial short term increase in turbidity in the lake can be expected.

The overburden is fully weathered rock and no further leaching of soluble minerals or metals is likely to occur.

B. Ore Transport

Since the distance between mine site and refinery is so short, no environmental effects associated with transport are considered noteworthy.

C. The Ore Processing and Refinery Operation

1. Impacts upon the Land.

Land use is not intensive in the vicinity of the proposed ore processing and refinery operations. Use is about equally divided between pasture for cattle and farming (corn and rice). These activities are not judged to be likely affected by the new operation.

One potential problem could develop from the slag buildup from ore processing. The present plan is to store the slag at the plant site pending possible future utilization for recovery of other metals. Few soluble minerals will be present to be leached. If unplanned, the slag heaps could be quite unsightly.

2. Impacts upon El Lago Capitán

a. Present condition of the lake.

El Lago Capitán is an unpolluted, relatively clear lake that is ideally suited for recreation, fishing, and even use as a water supply. The major use of the lake at present is fishing by individual commercial fishermen. Representative water analyses (based on 5 to 25 samples) are shown in the table below.

Constituent	Representative Concentration, ppm unless otherwise indicated
Silica (as SiO_2)	15
Total hardness (as $CaCO_3$)	96
Suspended solids	6
Dissolved solids	126
Chemical oxygen demand	5

Iron	0.22
	8.3 (pH units)
Coliform bacteria/100 ml.	20 (number of colonies)
Ave. temperature (winter)	75
Ave. temperature (summer)	90

The only potential difficulty for use of the water in the ore processing and power plants is the silica content. Water for high pressure boilers and turbines of the power production unit may require pretreatment.

The lake should be considered a major recreational resource as development of the area proceeds. The lake should be preserved in a good condition for such purposes.

b. Port operations

A port will be constructed next to the ore processing plant to receive the raw materials sulfur, sand, and oil. Oil is the only material which poses an environmental hazard. Oil barges will unload at the dock into an oil pipeline through which the oil will be pumped to storage tanks at the plant site. This Bunker C type oil will be used to fuel the 60 MW power plant which will provide steam and power for the ore processing plant.

Potential environmental problems could be Bunkder C oil leakage from a barge, an oil transfer pipeline, or from the onshore fuel storage tank. In the absence of controls, an oil spill would float on the surface and jeopardize fish, waterfowl, recreation, and the aesthetics of the lake.

The Bunker C oil will barged in under contract to a supplier. He may not be as reliable or as concerned with the local environment as La Corporación de Explotación de las Minas de Teleroy. The Corporación has therefore agreed to insist on guarantees for oil spill clean up from the supplier. Furthermore, oil spill containment booms and adsorbents will be stocked at the port in the event this equipment is needed to control a spill.

c. The ore processing and refining operation

Water from El Lago Capitán will be brought into the plant for two major purposes: (1) 30,000 gpm for the power plant condenser and auxiliaries cooling, and, (2) 9000 gpm for process and drinking water.

The 30,000 gpm of cooling water will be drawn in at an average winter temperature of 75 °F and an average summer temperature of 90 °F. Maximum temperature in the water body is about 95 °F. During use, these waters will be heated about an average of 20 °F, and will be discharged without treatment. Maximum temperature of the discharge will thus be about 115 °F. These waters will pass into a canal which will discharge into the lake. The matter of including a perforated diffuser pipe to disperse the heated water into the lake is under discussion.

Of the 9000 gpm of process water, all except 300 gpm will be used as withdrawn from the lake. The remainder will be processed through a water treatment plant for drinking water (200 gpm) and boiler feedwater (100 gpm). Major uses of the process water will be for wet ore crushing, cooling slag, cooling matte, and pelletizing the final product. Corporacion de Explotación de las Minas has asserted that the mixcellaneous process waters will be unpolluted, since they are essentially used in various cooling operations. Water is not used as a reaction medium since the ore processing is pyrometallurgical.

However, the presence of emulsified oils resulting from leakage of lubricating oils into cooling waters appears to be unavoidable in an operation of this magnitude. In total, the discharge of process waters from the plant will be contaiminated with soluble boiler salts, oils, heat, and suspended mineral solids.

La Corporacion de Explotacion de las Minas has agreed to install a settling basin through which the process waters will pass prior to discharge.

to the lake. This will allow settling of suspended solids and oils will float on the surface and can be removed by skimming. This precaution is important because emulsified oils are unsightly and will coat, clog, and cling to objects found in the lake. Emulsified oils are a hazard to waterfowl and fish. Suspended mineral solids such as iron, sand, and various oxides cause turbidity and settle in coves and other areas of little water movement. A soft and shifting lake bottom is created, unsuitable for the roe of most fish.

The Corporacion plans to construct a small sewage treatment plant for domestic sewage from the plant. Details of this plant are not presently available. Good treatment of sewage effluents is important, because bacterlological contamination of the lake by direct discharge of sewage or poorly treated sewage effluent might endanger the users who are dependent upon the lake as a source of drinking water. Excessive sewage discharges into a lake lead to many other problems as well.

d. The new village

The new village will house about 800 people in 200 homes. Water will be supplied from an intake pipe from the lake about 10 km. from the plant site. A package secondary sewage treatment plant will be installed in the village. The treated effluent will be discharged into a small stream which travels 5 km. prior to discharge into the lake. Discharge will occur about 2 km. from the intake pipe for potable water for the village. No pollutional problems are anticipated due to the ample dilution of the secondary effluent.

3. Air Quality Impacts.

There is no available data on air quality in Teleroy. Apparently no air sampling and analysis has been carried out. Visual observations and conversations with inhabitants indicates that the present air quality is good. The only notable existing source of air pollution is smoke from the slash and

burn practice of agriculture. However the smoke from this operation is reported to frequently hang in the air for a day or more at a time, especially during the summer.

The plant and the new village are surrounded by mountains, and inversions are apparently a common occurrence during the summer months. No hazards exist at present because of the low level of man's activities in the region. A potential problem is posed by the ore processing plant and the power plant. Potential contaminants from both the ore processing plant and the power plant are flyash and sulfur dioxide.

Extensive air pollution control facilities are planned to eliminate fly ash and other particulates from exhaust gases. A series of multicyclone filters and electrostatic precipitators will eliminate particulates from gases in the ore processing and power plant operations.

No plans are incorporated for removal of SO_2. Twenty two tons of sulfur (as SO_2) per day will be emitted by the power plant, and another eight tons will originate in the converter operation of the processing plant. Two stacks of 400 feet will be constructed in order to disperse the exit gases. Those gases are expected to contain about 0.05% SO_2.

Sulfur dioxide is hazardous to human health when breathed. It is odorous and corrosive to plant life as well as many metals. Two air pollution monitoring stations will be established at ground level one mile east and west of the processing plant to insure that ground levels of SO_2 are not excessive. (Editorial comment: If ground level concentrations exceed 0.1 ppm for 24 hours or 0.5 ppm for ½ hour during the months of heavy atmospheric inversion, then some requirement ought to be considered for the installation of SO_2- control technology, such as a wet scrubber).

D. Environmental Control Costs

The total cost of the planned air pollution control facilities is

$US 2.5 millions. Another $US 2.5 millions will be required for construction of the tall stacks.

Total water pollutional control costs are estimated at $US 1.5 million not including the cost of construction of a cooling water diffuser pipeline. The cost becomes $US 1.9 millions with the cost of the diffuser pipeline included.

The total of $US 6.5-6.9 millions represents about 4% of the total estimated cost of the project.

Environmental Quality Issues

by

Prof. Emil Chanlett

International Program in Environmental Aspects of Industrial Development
University of North Carolina, Department of Environmental Sciences and Engineering, School of Public Health. Chapel Hill, North Carolina, 1975

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Environmental Quality Issues

Professor Emil Chanlett

I. What environmental characteristics are of concern?
Use 700.4 - Biological, chemical, physical factors in the physical environment.

Why?
Use 700.6 Table - The Chips in the P Game.

II. Who shapes our environment?

Where are decisions made?

What factors enter into the choices?

III. What are the constraints?
Natural; economical; technological; social; political.

IV. Who has the responsibility for environmental quality control in the present framework of governmental services?
Global; international; national; state; local.

What are deterrents to the effectiveness of present controls?

V. What goes on in local health departments environmental control activities?

Can its productivity be determined? How?

Can its productivity be increased? How?

Does anyone else want the local jobs?

THE P NUMBER GAME - CAN WE PLAY IT?*

Professor of Sanitary Engineering
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School of Public Health
Department of Environmental Sciences and Engineering

Allen Gregg provides an invocation. "Clearly related to past, present, and future, three things mainly keep man together: from the past, it is shared experiences; in the present, beliefs generally agreed upon; and for the future. hopes and desires held in common." This is a call for the wisdom to recognize that the fabric of society, indeed of civilization is carried by these human responses. This is a call for the maturity to realize that the very fragility of the fabric requires restraint and sacrifice in changing it and in accepting it.

What is the P number Game? It is:

1. The number of people
2. The number of products
3. The number of power units
4. The number of places organized as socio-political units
5. The number of pollutants produced

So what's new? These are in exponential growth. A beautiful $P = P\ e^{kt}$ curve. The rate of increase is a fixed proportion of the concentration at the start of any time period in units of t. Nature abounds in e^{kt} and e^{-kt} functions. Bacteria merrily multiply by dividing according to it. Radioactive elements obediently decay according to it. Rat populations rise and fall according to it. The Pearl-Reed population curve plots a rise phase, e^{kt} and the decline phase e^{-kt}. These Johns Hopkins University men lived to see Baltimore rats validate their hypothesis, but not Baltimore people. They were confident that ultimately Baltimore people and all people would validate the curve.

How has all this exponential growth of the P Numbers come about? At the bottom of it is man's unique evolution among all life of one S and the three r's. 1. Speak 2. Write 3. Read 4. Arithmetic.

This capacity of storing and of transmitting his experiences has been an exponential plot in its own right. What power this has placed in our hands. Considering the brutes that we can be, we have done very well with it. If we have not done better, it is because selfishness can be and is institutionalized. That is difficult to undo. With the extra-ordinary exception of England, in recorded time institutionalized selfishness has been undone by violent revolutions as in the Kingdom of France, the Empires of China and Russia; by catastrophic wars as in the case of the Roman Empire, the Hitler Nazi Germany, and militaristic Japan; and by cultural shocks such as the Protestant Reformation, and possibly what is going on in your minds and many young minds of the world today.

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*Prepared 19 April 1970, Chapel Hill, N. C. for delivery on Earth Day, Rutgers University, New Brunswick, N. J. on April 22, 1970.

The most easily identifiable result of accumulating and of passing on knowledge and the one result which has continuously put us in an alternate series of pickles and powder puffs is the mastery of energy. Energy in the pure definition of physics is the capacity to do work. Consider my maternal ancestors who are recorded from 1702 in a Lutheran parish registry in North Germany - a bare 250 years. The several great grand pa-pas had to do their work with their muscles, a few draught animals, and a local wind-mill. Who had more? The mountain and hill people had water-power and the military hac gun powder for blowing up the fruits of the labor of others - their building fields and sons. Until 1702 things had been that way for a long time with a few possible wind-mill improvements. But who ever was entered in the birth registry in 1702 lived long enough to be around when James Watt improved the English steam powered mine pumps. Thermal power became a work horse during the last half of the 18th century. The exponential curve of energy began its rise. By the last half of the 19th century, electrical power from hydro and thermal sources was a reality. By its end, the petroleum fueled interna combustion engine was automobiling a few of the venture-some and the wealthy In the first half of this century nuclear energy came on the line, first for blowing up things and people and now in special uses as radioactive tracers, as medical and industrial tools, and as a third source of generating electricity. Take a look at the power at your command. It is considerably more than your grandfather had. It is enormously more than your great-grandfathe had. It is fantastically more than your great-great-grandfather had.

What has all this to do with Earth Day and the P Number Game? Power multiplies our capacity to do work. Work produces products, places, pollutants and apparently people. I shall leave the enigma of human reproductior to the demographers with a single observation taken lock, stock and caboodle from the world's top sanitary engineering statesman, Abel Wolman of Baltimor "Human reproduction is a vascinating phenomenom. It is our most successful cottage-industry, because the workers enjoy it immensely." Yet that is what it is all about - people.

Earth Day is concerned with environmental quality. The environment has no inherent quality. It has only such qualities as people assign to it. Poets and painters call forth images that we feed back the next time we see meadow, mountain or stream. Composers do it on large scale and small. Whoever has crossed our Great Western Plain must respond to the exhilarating plainative passages of Dvorak's Symphony No. 5 in E Minor, Opus 95 "From the New World". The listener relives the joy of vastness, serenity and strength as Dvorak evokes and enhances our remembered visual experiences. The sound tracks of "The Big Sky" and "Across the Wide Missouri" do some of the same with less sensitivity and fewer nuances. A dozen of Stephen Foster's ballad do the job with frank sentimentality.

It is the quality of people which assigns a quality to the environment. The quality of people is their sense of values expressed chiefly in a willingness to forego immediate gratifications for a longer term good. Our sens of values is the product of our nurture. Our nurture is from all of those about us and from our physical environment. That nurture is good when there is a balance of expectations and capacities, an exchange of appreciation and understanding; and a sense of being an important part of the action. Call i

belonging. Call it fitting in. Call it being capable of love. Then the essential components emerge. These are ability to recognize good and the readiness to do good, not out of any maudlin sentiment, not out of fear or terror, but because it fits our nurture and strengthens our power to be lovable and love able. M. F. Ashley Montagu sums up our need. "Human nature is good. It is our present human nurture that is bad. We need to conform human nurture to the requirements of human nature."

How do the P Numbers look? On a global base, people are at a growth rate between 2.0 to 2.5 percent per year, doubling in number in 28 to 35 years. Does it become more concrete to say it for India as the need to make room for 1 million new ones per month? That's enough new ones to equal New Jersey's population in 7 months. Products can be expressed in resource use. Copper and oil use and motor vehicle production will suffice as illustrations. World refined copper consumption rose from 5 million short tons in 1960 to 7.5 million in 1969. Petroleum use in the world is rising at about 8% per year. The USA rate is more modest, about 3.5 to 4% per year. Others are playing catch-up with Japan leading the catch-up game at a 23% increase in oil consumption per year. Motor vehicle production in the USA is 9 million per year plus another 1.6 million imported. The world produces a total of 24 million motor vehicles per year with the USA comfortably at the top followed by Japan, Germany, France, the United Kingdom and Italy. The USSR with only 1 motor vehicle for each 70 people cannot contain the consumer demand much longer.

Edwin Dale of the New York Times has strikingly capsuled the exponential growth of the USA economy with 100 billion dollars growth in the 13 years, 1944-1957 to a projection of a 500 billion dollar growth in the 13 years, 1969-1981.

All the value of goods and services produced are in constant value dollars. The growths in three 13 years periods are:

1944-1957	100 billion dollars
1957-1969	300 billion dollars
1969-1981	500 billion dollars

In this article, "The Economics of Pollution", New York Times Magazine, April 19, 1970, p. 28, Dale states:

> "...That is the law of compound interest. These are not numbers; they are tin cans and smoke and auto exhause. There is no visible escape from it. Applying the same percentage growth to a larger base every year, we have reached the point where our growth in one year is half the total output of Canada, fully adjusting for inflation. Another dizzying and rather horrifying way of putting it is that the real output of goods and services in the United States has grown as much since 1950 as it grew in the entire period from the landing of the Pilgrims in 1620 up to 1950...."

What about the power units? Electrical power use in the USA is at 1.5 billion KWh and rising at 7% per year. We now require a generating capacity

of about 1 KW per capita. To produce that power each year we burn 300 million tons of coal, 9 billion gallons of oil and 3 trillion cubic feet of gas. The hydro generated electricity is small and the nuclear reactor generated electricity still trivial, but rising rapidly.

The number of places is important as decisions on environmental quality are determined by governmental response. In the USA, the 50 states, 3,000 counties. 18.000 villages, towns, and cities and 40,000 special districts, townships and local authorities can rarely be ignored, by-passed, or circumvented. Each has a bit of sovereignty, zealously exercised as it sees its interest and its good. New Jersey is about average in this P number. There are about 1600 jurisdictions.

The number of pollutants can be enumerated by a look at you. How much mess do you make each day? You put out 5 pounds of solid wastes each day. This is food waste, paper, bottles, cans, plastics, and just trash. You use and dirty 50 gallons of water a day, bathing, hand washing and toilet flushing. Your sewered waste requires about 0.2 pounds of dissolved oxygen per day. That sounds modest enough, but nature has squeezed us badly on that item. Oxygen is not very soluble in water. Natural water that has 80 pounds of dissolved oxygen in a million gallons is well oxygenated. Streams that have already received a load of wastes may not have enough to keep trout and bass alive. These fish require about 40 pounds in a million gallons. Your daily waste load requires all the oxygen that is in 5,000 gallons of water that has just enough dissolved oxygen in it to keep trout and bass alive.

You do most of your dirtying of air when driving a car. A car that runs 10,000 miles per year, the USA average, dumps 3½ pounds of carbon monoxide of unburnt hydrocarbons per day. That's a "fifth" size whiskey bottle full of gasoline. Your share of all the mess discharged from all sources into the air is 4 pounds per day. 60% is from motor vehicles, 30% from electricity generation and manufacturing, and 10% from space heating and solid wastes burning.

Manufacturing and agricultural liquid and solid wastes have not been assigned to you. That would bring your per capita water use to 2100 gallons per day. That's 9 tons. The solid wastes from animal and food protection makes the Augean stables that Hercules flushed out a modest accumulation.

So far all has been in units of filth - pollution by dictionary definition. The rub is that the filth is not just a nuisance but is accompanied by specific biological pathogenic organisms, protozoa, bacteria, virus and helminths; by specific chemical toxicants such as lead, carbon monoxide, dioxin, and alpha benz pyrenes, to name 4 of about 400 well identified ones. As all of this is either for energy production or from energy use, including your eating, and as energy transfer is not more than 50 to 75% efficient, there is also an exacerbation of physical energy. Depending on the transfer process, this comes out as heat, noise, and radiations. Call it bum engineering, but until recently the goal was maximum mechanical efficiency and let the energy exacerbations fall where these may. Carl Sandburg got a big bang out of Chicago, hog butcher of the world. the throbbing municipal might of incomplete engineering. A jet's roar, a locomotive's rumble, a subway train's

screech and clatter give me a kick as an occasional listener. One thing that Car Sandburg and I share is urban retreat. He from Chicago to Flat Rock N. C.; I from NYC to Cloud Crest, N. C.

What Are The Consequences, Actual and Hypothetical, Real and Fancied of All This Mess?

40 minutes not 40 credit hours is the time allotment for this discourse. Therefore the Chapter and Verse of communicable diseases, occupational diseases, radiation injury, hearing loss, death and dismemberment of accidents, and eye damage by ultra-violet, neutrons, laser, and micro-wave are mentioned not documented. For these, cause and effect are certain, and for many circumstances specific exposures stated in time, intensity or concentration can be predicted as safe, or as hazardous, or as lethal. Moving from such specific pathology to the conditions which plague urbanized people under the labels of heart disease, cancer, vascular lesions affecting the central nervous system, we encounter the three leading causes of death in the USA. The rates in order per 100,000 people per year are: for the heart about 365 and steady; for the cancers 160 and rising; for the vascular lesions 100 and declining slowly. Total deaths per year, all causes, in the USA are about 1000/100,000. Therefore the first three, adding to 625/100,000, cover 62.5% of all deaths per year. The next 5 causes are accidents about 55 and steady, pneumonia 30 and edging down slightly, diseases of early infancy 25 and edging down; arteriosclerosis holding just below 20; and diabetes mellitus holding at 18 to 19. These are the stock quotations of the leading causes of death. Close on the heels of these is suicide, a bitter indictment of our adjustment.

What our filth has to do with these chronic, degenerative diseases no man knows. There are a few carcinogens loose in the environment in very low concentrations. That's so for a few poisonous metals and traces of radioactive elements, too. Except for specific occupations such as chromate workers and uranium miners, the consequences of the exposures to the carcinogenes are not predictable. Let there be no misinterpretation. There must be the most prudent use of all biological, chemical and physical agents known to impair life processes, and the maximum of wisdom in their release to the free environment. Yet to have a violent attack of chemo-phobia at the mention of any of these with a name longer or less familiar than ethyl alcohol or tobacco smoke is either ego-mania or hypocrisy. What else could be said of us, who spend $15 billion for drinking alcohol, $10 billion for smoking tobacco, and kill 55,000 fellow travellers on our streets and roads each year? There is no "they". There are, You and I, Us and Me. I am one of us. I drink alcohol. I smoke tobacco. I drive cars.

Let one more piece of vital data be observed and contemplated at leisure. In the 50 years from 1920 to 1970 the life expectancy for all people at birth of USA has increased by 15 years--from 55 to 70 presently. For all women, longer--from 54 to 74. For non-whites both sexes together from 45 to 65, a 20-year gain; for non-white males 45 to 60 and for non-white females from 45 to 68, a 23-year gain. The non-white males, predominantly balcks are at the short end of the stick, but that is not news to them and it should not be to you. In fact, until the black male can earn a better share for himself, there's going to be a lot of news--most of it bad. The change has to come from where things count, the hiring hall, and the promotion desk of the personnel department.

The question on the consequences of a messy environment has not yet been answered. It will be best if it never is answered definitively, as that would require letting it go to pot while documenting and charting the debacle. There has been a lot of speculation and much more is being aired on the fate of the environment and its contents. There are several hypotheses. Among the myriad of statements on environmental quality, environmental deterioration and environmental hazard, three major hypotheses recur.

1. The impacts of technology, urbanization and population density are outstripping man's biological capacity to adapt. The impairments can appear in time scales varying from an individual's lifetime, to a generation or two, to an evolutionary span of time.

2. The impacts of technology, urbanization and population density are so violent that the stability of the present ecosystem is being changed so rapidly that the earth's life support system will collapse.

3. The impacts of technology, urbanization and population density require the maximum utilization of the assimilative capacity of the physical environment for the support of the human race. This can be done by applying present knowledge fully and effectively through existing social and political mechanisms before catastrophe.

The first 2 hypotheses are being ably stated these days and usually less ably documented and analyzed. I would be pleased to take on the analyses, but it would be the analyses of a non-believer. This is a day of dedication for saving what is left and of proclamation of our faith in our capacity to do the job. Therefore I stand on hypothesis three. Therefore I call for action to use the assimilative capacity of the environment prudently, with the humbling realization that the manifestations of our life style are but a speck in the panorama of evolution, even of man's evolution. It may not even be a very good speck. It does have very good possibilities. The chief quality required to realize those possibilities is unselfishness. We will need more knowledge to do the job. Yet we are not in bad shape on the technology. The fastest way to improve a technology is to use what you have. Both the user and the payer will reward the innovator, the inventor, the developer and the researcher. The sulfur content of crude oil is an example. A few years ago, the idea of sulfur removal from Venezuelan crudes had dim prospects. Today a $120,000,000 desulfurizing plant is nearing completion at the Amuay Refinery of the Creole Petroleum Corporation on the Paraguana Peninsula in Venezuela. The process will add from 65 to 85 cents to the present well-head cost of $2 for each 42 gallon barrel. It will keep Venezuelan crude marketable in New York, Venezuelan crude contains 1.5% sulfur. In October 1969 New York City set a limit of 1.0% on sulfur content. This limit will reduce to 0.3% in October 1971. It costs 5 cents per barrel for each 0.1% of sulfur removed. You can bet that the cost will come down and that the linear programmers at Esso Marketing have most of the conceivable blending formulas ready. Nor is the sulfur removed going to be wasted.

What About Our Present Approaches to Managing Contaminants and Pollutants?

There are three identifiable means in use to keep contaminant and pollutant loads manageable. There have been bounds on individual intake. source

control, and estimates of environmental receptor capacity. Examples of restricting contaminants in work places by establishing limits on intake are Threshold Limit Values for Toxic Gases, Vapors, Fumes and Dusts; Maximum Permissible Dose and Concentration Tables for the airdose; the inhalation an ingestion of radionuclides; and Federal Radiation Council guidelines for the permissible daily intake of ^{226}Ra, ^{89}Sr, ^{90}Sr, and ^{131}I, apply to all of us. Public Health Service Drinking Water Standards which started in 1914 and the California Standards for Ambient Air Quality and Motor Vehicle Exhaust of 195 are further examples of this very useful technique. Other examples are bacte standards for milk and food, and tolerance levels for chemical contaminants, additives, and filth in foods.

Control or at least management at the source has been a powerful tool against contaminants. Local exhaust ventilation in work places is a good example particularly when followed by a satisfactory air cleaning device. Emission Standards for stacks is a way to put bounds on air pollution. Limit on pollutional loads of liquid waste are familiar. These may be sewer use charges based on volume and strength of the waste. These may be restrictions on pH value, the hydrogen ion concentration, of the discharge to oblige at least neutralization. These may be more sophisticated sets of parameters of effluent characteristics of raw or treated wastes from an industrial complex. An example of these are the industry standards established by the Industry Committee of the Ohio River Valley Stream Sanitation Commission. A final example is the limits on the motor vehicle exhaust content of CO, and unburned hydrocarbons, promulgated first by the California State Department of Public Health for motor vehicles sold in that State, and applied since 1968 to all cars sold new in the U.S.A.

The third means for keeping contaminants and pollutants from overwhelming the physical environment can be clumsily described as staying within the receptor capacity. An example of receptor capacity is the prediction of the oxygen say curve of a stream. Two predictions, supported by as many observations as possible and the maximum of professional judgment, are joined. One is the deoxygenation of the receiving waters by the organic pollutional load. The second is the reaeration rate of the stream in the face of the pollutional stress. The resource is the dissolved oxygen content, being depleted by the oxidation of the organic load by microbial activity, and being renewed by natural aeration and oxygen production from photosynthesis. All sanitary engineers of the "wet and dirty" variety have been through the exercise of calculating an oxygen sag curve, and if fortunate, verifying it by sampling along a stretch of stream.

More sophisticated exercises by sanitary engineers have involved mathematical models of estuarine waters to predict pollutional loads which may be imposed by heavy pollutors without deoxygenating the receiving body and without provoking the consequent stench and visual distress of anerobic decomposition. When verified beforehand by field observations, these have been reliable enough to schedule production and discharge of wastes from manufacturing plants. An example is a large pulp and paper mill on Gray's Harbor, Washington.

A final example is a partial prediction technique. It is the use of alert levels for air pollutants and subsequent control actions which can be escalated in accord with concentrations. California uses the terms "Adverse."

"Serious," and "Emergency." The control actions move through cautionary advise to voluntary restraint to mandatory prohibition. In the Los Angeles area schedules exist to manage traffic volumes, industrial production and fuel used for power generation in the face of severe prolonged smog episodes. The evacuation of the cardio-respiratory cripples should be on the emergency agenda.

How Must The P Game Be Played?

Contemplating the rising tide of humanity and its debris, there may be alternatives only as an arm chair exercise. One is to sit back and rock, resting the case on a laissez faire, letting nature take its course. That alternate receives scant attention from the sane and the sensitive. Although there are times when our political leaders and economic managers in effect seem to be following that course. In fact, there are moments when professional colleagues seem on it. That's particularly true at budget making time.

Two is to pursue the present course, which is an item by item attack. We get at the dirty air, the dirty water, the refuse dumps, and nasty nuclear debris, the historically vile pathogenes. Much of our efforts are a bush fire fight. A constant string of emergencies consume our time and energy. The planned action remains on the shelf. Even in stream sanitation efforts where river basins have been the strategic and tactical targets, it has been barely possible to hold the line. The optimistic goal of rolling back the pollutional loads and restoring the waters to pristine quality is heard only in loose political talk. It is touch and go to hold the oxygen sag curve where it is, even by such intense activities as the Ohio River Valley Stream Sanitation Commission. The history of the Los Angeles Air Pollution Control District repeats the record, in whicht the most intense control effort ever mounted anywhere barely holds the line in that situation.

Three is to maintain and strengthen our present operations and to put these in a broader strategic concept. The first stage is to seek a much wider base for the management of the environmental resource of the assimilative capacity for wastes. Can the analysis of the assimilative capacity of the environment lead to mathematical models to permit the prediction of the behavior of contaminants? Can systems analysis lead to a better management of the resource of the physical environment to absorb wastes in such a manner that the concentration of the initial contaminants and of resultant products remains below the threshold of damage? In an article on the technological frontiers in wastewater management, Gotaas of Northwestern University states: "Most effective planning, design, and management of the components, subsystem, and major systems related to water in man's environment will not be accomplished until systems engineering is developed to better understand interrelationships and to select the optimal alternatives."

To realize the possibilities of systems analysis we will need at least four things:

1. More itemized information on what contaminantes and pollutes
2. More information on man's interation with contaminants
3. More information on the behavior of the contaminants and pollutants in the open environment.
4. The deployment of the methods of systems analysis and computer capabilities.

That is how the P Game will have to be played. The questions "Can we play it?" does not have to be answered at all. You have no choice. I have no choice. We are in the P Game now. We will not lose the P Game because hypothesis one will over take us. We will not lose it because hypothesis two will catch up with us. We will surely lose it if the proviso of hypothesis three is not met. The existing social and political mechanisms must prove worthy of the task and of their heritage. It has been a heritage of change. That change has not been peaceful, nor yielded with gentility. Some tall sacrificing is ahead. The kitchen is going to be very hot for a long cook-in. The test is whether we can do it in the frame work of a democratic free society.

The worst that can happen is that our conglomeration of people become ungovernable. Calcutta appears to be moving that way. Some of our ghettos show early signs. But life goes on. The quality of life sinks. The humanity in man sinks. Two things can and must be joined to change the course of the exponential growth of the P Game. These are capital and values of those who are forever young. The managers of capital whether in Detroit, New York, London, Tokyo, Moscow or Peking have too much at stake to drift to the ultimate chaos of the P Game. The capital amassed and invested came from sacrifice and denial for future benefits. It is also power. It can and will be deployed for clearning our dirty environment. Those who are forever young must make their values clear to all and translate these into effective and productive action.

What effective and productive action must be undertaken to manage our pollution?

1. Back the rhetoric on population and pollution control with large commitments of private and public capital to apply the techniques and technology at hand.

2. Increase the number of educated and trained men and women for the job that must be done by increased financial support to those educational institutions already preparing professionals and technicians in environmental control in specific practices and in overall planning and management.

3. Transfer the cost of waste disposal to the cost of production by service charges, ultimate disposal taxes and tax incentives and write-offs where technological changes result in less and more easily disposable wastes.

4. Up-date our laws, regulations and administrative structure to facilitate control including the speed up of legal procedures to assure compliance.

5. Factor the quality of people and of places into our policies and our decisions on the use and development of all of our resources, human, land, air and water.

6. Hammer hard in our research and development mills to increase our ability to predict the effects of our wastes on people. animals and plants, separately and together as a life system.

7. Develop, sharpen and sensitize our sence of values so that we see our brief transit on this planet for what it is, a sharing of interdependence requiring all to be good.

The issue before us has been put by Ansel Adams and Nancy Newhall by poetry and by photography in "This is the American Earth" with this question

> "Shall we not learn from life its laws, dynamics, balances? Learn to base our needs not on deaths, destruction, waste, but on renewal? In wisdom and in gentleness learn to walk again with Eden's angels. Learn at last to shape a civilization in harmony with earth?"

The Effects

The Agents	Human Disease and Specific Impairmen	Human Discomfort, Annoyance or Distaste	Substantial Unbalancing of 1 or more Ecosystems
Biological			
Chemical			
Physical			

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Biological, Chemical and Physical Factors in the Physical Environment

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I. The Biological Agents
   A. Bacteria
      1. Pathogenes for which there is epidemiological evidence of disease. Koch's postulates met.
         a. by intestinal and urinary exits to water, food, soil, there are the causative agents of cholera, dysentery, leptospirosis, typhoid or paratyphoid fever, tularemia in secondary way by eating partly cooked rabbit or drinking contaminated water.
         b. to milk from cows or man source contamination.
            (1) from cows - bovine tbc, septic sore throat, brucellosis at secondary level
            (2) from man - diphtheria, scarlet fever, tbc, Haverhill fever (rarely of cow origin)
         c. from animal sources by contact - brucellosis with animal or meat; anthrax, glanders
         d. from food contaminated other than by excreta - botulism, staphlococcus poisoning, streptococcos infection (massive)
         e. fly borne - all excreta types
         f. crowding in human habitat - hypothetical sans epidemiological support
         g. via insects - mechanical transfer of excreta sources by flies and roaches, plague by fleas from rat to men, by lice from man to man.
         h. air borne - spray and particulate carried
      2. The "fellow travellers" indicators of contamination
         a. Coliform - The bacterial pedigree, gram, bacillus, non-spore forming, ferments lactose with production of gas at 35°C in 48 hrs.
         b. Feccal streptococci - S.feccals, S. bovis and S. acidominimus 1st human, latter 2 bovine, porcine about equal 1/3 of each.
         c. Neiserria catarrhalis - habitat upper respiratory tract - of interest for swimming waters.
   B. Virus
      1. Free in water via excreta - infectious hepatitis, polimyelitis, Coxsackie and ECHO
      2. Free in air - psittacosis - ornithosis
      3. Insect borne - yellow fever, dengue, trachoma (direct contact involved), poliomyelitis possibly, viral encephalitides by mosquitos and ticks, viral fevers by mosquitos, ticks and mites.
      4. From animal sources - rabies from dogs, bats, foxes via biting, foot and mouth disease (rare in man)
   C. Rickettsia
      1. Via milk from cows - Coxiella burneti producing Q fever
      2. Via fleas from rats - Endemic or Murine typhus by R. prowazeki
      3. Via mites - Scrub typhus by R. tsutsugamushi
      4. Via lice - Trench fever
      5. Via ticks - Rocky Mt. Spotted Fever from rabbits. dogs. and field mice.

D. Protozoa
1. E. histolytica of amebic dysentery - from feces back to man via food and water, also flies and hands.
2. Via anopheline mosquitos, approximately 30 of 1700 species transmit, 1 of 4 Plasmodiae - vivax, falciparum, malariae, ovale.
3. Via sandflies - Leishmaniasis by phlebotomus fly

E. Helminths
1. Boil, and and/foot tranferred intestinal worms exiting in feces - hookworm, ascaris, whipworm, strongyloides
2. Via water - schistosomes from feces and urine to water via snail host to cercaria stage to enter man via skin.
3. Via water - from skin, larva discharged to water to crustacean, Cyclops, to water with Cyclops swallowed by man - infection Dracontiasis, or guinea worm infection. Female worm 1 meter long usually in the leg.
Via water - Echinococcosis or hydated disease, by a flatworm, of dogs, "the dog tapeworm," out via feces as eggs, enter via water, food, and hands, eggs have long envr. survival; larvae infections on sheep, cattle, pigs, camels, mouse, reindeer, caribou and man.
5 Via the blackfly - a filarial trematode worm, man to man via bite. Insect vector a flowing water breeder. Onchocerciasis.

F. Fungi
From soil by contact or airborne

		Contact	Airborne	
a.	Blastomycosis - North America	X	X	
b.	Blastomycosis - South America	X	X	also oral man to man contact.
c.	Chromomycosis	X		
d.	Coccidicdomycosis	X	X	principally airborne, dogs & rodent feces involved.
e.	Cryptococcosis		X	pigeon feces involved.
f.	Histoplasmosis	X	X	chicken houses, bat caves, rat burrows involved; rarely may be food borne.
g.	Nocardiosis	X	X	sporadic disease world-over.

II. The Chemical Agents
A. Encountered occupationally by inhalation of dusts, fumes, gases, and vapors.
1. The metals and minerals - most of the notorious actors.
a. Hg vapor and dust
b. Pb in many compounds not equally toxic
c. Mn - a nerve poison
d. Chromium compounds - ulcerative and carcinogenic
e. Zinc oxide - a transient and acute poison, temporarily disabling
f. Free Silica - silicosis - long term cumulative exposure effect
g. Asbestos - asbestosis - long term cumulative exposure effect
h. Arsenic compounds
i. Vanadium

j. Phosphorous compounds
k. Selenium
l. Uranium
m. Antiomny
n. Molybdenum
o. Zr compounds
p. Ba

2. The gaseous forms
   a. CO
   b. Sulfur compounds - H_2S; SO_2
   c. The halogens - Cl_2, HF, F_2, HF, I_2, Br_2, HB_r, Phosgene
   d. Nitrogen compounds - Oxides of N
   e. O_3

3. The organic compounds - solvent vapors, most also skin irritants
   a. Aliphatic hydrocarbons - simple marcosis
   b. Aromatic hydrocarbons - Benzene the bad actor
   c. Chlorinated hydrocarbons - CCl_4, Trichlor-ethylene. Narcosis and liver and kidney damage; perchlore ethylene
   d. Alcohols - Methanol, optic nerve damage; Ethanol - drunk; Butanol - no systemic toxicity; irritant to eyes, nose, skin.
   e. Organo - phosphorous compounds - derivatives of nerve gases of Nazis for pesticide use. Parqthion, Guthion, Malathion. Will take up under pesticide issues.

B. Encountered in water and food
   1. See PHS Drinking Water Studies for the established ones.
      a. Rarely an issue of chronic poisoning from low level concentrations.
      b. Special events - high nitrates in infant milk reconstitution - high fluoride waters; plumbing system pick-up of lead.
      c. Viewed as a contribution of total body burden as in case of lead from air, food, and water.
   2. Food
      a. Naturally occurring - a few possibilities such as Se; solanin in sprouting potatoes; mushrooms, ergot in rye.
      b. Man made additives for flavor, color, preservative, disinfectant, fungicide, nutrient protector.
      c. Residues from growth and processing techniques - soil fumigants, herbicides, pesticides, growth hormones.
      d. Other process ingredients and additives - stabilizers, anti-biotics anti-oxidants, specific nutrients.

C. Encountered in the community air
   1. Products of combustion of fossil fuels
      a. 1. CO - transient traffic highs exceeding occupational TLV for 8 hr. exposure. A 5% carboxyhemoglobin is a high risk for the cardio-vascular-renal cripple. For each 1ppm by vol. in air we get 1/5 to 1/6 of 1% carboxyhemoglobin in our blood. All combustion sources produce CO.
      b. 2. SO_2 - from all sulfur bearing fuels, coal highest, fuel oil variable, natural gas nil. At levels below detectable odor. SO_2 causes increased airway resistance with risk to those with chronic bronchitis, emphysema, and asthma. No bargain for cardio-vascular cripples.
      c. 3. The unburned hydro-carbons, oxides of N, ozone cycle with UV light produces photochemical smog, eye irritation, and has demonstrated carcinogenic (at least to mice) compounds. Motor vehicle exhaust provides the hydrocarbons and the oxides of N.

a. Smoke, dust, particulates, SO_2 and its interactions produce a parcel of dirty air typical of London and New York smog.
   (1) Persistent periods have produced mortality excesses in London in 1952 and 1962 from the cardiopulmonary. Earlier there were Donora, Pennsylvania, 1948, Meuse Valley, Beligium 1923, and New York 1953.
   (2) Epidemiological evidence relates dirty air with rising rates and geographical highs of chronic bronchitis, emphysema, and lung cancer. British data the most extensive, detailed, and statistically significant.

2. Industrial specials
   a. Fluorides from phosphate processing
   b. Odors from pulp and paper
   c. H_2S from oil refining
   d. Dust from cement and minerals
   e. Smoke from asphalt plants
   f. Metallic fumes and dusts from steel mills and foundries.

3. The mix of health effects, aesthetics, economic damage, plant damage, animal damage is noted, and is more difficult to assess than the analogies from dirty waters.

D. Encountered as residues in the general physical environment.

1. Soil surface run off and percolation waters dissolving nitrates, phosphates and other compounds with changes in receiving surface waters and ground water.
2. Pesticides residues in water, food and all fatty animal tissue. The chlorinated hydrocarbons persist. The organo-phosphorous compounds hydrolyze.
3. The case of the synthetic detergents - ABS non-biodegradable; LAS biodegradable at some rate faster than ABS.
4. Build-up of phosphates, and of less immediate consequence nitrates and chlorides in water re-use.
5. Air-borne, water-borne, and food borne radioactive particulates and gases from weapons tests, nuclear reactors, and radioisotope use. Items of concern ^{14}C, ^{90}Sr, ^{137}Cs, ^{85}Kr.

III. The exacerbations of physical energy.

A. All accidents, excepting burns, fire, and electricity can be viewed as uncontrolled manifestations of the elemental physical forces expressed or implied by:

(1) Force = mass x acceleration

(2) Kinetic energy = ½ mass $(\text{velocity})^2$

(3) Momentum = mass x velocity

(4) Force x time = mass x velocity

(5) These prevail in falls, collisions, and even miss-manipulation of hand and power tools - a misapplication of energy.

(6) Results in U.S.A.

a. For 1970 rounded estimates are:

	Deaths	Disabling Injuries (1 day or mo Bed disabl
Total	120,000	10,500,000
Motor Vehicles	55,000	1,750,000
Home	30,000	4,500,000
Public	20,000	2,250,000
Work	15,000	2,000,000

b. 4th leading cause of death - all causes, all ages.
1st cause of death - ages 1 through 34

c. Costs - Estimated $\$15 \times 10^9$/yr.; Lost time 460×10^6 days/yr.
Direct cost and losses.

d. Rising in all countries of the world as more energy is used. Motor vehicle increases pace the rise. Mechanized manufacture, farming and home activities producing rises in all countries.

B. The Electro-magnetic Energy Spectrum, or Radiant Energy

1. Visible light is a small slice (3%) of the whole range of radiant or electro-magnetic energy thus far observed and distinguished by man.

   a. The Short (wave length) family - Cosmic products, Gamma, X-ray ("Eu nao sinta nada, absolutamente nada.")
   b. On the short side of Visible - Ultra-violet - "a deceptive deceiver
   c. Visible Light - what your eye records - VIBGYOR. It all looks about the same. Colors and feelings.
   d. On the long side of Visible - Infra-red - for cooking and baking, or why use charcoal?
   e. The micro-wave and radar family - Can you cook without having anything hot?
   f. The Radio family - "U.H.F.", "V.H.F." Short Wave, the old-fashioned Long Wave (that's all mother had to know). Why so innocent?
   g. The A.C. and D.C. family.

2. The Quantum Theory; $E = h\nu$, Max Ludwig Planck reaches the Great Divide between Classical and Modern Physics - 1900.

   a. Energy is a series of tiny packets (quanta or photons).
   b. Planck theorizes that all energy forms thus far included in E-MES are a series of quanta.

      (1) The energy of the quanta "stream" is the basis of our classifying it as γ, X, U.V., Color, I.R.; micro-wave, radar, Radio-T.V.; A.C.-D.C. (It all can give you a "kick," therefore know how to control it.)
      (2) Energy - Planck's constant (h) X vibrations per second (ν) ν = frequency. All radiant energy travels at the same speed, and so-called "speed of light," 186,000 miles per second, or 300,000 kilometers per second.
      (3) Any component of the EMES can be wholly characterized by any one of (a) its frequency expressed in Hertz (Hz); or (b) it expressed in electron Volts (eV); or (c) it wavelength, (lambda, λ), expressed in cm.

(4) Speed (c) = frequency (ν) X wave length (λ) /lambda/ . For EME, light and all the rest $c = 3 \times 10^{10}$ cm/sec. Express λ in cm and frequency in Hz to solve $\nu = \frac{c}{\lambda}$ -- for other units charge c to fit .

(5) $h = 6.62 \times 10^{-27}$ erg - seconds an action unit in physics.

3. What makes the E? The same phenomena that makes us "biologically" vibrant, stimuli. In all matter, this stimuli from or to EME is an energy absorption or release.

a. The structure of the atom.

(1) The heavy, lazy nucleus at the center full of protons and neutrons and a couple dozen "strange particles." Labelled "DO NOT DISTURB." This sign was respected until approximately 1938, except for a few dozen physicists. Approximately 1900, physicists put up a second sign: "Keep out; this means you, Chemists."

(2) The electrons "dance" about the nucleus. The number of dancers (electrons); their distance from the nucleus (say the orchestra) the speed at which the "e's" move: give the configuration its identity - which we call elements. The "e's" travel in orbits around the nucleus. The relative distances are very great. There are profound and powerful forces binding the nuclear parts and the orbital parts, controlling their motion. System is stable.

b. Changes in the structure of an atom require and produce energy.

(1) When outside force changes the orbital position of an "e", energy is emitted. An electron stream in a Coolidge tube hits the copper target, moves an "e" from its stable orbit causing a characteristic X-ray.

(2) When outside force changes the nucleus, or when an element of the naturally radioactive series is involved, violent energies are involved. This is atomic fission, atomic fusion, or involves radioactive isotopes. Alpha, beta, gamma, and moderated neutrons, are on the loose, as an element is split into several elements, or an element is fused into a new element. U 235 "fissed." H or Li fuse to He. (Dr. Einstein can be seen on the sidelines (1905) carrying a sign, $E = mc^2$. His E and c are the same as Planck's. The m is for mass. In a brief 40 years, Alamagordo Furthermore, Einstein rescued Planck's paper from oblivion. Robert Milliken gave experimental proof in $E = h\nu$ in 1911.

c. All electro-magnetic energy involves changes of one sort or another of matter, hence its orbital electrons or its nuclear composition. (Most things react when asked to change, even if only by changing.) $E = h\nu$ and $E = mc^2$ state that all things in the universe are energy states.

C. Ionizing Radiation and its Control

1. The Origins of Ionizing Radiations
   a. Radioactive Nuclei
   b. Radiation Producing Machines

2. The Emissions

3. Units and What These Measure
   a. The Amount of Radioactivity--the Cause
   b. Units for Exposure, Absorbed Dose and Biological Effect
      (1) The Roentgen--Solely for Exposure
      (2) The Rad--Solely for Absorbed Dose
      (3) The Dose Equivalent in Rem for Biological Effect

4. Biological Damage from the Ionization of Tissue
   a. Some Facts and Hypotheses on Mechanisms of Biological Damage
   b. Acute Radiation Effects
   c. Delayed Radiation Effects

5. Limits on Exposure and Dose by Voluntary and Official Groups
   a. What Population Groups and Circumstances Do the Limits Cover?
   b. What Conditions of Expose and Dose Effects Do the Limits Cover?
   c. Do You Understand the Intent of the Limit Terminology?
   d. The Voluntary Organizations, ICRP, 1928 and NCRP, 1929
   e. Official Agencies in the USA which Set Limits
   f. Uniform Units Recommended by ICRU Are in Use
   g. Can Limits be Set for the Intakes of Whole Populations and an Intensity of Control be Recommended to Hold the Limits?
   h. Legal Authority to Control all Radiations from Electronic Products

6. Radiation Protection--Principles and Techniques
   a. Initial Precepts on Radiation Use and Radiation Users
   b. Illustrations of Protection against Internal Radiation
   c. Illustrations of Protection against External Radiation

7. Instrumental Measurement
   a. Electrical Effect Instruments
   b. Measurement by Chemical Effect
   c. Measurement by Light Generation
   d. Measurement by Thermoluminescence

8. Changes and Developments
   a. Biological Effects
   b. Limits, Standards, Guidelines and Criteria
   c. Protection--Health Service Use
   d. Nuclear Fueled Power Generators
   e. Environmental Surveillance
   f. Disposal of Wastes

9. Appraisal

D. The Thermal Environment

1. The Nature of the Issue
   a. Miasmas and vitiation
   b. The case of the "schwitz kasten"
      (1) Physical not Chemical
      (2) Cutaneous not respiratory
   c. Health or comfort?

2. Heat Transfer and Balance
   a. The physical processes of transfer
   b. The living processes of metabolism and storage
   c. The relations as $M \pm S = \pm R \pm C \pm E$
   d. Effect of relative humidity and air movement

3. Parameters of the Thermal Environment
   a. Temperature
   b. Relative humidity and air movement
   c. Effective temperature

4. Thermal Extremes
   a. Physiological failures caused by heat stress
      (1) Heat prostration
      (2) Heat cramps
      (3) Heat stroke
   b. Physiological regulations by heat transfer by:
      (1) Conduction
      (2) Convection
      (3) Radiation
      (4) Evaporation
   c. Defining the adequate conditions by
      (1) Air movement
      (2) Relative humidity
      (3) Thermal indices
      (4) The net result expressed as Effective Temperature

5. Cold Extremes - Stresses due to cold are well defined for military and exploration activities in Polar and high altitude situations. Tolerances are known for USA well nourished males. Artic North Slope oil extraction will test civilian application. USSR experiences are not readily available, but are extensive.

   a. Pathology from extreme cold
      (1) Acute transient inflammation - pain to skin temp. drop to 59°F; to numbness at skin temp. of 50°F. Vaso dilation and constriction "hunting".
      (2) Trench or Immersion foot - cold and wet feet for several days. Gangrene the end point: Cause blood and/or lymph ooze to tissue.
      (3) Frostbite - skin and/or tissue freeze at skin-tissue temp. of -5° to -10°C (+23° to +14°F). Skin/tissue at -15 to -20°C (+5 to -4°F) for 10-15 minutes goes necrotic and gangrenous. Treat frostbite by rewarming in exactly 42°C water (107.6°F) immediately. The faster the better.

(4) General body cooling
(a) Coma at body temp. of 80°F (26.5°C)
(b) Death at body temp. of 77°F (25°C) to 70°F (21°C)
(c) Immersion in water at temp. below 60° to 68°F (15 to 20°C) cools body faster than heat production. Death at body temp. of 77°F (25°C)

b. Tolerances: See Tables 4 and 5. Sartwell-1965 Prev Med and PH p. 725.
(1) Inactive: max of 6 hrs at -10°F (-23.3°C) air temp without special clothing
(2) Inactive: max of 1½ hrs at -40°F (-40°C) air temp without special clothing
(3) Inactive: max of 25 min. at -70°F (-56.7°C) air temp. w/ special protection
(4) Nude: max of 8 hrs at 46°F (7.6°C)
(5) Wind chill has been defined. Example: 45 mph wind at 20°F (-6.7°C) chills as rapidly as 2 mile per hour wind at -40°F (-40°C)
(6) Water immersion: at 40°F (5°C) rectal temp drops 11 to 12°F. Dead in 1 hr.
Water Immersion: at 60°F (15°C) survival 2 to 5 hrs
" " : at 62°F (16.7°C) survival 8 hrs.

6. Good Practice Standards
a. American Public Health Association Committee Statement (old but good)
b. Recommendations of ASHRAE

E. Visible Light and Lighting

Hygienic Value of Lighting
a. Physiological benefits
(1) Reduces obscure ocular symptoms
(2) Lessens degree and rapidity of ocular accommodation, particularly for older persons
(3) In terms of illumination of premises, promotes cleanliness
(4) Good natural lighting has bacterioidal effects

b. Psychological benefits

2. Illumination characteristics and their measurement
a. Range of the visible spectrum and color wavelengths.

b. Units
(1) Foot-candle
(2) Lumen
(3) Brightness
(4) Reflection factor
(5) Brightness ratio
(6) Candle power

3. Lighting and the visual task
a Factors to control
(1) Intensity
(2) Contrast
(a) Contrast within center of visual task
(b) Effects upon the surroundings
(3) Glare - misplaced brightness
(4) Texture and texture contrast

b. Lighting standards
(1) American Standards Association
(2) Illuminating Engineering Society
(3) Miscellaneous codes

4. Attaining Good Lighting
a. Daylight use

b. Electric lighting
(1) Lamp and luminaire characteristics
(2) Design methods

F. Non-ionizing Radiations in Particular Applications

1. Ultra-violet

   a. Characteristics

   b. Applications

   c. Hazards and their Management

2. Laser

   a. Characteristics

   b. Applications

   c. Hazards and their Management

3. Radar and Micro-wave

   a. Characteristics

   b. Applications

   c. Hazards and their Management

G. Noise - Unwanted Sound

1. Physical Characteristics of Sound and Units of Measurement
   a. Wave character of sound and air transmission
   b. Units
      (1) Frequency
      (2) Intensity and sound pressure level
      (3) The decibel scale
      (4) Acoustic power
   c. Familiar sound and noise sources in decibels
   d. Loudness level in phons and loudness in sons

2. Effects of noise on man
   a. Speech communication interference
   b. Nuisance
   c. Hearing loss
   d. Obscure and demonstrable effects

3. Noise Limits
   a. In work places
   b. In the community

4. Noise Measurement
   a. Instrumentation
   b. Precautions in use
   c. Interpretation of observations

5. Noise Control
   a. Occupational exposures
   b. Community noise
      (1) Transportation
      (2) Transmission within buildings
      (3) Manufacturing

6. Issues to be Faced
   a. Damage criteria
   b. Aircraft noise and sonic boom
   c. Highway noise
   d. Architectural and mechanical engineering techniques to minimize noise in buildings.

H. Noise, Energy and Power - Units of Measurement

1. Physically its sound, rarefriction and compression of air.

2. Noise unwanted sound, therefore defined subjectively and for some frequencies and intensities supported by medical evidence of injury.

3. The units.

a. Frequency - cycles per second. Human hearings range from 35 to 15,000
b. Intensity - measured in decibels, which are logarithmic units to express the ratio between sound pressures. The reference level is 0 db, a sound pressure of 0.0002 dynes/sq.cm. or 1 microbar. (The pressure of a fly landing on a kitchen table.)
The scale is analogous to pH numbers. It measures Sound Pressure Level. Mathematically it is

$$SPL = 20 \log \frac{P}{0.0002} \text{ db referenced to } 0.0002 \text{ dyne/cm}^2 \text{ or microbar}$$

Note: Dyne = force required to accelerate 1 gm to 1 cm/sec/sec
c. Acoustic power is the power level expressed in watts. The watt is the unit of the rate of doing work. It is one joules/second or 10^7 ergo/sec. There is no simple relation between acoustic power and sound pressure level. Acoustic power is very difficult to measure.
Note: Erg - work unit, force of 1 dyne acting thru 1 cm.
d. Decibels are not additive (Read Jones, pg. 7,8,9) 2x Acoustic power → 3 db rise, 10 x acoustic power → 10 db rise; 100 x acoustic power → 20 db rise.

4. The noise issues

a. Deafness or hearing loss (Jones, pg. 12)
b. Speech communication interference
c. Nuisance effect
d. Effects such as loss of appetite, sleep, anxiety.

5. The decibel - details of its logarithmic derivation

$$db = 20 \log_{10} \frac{P}{P_{ref}} \qquad P_{ref} = 0.0002 \text{ microbar threshold for human ear response.}$$

$$\text{at } P = 0.0002,\ db = 20 \log_{10} \frac{.0002}{.0002} = 20 \log 1 = 20(0) = 0$$

$$\text{at } P = 0.02,\ db = 20 \log_{10} \frac{.02}{.0002} = 20 \log 100 = 20(2) = 40$$

$$\text{at } P = 0.2,\ db = 20 \log_{10} \frac{0.2}{.0002} = 20 \log 1000 = 20(3) = 60$$

$$\text{at } P = 2,\ db = 20 \log_{10} \frac{2}{.0002} = 20 \log 10{,}000 = 20(4) = 80$$

$$\text{at } P = 20,\ db = 20 \log_{10} \frac{20}{.0002} = 20 \log 100{,}000 = 20(5) = 100$$

6. db of familiar sound and noise

0	Threshold of audibility
15-20	Whisper
30-35	Private office or home in quiet, no typing, no radio on
40-50	Average conversation, average office
60-70	Average radio sound level, large store
70-80	Noisy office
90-100	Loud traffic
110	Elevated train
120	Jet aircraft, threshold of pain

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Human Population Growth

From: The Natural Environment: Wastes and Control. Revised Edition. Pacific Palisades, California: Goodyear Publishing Company, 1974. Pp. 244. By R. F. CHRISTMAN, et al.

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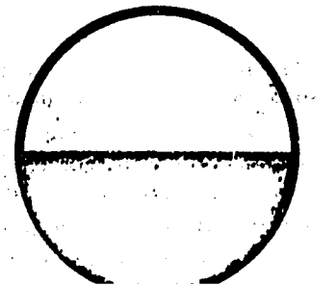


No topic has ever been more important to the current inhabitants of the earth nor more difficult to approach because of deeply held personal beliefs than the need for population control. Beginning with Malthus' warning in 1816 that human populations grow inherently faster than does their ability to produce food, and continuing through the more current recommendations of international study commissions, advice has been repeatedly given and dismissed as "interesting, perhaps, but not sufficiently important" to move ordinary people to change life-long habits. A wide range of "expert" opinion has been heard regarding the severity of the population threat. Not all the voices that have been raised, however, have been in favor of population control.

Some experts view the population problem as nothing but a mirage. They hold that growth is good and that a growing economy is always a healthy one; that man is resourceful, has always adapted to social and environmental changes in the past and will continue to do so in the future. Unfortunately, this view is not consistent with the observable facts. Certain countries (Taiwan, for example) have slow growth rates and slow economies; others (such as Japan) have slow growth rates and excellent economies; and others (particularly India) have enormous growth rates in the face of abject poverty.

Others admit that a real problem exists, but maintain that it is a solvable problem. Such ideologically diverse groups as the Marxists and the Roman Catholics share this view, but hold it for different reasons. The Marxists consider that we do not have a food production problem, but only a food distribution problem. The facts simply do not support this position. Much

of the world is currently hungry—perhaps as many as 20 million deat each year are attributable to starvation. If the world's food production wer spread evenly among the earth's present inhabitants, it is questionabl whether any individual would be well nourished. The Catholic view place great confidence in the ability of technology to solve the food shortag through the increased application of fertilizer and pesticides to farmlanc Most agricultural experts, however, are not so optimistic. Others who plac great faith in scientific research believe that, although the population prob lem is deadly serious, it can probably be resolved through developing nev hybrid grains that will greatly increase farm yields, (the "*Green Revolution*" and through increased farming of the sea.

Finally, there are those who contend that it is already too late to preven global disaster. Regardless of new solutions, the world's population is increas ing too rapidly to prevent the eventual onslaught of pestilence, famine, anc social disorder before any critical breakthrough could be implemented.

Human population control for planet earth is inevitable in one form or another, and nothing is more demonstrable in the animal world than the natural control of population.[1] We may continue our present course of action and expand our numbers to the finite carrying capacity of the physical environment. This would ultimately mean emigration to other planets and a margin of safety reduced to such precarious levels that a change of climate or an occasional famine would permit nature to control our numbers—effectively, but tragically. Alternatively, we may decide in the future to control our numbers with a wider safety margin and a broader selection of styles of life for those who do walk the earth and coexist with the things they eat. A nice feature of this alternative is the extra time it would give us to reach a more accurate understanding of the earth's carrying capacity in relation to how we live. And if it took us a long time to come to understand our environment, while we tried to control our numbers, many millions of deaths from starvation and deprivation might be avoided.

A HISTORY OF HUMAN POPULATION GROWTH

Early data on man's population increase are speculative at best, since sufficient historical information is available only after 1650 A.D. Estimates of population size and density prior to that time must be based on the archeological record and what can be gleaned from studies of primitive cultures that exist today. Demographers calculate that the total human population at the time of Christ was slightly larger than the present population of the United States, or approximately 200 to 300 million, and that this number doubled by the middle of the seventeenth century. However, it took only 200 years for that number to double again, resulting in a global population of around 1.0 billion by 1850 A.D., and only another 80 years to reach 2.0 billion, by the late 1920s. This increase is graphically described in Figure 10-1, from which

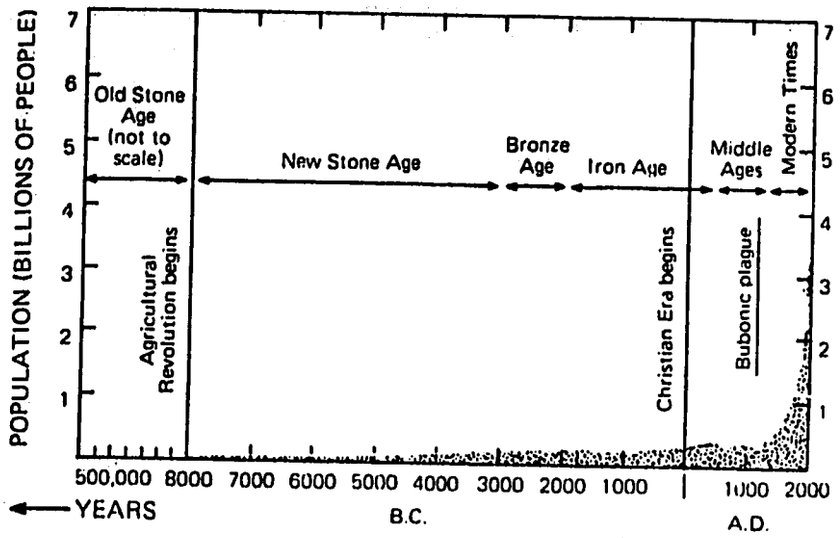


Figure 10-1. Human Population Growth on a Linear Scale
Adapted from POPULATION BULLETIN, vol 18, no. 1.

it is clear that both the rate of increase and the total number of individuals are accelerating rapidly. We are now expecting 4.0 billion inhabitants by the mid-1970s (a 45-year doubling time), when the rate of increase will produce another doubling in only 35 years. Although the history of population growth is interesting, the important point is that the time required for enormous changes in the numbers of human beings (doubling from 4.0 billion to 8.0 billion, and so on) is now so short that vast increases in population lie well within the time required to devise and implement the means of controlling them. Even if we elected right now to control the earth's human population, we would have to plan for an ultimate population substantially larger than the present number.

Focusing on broad periods of time and global growth patterns tends to mask important subpatterns in local population fluctuations. In man's history, regional populations have risen and fallen as a consequence of changes in climate, wars, famines, and discoveries, although the overall result has been an explosive increase. The natural biological characteristics of *Homo sapiens* have had much to do with man's current population "success."[2] First, as a species, man is rarely specialized in his diet, permitting him to adapt to sudden changes in food sources. Second, he is an intelligent and resourceful being, which, when combined with his opportunistic diet, assured him of a high probability of survival in spite of the elements and tended to maximize his territorial expansion. Third, he is socially oriented and has a great propensity for storing his learning and passing it on to younger generations. In

fact, most of the habitable prehistoric world may have been occupied by early man (*erectus-sapiens*) and divided into hunting-gathering territories as long as 2 or 3 million years ago.[3] Advanced knowledge in weaponry and in the use of fire allowed these early populations to flourish at the expense of the wild game food sources. This period of human development has been referred to as the "cultural revolution" and ultimately led to a depletion of food resources (known as "*Pleistocene Overkill*"), which momentarily slowed population growth rates. Perhaps 50,000 to 300,000 years ago, early man learned that his numbers could be more safely supported by adopting a primary consumer role and growing his food in managed agricultural settings instead of chasing it on the hoof.

Freedom from the daily search for food gave man the time for other pursuits, and his inventive nature responded by developing metal tools, dividing labor, and creating a more sophisticated social structure. Thus the "agricultural revolution" was the second major level on the human population growth curve, as depicted on a log-log scale in Figure 10-2. This new freedom from chasing one's dinner did not include immunity, however, from the often tragic impact of famine and disease. As the Ehrlichs have stated:[4]

> Civilizations grew, flourished and disintegrated; periods of good and bad weather occurred; and those apocalyptic horsemen, pestilence, famine and war took their toll. Although the global trend . . . was one of accelerating increase, a great many local population explosions and crashes are concealed in that trend. For example, bubonic plague (Black Death) killed an estimated 25 percent of the inhabitants of Europe

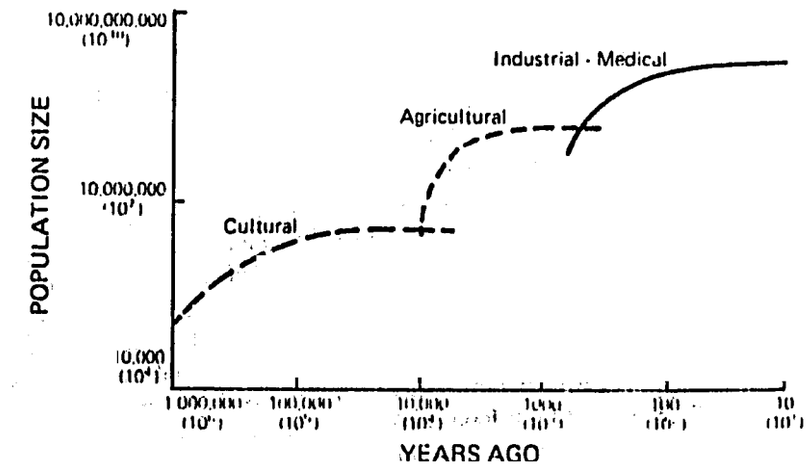


Figure 10-2. Human Population Growth on a Log-Log Scale.
Adapted from Deevey, "THE HUMAN POPULATION." Copyright © 1960 by Scientific American Inc.

> between 1348 and 1350. From 1348 to 1379 England's total population was reduced by almost 50 percent. . . . Many cities lost half or more of their inhabitants in the second half of the fourteenth century.

According to Boughey, the global outbreak of influenza in 1919 is conservatively estimated to have killed many more (10 to 15 million) than actually died in the battles of World War I. More recently the Asian "flu" form of influenza virus is thought to have killed 9 million people during the 1967 to 1968 period. The threat of infectious and contagious disease is aggravated by the increased close contact among people in modern city life. On the other hand, immunization programs are easier to administer in organized urban settings, and advances in our ability to control contagious diseases tend to lessen the threat of epidemics. Wars have often had dramatic effects on the populations of those territories involved but have had apparently no significant effect on world population growth. Bates has pointed out that the 300 years following 1650 were a period of almost continuous warfare for the human community, and, at the same time world population growth reached its first significant proportions.[5] The United States has lost about 1.0 million people in all of its wars, and at present growth rates that number is replaced in about 4 months. The destructive potential of modern thermonuclear warfare, however, casts a different light on war's effectiveness to control population growth.

Robert Malthus recognized in 1816 that human population growth has a potential for increase greater than the increase that actually occurs because of limited resources. He believed that the checks on population growth that keep the potential from being realized can be reduced to war, disease, and famine. At present, it does not appear that war (short of nuclear disaster) and disease (short of highly virulent forms of bronchial disease) can be relied on as effective checks on population growth.

Famines are another matter. The Ehrlichs have stated:[6]

> One study, by Cornelius Walford, lists more than 200 famines in Great Britain alone between 10 and 1846 A.D. Another counts 1,828 Chinese famines in the 2019 years preceding 1911, a rate of almost one a year. Some of these famines, and similar ones in India, have been known to result in many millions of deaths. Even in this century famine has killed many. . . . perhaps 5–10 million deaths have been attributable to starvation in Russia (1918–1922, 1932–1934) . . . 4 million deaths in China (1920–1921) and 2–4 million deaths in West Bengal, India (1943).

Today we are faced with enormous demands on the world's food resources. There are not only more people to be fed and more to be planned for than ever before, but individual demand is accelerating because of expectations of affluence. Unlike any previous period in history, those who are hungry and impoverished are more painfully aware, thanks to improved methods of communication, of the life styles of the more fortunate sectors of the

global community, and they certainly cannot be scorned for wanting to live the same way. In addition, even in the more well-to-do sectors, social pressures often demand increased personal affluence. Before discussing the implications of these pressures on population growth, we must examine some facts and figures on population growth rates.

POPULATION ARITHMETIC

Birth rates are usually expressed as the number of births per thousand members of the population per year. They are calculated by dividing the number of live births in a year by the population (expressed in thousands) at the midpoint of that year.

Example:

The population of the United States at the midpoint of 1969 (July 1) was estimated as 203,100,000, or

$$\frac{203{,}100{,}000}{1000} = 203{,}100 \text{ thousands}$$

If the number of live births for the year ending September 30 was 3,534,000 then the birth rate for the year 1969 was

$$\frac{3{,}534{,}000}{203{,}100} = 17.4 \text{ births per thousand.}^{7}$$

Death rates are calculated similarly. Additions to a population can also come from immigration, and subtractions from emigration. These must be considered as well in calculating overall growth rates. In general, for any nation or territory,

Growth Rate = (Birth Rate + Immigration Rate) − (Death Rate + Emigration Rate).

The equation is simplified when applied to the growth rate of the planet, since immigration and emigration rates are zero. Population data for countries ranging from high growth rates to low growth rates are shown in Table 10-1. A more extensive list of countries would reveal a relative scarcity of birth rates in the twenties and thirties per thousand and, as Boughey has pointed out, this is not fortuitous. Those nations that have adopted population control measures tend to have birth rates below 20 and those that have not have rates remaining in the forties and fifties per thousand. There is no in-between.

When all available statistics on birth and death rates since 1750 are analyzed, several important trends appear. First, the crude birth rate (not corrected for population age structures) remained at about 40 for all nations until around the turn of the twentieth century, when it began to fall (to 20 or fewer) for the more advanced, industrialized nations. The less advanced,

TABLE 10-1

Population Data for Selected Countries

COUNTRY	POPULATION—mid-1971 (in millions)	BIRTH RATE per 1000	DEATH RATE per 1000	GROWTH RATE (%)
Sudan	16.1	48.9	18.4	2.8
Japan	104.7	19.2	6.6	1.1
Colombia	21.8	44.6	10.6	3.2
Algeria	14.8	49.1	16.9	3.5
India	550.3	42.8	16.7	2.2
Guatemala	5.4	39.0	15.0	3.1
Mexico	50.8	43.4	9.9	3.2
Australia	12.7	21.7	8.7	1.9
United Kingdom	55.6	16.2	11.6	0.4
United States	207.1	17.3	9.3	1.1
Sweden	8.1	14.1	10.2	0.8
Belgium	9.7	14.5	12.4	0.5

From 1972 United Nations Statistical Yearbook.

underdeveloped (or developing) nations still tend to have birth rates near 40 per thousand. Second, for all nations there has been a dramatic reduction in death rates from the low to mid-thirties per thousand in 1850 to 15 or fewer in the 1950s (Figure 10-3). This decrease in death rate is the most important single cause of the current population explosion. It began in the industrialized nations when man began to understand disease and improve sanitation. World War II caused recent advances in medical research in antibiotics and in controlling disease vectors with DDT and other pesticides to be exported to all corners of the earth. Dramatic declines in the death rates of underdeveloped nations followed—plummeting in some cases from as high as 40 per thousand to a low of 5 or 6 per thousand within a 20-year period. Finally, in the more advanced nations, birth rates have generally declined during the late industrialization period. This phenomenon, called the "demographic transition," which slows overall growth rates, occurred in Europe around the turn of the century and more recently in North America.

It is hazardous to compare overall population growth rates for different countries calculated from crude birth and death rate data because of the significant influence of population age structure on short-term population growth. For instance, identical death rates for two countries are comparable only when the mortality is occurring in the same age group in each population. Real populations vary considerably in age and sex distribution, life expectancy and marriage ages, as well as in the specific mortality and natality of each age group.[8] Developed nations have experienced declining birth and death rates and tend to have more uniform age structures than those whose birth rates remain high. In the latter case, decreased infant mortality in addition to lowered overall death rates have further inflated the population of the younger age groups. The potential for explosive population increases

is realized when these large blocks of young people move upward in the age structure and reach their reproductive years. This is the case in most underdeveloped countries of the world, where as much as 40 to 50 percent of the total population is under 15 years of age (creating a high dependency load). As Paul Ehrlich has pointed out, even if we were making great progress in reducing birth rates in these countries (and we are not), 30 years would pass before population growth would be slowed down.

The present world population is around 3.7 billion. Its major regional contributions are listed in Table 10-2. It is clear from inspecting the data in this table that the majority of the world's present population lives in underdeveloped regions and that this proportion of the total is increasing rapidly. At present world growth rates we may exceed 7.0 billion by 2006.

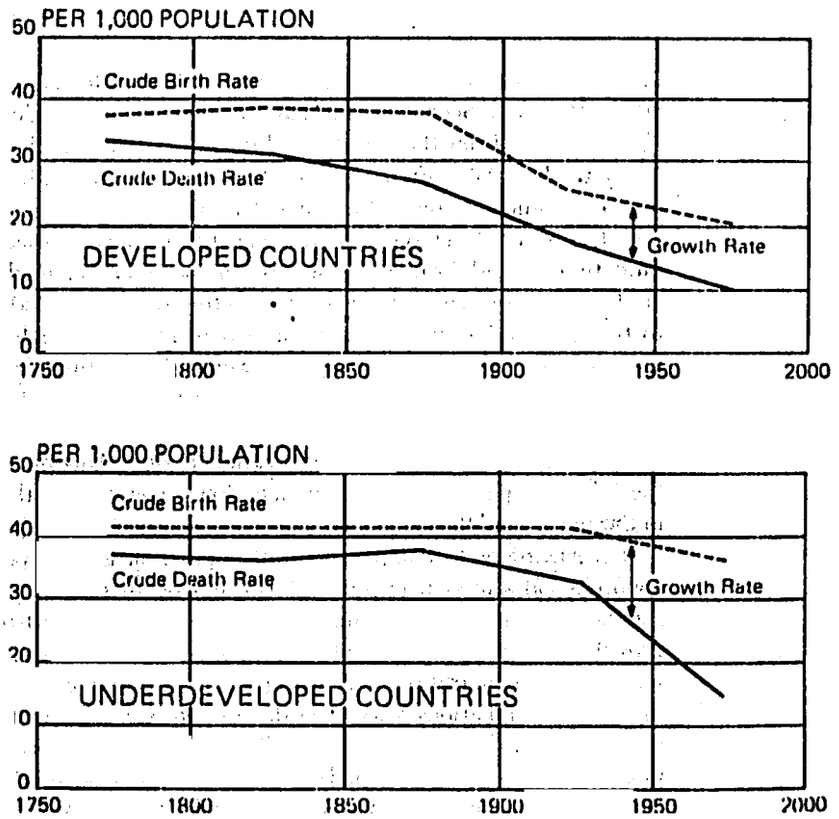
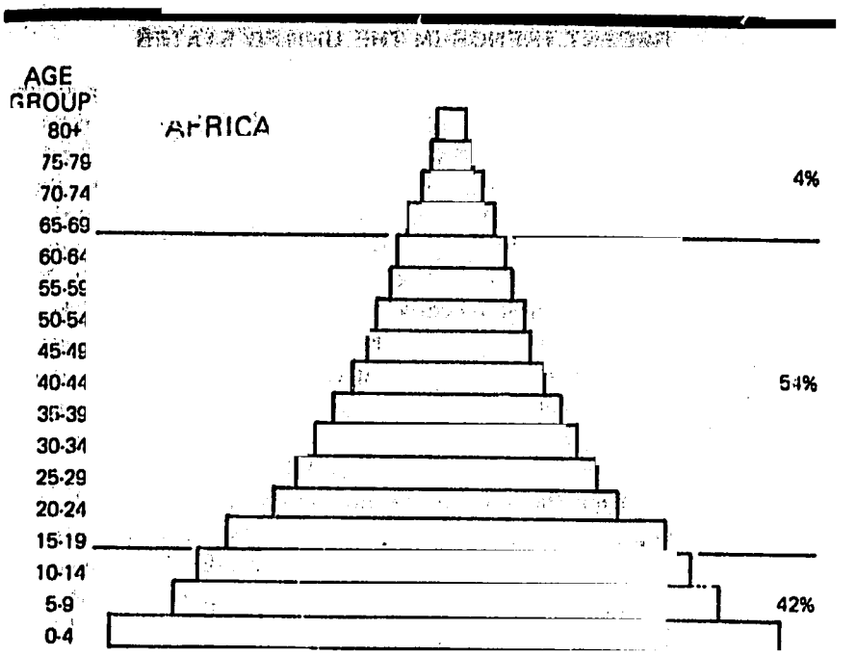


Figure 10-3. Birth and Death Rates in Developed and Underdeveloped Nations
Adapted from A CONCISE SUMMARY OF THE WORLD POPULATION SITUATION IN 1971 (New York: United Nations, 1971)



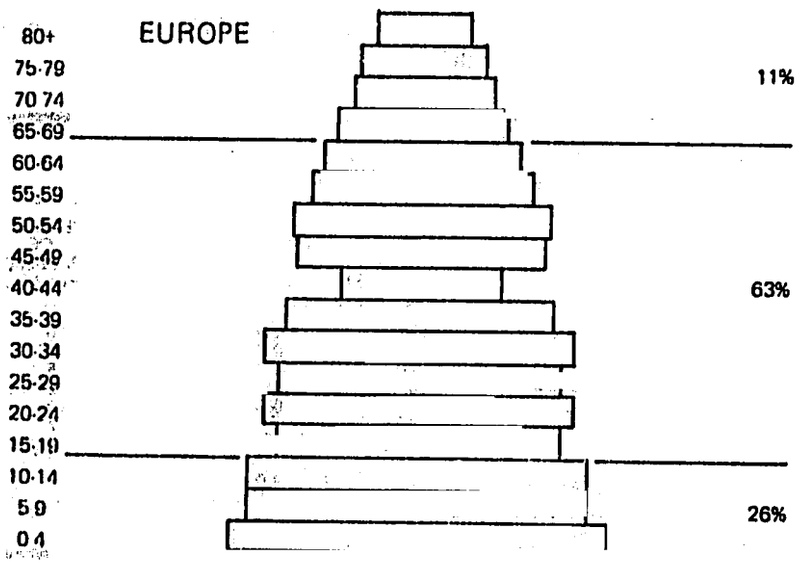


Figure 10.4.—Age Structures in Growing and Stable Populations
Adapted from "Population Trends in Developing Countries," FINANCE AND DEVELOPMENT QUARTERLY, International Monetary Fund and World Bank, [illegible]

RECENT TRENDS IN THE UNITED STATES

The population of the United States is still growing although the rate has slowed. Some have suggested that the United States has reached zero population growth because of a considerable decline in birth rates since the 1960s. These notions tend to be reinforced by occasional news items reporting even further recent decreases in birth rates. It is simply untrue, however, to state that the United States has, in 1974, reached a zero-growth plateau; our population was estimated at 203 million in mid-1969, 207 million in mid-1971, and most recently passed 210 million in March of 1974.[9] In 1972 alone, 1,630,000 individuals were added to the U.S. population. What has happened is a remarkable decrease in the birth rate since the 1960s, and a concurrent decrease in the fertility rate. The fertility rate is a better index of birth trends because it measures the births per thousand women in their reproductive years (ages 14 to 44). The fertility rate in the United States fell from the 120s at the turn of the century to a low of 75 during the depression years, 1932 to 1936. From then until the late 1950s, the fertility rate rose again to about 120, but has steadily fallen since. In March of 1974, a record low was reached of 67 births per thousand, and indications are that it is still falling.[10] This fertility rate is at or below what would be required just to maintain our population. Replacement fertility, or 2.11 births per woman, is the rate that will just replace parents when they die. Why this rate is not exactly 2.0 is due to the fact that our population is not precisely divided 50-50 into males and females. Why then have we not reached zero population growth?

TABLE 10-2

Present Status of Population in Major Regions

REGION	POPULATION—MID-1971 ESTIMATES (IN MILLIONS)	GROWTH RATE (%)	YEARS TO DOUBLE	PERCENT OF PRESENT POPULATION†	PERCENT OF YEAR 2000 POPULATION‡
Africa	354	2.6	27	10	13
Asia	2104	2.3	30	56	58
North America	230	1.3	54	6	5
Latin America	291	2.9	24	8	10
Europe	466	0.8	88	13	9
USSR	245	1.1	64	7	5
Oceania	19.6	2.1	33	0.05	0.0
WORLD (Total	3706	2.0	35		

1965–71 average rates.
†Does not sum to 100 percent because of rounding.
‡Based on United Nations "medium" estimate for year 2000 for each country and for total world population of 6.5 billion.

[illegible]

TABLE 10-3
Estimated Numbers of Women in the 20-29 Age Group in the United States

YEAR	NUMBERS (in millions)
1968	14.3
1975	18.3
1980	20.0

From POPULATION RESOURCES AND ENVIRONMENT: ISSUES IN HUMAN ECOLOGY, by Paul and Anne Ehrlich, San Francisco: W. H. Freeman, 1970, p.33.

The reason is that these low numbers are rates, that is, births per thousand women. The rates say nothing about the actual numbers of women, and there are significantly more women entering their reproductive years because of the post-World War II baby boom: 40.2 million in 1967, 42.3 million in 1970, and 46.9 million estimated for 1975. Furthermore, the subgroup of women aged 20 to 29 bear most of the children, and the numbers of these will continue to increase through 1980, as shown in Table 10-3. If the trend toward decreased fertility continues, or even holds constant, and if the death rate does not change, we may well reach a no-growth plateau before the turn of the twenty-first century. Reaching this plateau is important even though the United States will represent only 5 percent of the world's population at that time. To persuade other countries to control their populations, it will be helpful to have controlled ours first.

POPULATION PRESSURES ON FOOD AND MINERALS

It would be valuable to know how many people the earth can support. Estimates have varied from somewhat fewer than we have now (4 billion) to several times the present number (30 billion). The simple truth is that we do not know the limits of our biosphere. Our continued population growth in the face of this ignorance is something like the foolhardy man who accelerates a car down a highway at night, his headlights turned off, having good reason to believe that something is blocking the road ahead.

It does seem clear that the ultimate safe number of the earth's inhabitants will depend heavily on the style in which they choose to live. There are currently tremendous variations in the quality and styles of life among the earth's inhabitants. The most demanding of these styles in relation to the use of resources and the generation of waste products is that adopted by the United States. We constitute roughly 6 percent of the world's population but use over one-half of the world's resources in satisfying our desires for automobiles, electricity, recreational pursuits, and other amenities. This consumption may reach 80 percent of total world consumption by 1980.[11]

It is difficult to speak of material or even of political self-sufficiency when the United States is so highly dependent on foreign supplies for most of

TABLE 10-4

Consumption of Minerals in the United States

MINERAL	U.S. CONSUMPTION AS % OF WORLD PRODUCTION (1972)	U.S. IMPORTS % OF U.S. CONSUMPTION 1950	1960	1971	1972
Manganese Ore	12	95	122	98	95
Iron Ore	15	8	32	35	28
Copper	27	36	34	17	18
Zinc	24	48	50	56	52
Tin	30	104	66	71	77
Lead	38	44	36	19	26
Molybdenum	23	1		2	—

Adapted from *Mining and Minerals Policy* (1973), Part Two, Appendices

its industrial raw materials. The U.S. consumer received warning of his dependence on foreign supplies during the 1973 to 1974 fuel crisis. Energy is not the only substance we may run short of, and ironically, we may be closer to self-sufficiency in relation to energy because of our nuclear technology and enormous coal reserves than we are in relation to basic minerals (Tables 10-4 and 10-5). At current rates of use, known supplies of lead, zinc, copper, and tin will be exhausted before the year 2000, even with no additional population growth.[12] Nickel, cobalt, manganese, and molybdenum will last another century, and chromium and iron another 2000 years. Clearly, we are not out of the woods with "crises" and shortages; we are actually just entering them. Known reserves of minerals often do not include low-grade deposits that are presently uneconomical to mine and process, and of course they do not include estimates for new discoveries. In trying to decide just how much growth we can permit, we must allow for some reduced intensity in life style and for an increase in recycling efforts (Table 10-6). Just how much sacrifice we will be willing to make is uncertain, but it seems obvious that known resources are simply insufficient to permit even the present world population of 3.7 billion to live at current U.S. standards. If this could be done it would require "75 times as much iron as is now extracted annually, 100 times as much copper, 200 times as much lead, 75 times as much zinc, and 250 times as much tin," as Ehrlich has noted.[13] The increase in pollution load, waste by-products, and heat, in addition to extra energy demands, would be enormous.

Mankind faces a more basic but related problem—to supply food for his growing numbers. In 1967, the Panel on World Food Supply of the President's Science Advisory Committee issued a 3-volume report containing a description of the world's food problem, including nutritional requirements and recommendations for alleviating shortages in the next two decades.[14] This

study estimated that in underdeveloped nations, or two-thirds of the world, 20 percent of the individuals are currently undernourished and 60 percent are malnourished. These and other studies estimate that between 1 and 2 billion people of the present population of 3.7 billion are not receiving an adequate diet. How many are actually starving is unknown, since data tend to be unreliable where the problem is severe, but it is estimated that 500 million (0.5 billion) people are either chronically hungry or starving. The Panel further reported that the current world average for caloric need is around 2300 calories per person per day. This requirement, when compared to the estimated (United Nations FAO estimate) 2400 calories per person per day currently available at the world market place, makes the margin between supply and need quite precarious. The problem is further aggravated beyond what the margin implies by the uneven distribution of food.

All practical solutions to this problem will require rapid implementation of effective international population control programs, the production of

Table 10-5

Supply of Selected Minerals

MINERAL	U.S. RESERVES AS % OF WORLD RESERVES (1972)	YEARS OF SUPPLY AT PRESENT RATE OF CONSUMPTION
Antimony	2	95
Cadmium	29	74
Copper	24	53
Iron	4	40
Lead	35	62
Titanium	20	100
Tungsten	6	26
Uranium	32	21
Zinc	23	60

Adapted from *Mining and Minerals Policy (1973)*, Part Two, Appendices.

TABLE 10-6

Recycling of Selected Minerals in the United States

MINERAL	RECYCLING, AS % OF ANNUAL U.S. CONSUMPTION (1972)
Copper	20
Iron	33
Nickel	34
Platinum*	22
Potash	0
Manganese	1
Lead	35
Zinc	5

*Platinum group metals, includes ruthenium, rhodium, palladium, osmium, iridium and platinum

Adapted from *Mining and Minerals Policy* (1973), Part Two, Appendices

more food, and improvements in our ability to distribute it. World food production must be increased by at least half again as much as current production, if we are to feed the estimated 1985 population even at the insufficient 1965 levels.[15]

The simplest way to produce more food is to put more land under the plow, although this is not as easy as it would seem. In the United States, we already use some 300 million acres of our 350-million acre total. The remaining land is not our best and is being eaten into by urban sprawl at the rate of 1.0 million acres per year. On a global basis, there is probably 2 to 3 times as much arable land as has been either cultivated at some time during the last few decades or has been harvested in any given year. Unfortunately, most of this land (over 4 billion acres) lies in the tropics, where our present agricultural production technology is inadequate, at least for the humid and subhumid tropics. The President's Science Advisory Committee suggested that developing this land should be a long-range project to be met through increased research on new varieties of plants and new methods of fertilization. Furthermore, this land, if it could be made to produce food, is geographically removed from the location of present and future food needs. The report summary states: "The very large disparity between population size and potentially arable land in Asia, on the one hand, and South America, North America and Africa on the other, suggests that very large-scale intercontinental migrations, such as characterized most of the nineteenth century, might well become important again in times to come."[16]

If the imminent food problem is not to be met by introducing new farmlands, it will have to be met by increasing yields on present land and by more efficiently using available food by reducing waste and spoilage. The problems with this proposal are still enormous. The people and institutions of Asia are not accustomed to thinking of farming as a business, and there are limits to the effectiveness of directly transferring agricultural technology to underdeveloped nations. Instead, adaptive research, or developing new varieties of plants, should be carried out in Asian fields, for example, and not flown in from Iowa. Training programs, fertilizer and capital will be required on massive scales; to bring fertilizer applications in India alone up to the per capita level of Japan or the Netherlands will take one-half the world output.[17] An economic investment on the order of $12 billion above the 1965 base would be needed to raise Indian food production even 4 percent.[18] Obviously, these proposals imply unparalleled peacetime cooperation between developed and underdeveloped nations.

Increasing farm yields in the underdeveloped nations through applying agricultural techniques and improving fertilizers is half of what is referred to as the "Green Revolution"—growing more food to stay ahead of the population explosion. The other half is developing new high-yield strains of food crops (rice, wheat, and sorghum), which hold significant promise for increased food production. Early results have been encouraging in Asia, where over 34 million acres have been planted within 5 years of introduction.

In 1968, the Indian wheat harvest was 35 percent above record, and the Pakistani crop was 37 percent higher, than ever before.[19] Some biologists are still skeptical, claiming that these "miracle crops" may ultimately attract miracle pests and that early harvest gains were actually due to better regional weather. They contend further that risks are being taken by converting substantial acreage to these new plant hybrids, thereby hazarding unknown susceptibilities to plant disease and pests and escalating pesticide requirements. Furthermore, it is still unknown whether these plants will grow throughout Asia, and whether similar plants can be developed for South America and Africa.

Probably the best that can be said for the Green Revolution is that the extra food it may generate (if these programs work) will give us a little extra time to develop effective patterns of international cooperation for controlling human population growth.

THE HUMAN CHALLENGE

It is difficult to avoid pessimism about the future well-being of the millions of needy individuals in the underdeveloped nations when one considers the physical dimensions of the problem and the efficacy of governmental and political action. Nor can we afford the sanguinous notion that whatever happens to the poorer countries will not seriously affect our own lives. The political implications of rising pressures on resources are staggering. Even if the United States made no further advances in its "standard of living," someone would have to explain to a burgeoning group of have-not nations why they cannot live as we do, and why they should continue to supply us with the raw materials of our comfort. In the past, the United States has enjoyed a relatively luxurious position in regard to technological development and food production, but much of this well-being has come at the ecological expense of the rest of the world. Our present food surpluses, which used to be dealt with as "charitable" contributions to the foreign needy, are now for sale on world markets where those with money are all too eager to buy. Continued escalation of food prices in the United States is unavoidable because exporting our food surplus will become increasingly necessary to pay for energy and other resources we cannot produce ourselves (Table 10-5). Even the industrial technology and capital we send abroad may be worsening the problem if the biosphere will not permit the present world community to live at Western levels of consumption.[20] Our science and technology are far from providing an early solution and are in fact still trying to describe the problem adequately.

We are learning that previous efforts to help may have been counterproductive. Clearly, the underdeveloped nations will profit most from managing their own resources and controlling their own futures, but they will be unable to do this under the economic thumb of massive Western industrial empires. At the same time, these nations urgently need help from the West in the

form of training, guidance, materials, and economic underwriting. The great challenge of the immediate future, then, comes down to the question of how to help the hungry masses without destroying their social structures, value systems, and sense of dignity. Maintaining national boundaries or preserving any particular governmental form becomes a less significant issue when contrasted with the tremendous challenge of ensuring human survival.

Can we restructure national aims? Can we separate foreign aid from the special interests of business? Can we distribute the fruits of industrialization without further industrialization? Can we commit ourselves to a concept of growth based more on the quality of life than on economic "root, hog, or die" prosperity measures? If we could settle these questions wisely, we might end up exerting some genuine leadership toward reaching humanitarian goals and be able to display meaningful, nondestructive ambitions to the underdeveloped nations of the world instead of displaying the automobile, the transistor radio, the electric carving knife, and other so-called achievements of advanced society. But, as in the case of population control, we will first have to demonstrate our good faith by restructuring our own value system in order to be credible to the rest of the world.

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17. Ehrlich and Ehrlich, *Population, Resources, Environment*, p. 96.

18. *The World Food Problem*.

19. Ehrlich and Ehrlich, *Population, Resources, Environment*, p. 97.

20. Watt, K. F. *The Titanic Effect. Planning for the Unthinkable*. Stamford, Conn.: Sinauer Associates, 1974.

MINERAL RESOURCES IN FACT AND FANCY

by

Preston Cloud

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MINERAL RESOURCES IN FACT AND FANCY

Preston Cloud

Optimism and imagination are happy human traits. They often make bad situations appear tolerable or even good. Man's ability to imagine solutions, however, commonly outruns his ability to find them. What does he do when it becomes clear that he is plundering, overpopulating, and despoiling his planet at such a horrendous rate that it is going to take some kind of a big leap, and soon, to avert irreversible degradation?

The inventive genius of man has got him out of trouble in the past. Why not now? Why be a spoil-sport when brilliant, articulate, and well-intentioned men assure us that all we need is more technology? Why? Because the present crisis is exacerbated by four conditions that reinforce each other in a very undesirable manner: (1) the achievements of medical technology which have brought on the run-away imbalance between birth and death rates; (2) the hypnotic but unsustainable national dream of an ever-increasing real Gross National Product based on obsolescence and waste; (3) the finite nature of the earth and particularly its accessible

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mineralized crust; and (4) the increased risk of irreversible spoilation of the environment which accompanies overpopulation, overproduction, waste, and the movement of ever-larger quantities of source rock for ever-smaller proportions of useful minerals.

Granted the advantages of big technological leaps, therefore, provided they are in the right direction, I see real hope for permanent long-range solutions to our problems as beginning with the taking of long-range views of them. Put in another way, we should not tackle vast problems with half-vast concepts. We must build a platform of scientific and social comprehension, while concurrently endeavoring to fill the rut of ignorance, selfishness, and complacency with knowledge, restraint, and demanding awareness on the part of an enlightened electorate. And we must not be satisfied merely with getting the United States or North America through the immediate future, critical though that will be. We must consider what effects current and proposed trends and actions will have on the world as a whole for several generations hence, and how we can best influence those trends favorably the world over. Above all, we must consider how to preserve for the yet unborn the maximum flexibility of choices consistent with meeting current and future crises.

NATURE AND GEOGRAPHY OF RESOURCES

Man's concept of resources, to be sure, depends on his needs and wants, and thus to a great degree on his locale and place in history, on what others have, and on what he knows about what they have and what might be possible for him to obtain. Food and fiber from the land, and food and drink from the waters of the earth have always been indispensable resources. So have the human beings who have utilized these resources and created demands for others—from birch bark to beryllium, from buffalo hides to steel and plastic. It is these other resources, the ones from which our industrial society has been created, to which my remarks are directed. I refer, in particular, to the nonrenewable or wasting resources—mineral fuels which are converted into energy plus carbon, nuclear fuels, and the metals, chemicals, and industrial materials of geological origin which to some extent can be and even are recycled but which tend to become dispersed and wasted.

All such resources, except those that are common rocks whose availability and value depend almost entirely on economic factors plus fabrication, share certain peculiarities that transcend economics and limit technology and even diplomacy. They occur in local concentrations that may exceed their crustal abundances by thousands of times, and partic-

ular resources tend to be clustered within geochemical or metallogenic provinces from which others are excluded. Some parts of the earth are rich in mineral raw materials and others are poor.

No part of the earth, not even on a continent-wide basis, is self-sufficient in all critical metals. North America is relatively rich in molybdenum and poor in tin, tungsten, and manganese, for instance, whereas Asia is comparatively rich in tin, tungsten, and manganese and, apparently, less well supplied with molybdenum. The great bulk of the world's gold appears to be in South Africa, which has relatively little silver but a good supply of platinum. Cuba and New Caledonia have well over half the world's total known reserves of nickel. The main known reserves of cobalt are in the Congo Republic, Cuba, New Caledonia, and parts of Asia. Most of the world's mercury is in Spain, Italy, and parts of the Sino-Soviet bloc. Industrial diamonds are still supplied mainly by the Congo.

Consider tin. Over half the world's currently recoverable reserves are in Indonesia, Malaya, and Thailand, and much of the rest is in Bolivia and the Congo. Known North American reserves are negligible. For the United States loss of access to extracontinental sources of tin is not likely to be offset by economic factors or technological changes that would permit an increase in potential North American production, even if present production could be increased by an order of magnitude. It is equally obvious that other peculiarities in the geographical distribution of the world's geological resources will continue to encourage interest both in trading with some ideologically remote nations and in seeking alternative sources of supply.

RECOVERABLE MINERAL RESERVES

Consider now some aspects of the apparent lifetimes of estimated recoverable reserves of a selection of critical mineral resources and the position of the United States with regard to some of these. The selected resources are those for which suitable data are available.

Figure 1 shows such lifetimes for different groups of metals and mineral fuels at current minable grades and rates of consumption. No allowance is made for increase of populations, or for increased rates of consumption which, in the United States, tend to increase at twice the rate of population growth. Nor is allowance made for additions to reserves that will result from discovery of submarine deposits, use of submarginal grades, or imports—which may reduce but will not eliminate the impact of growth factors. Data are updated from the U.S. Bureau of Mines compendia *Mineral Facts and Problems* and its *Minerals Year-*

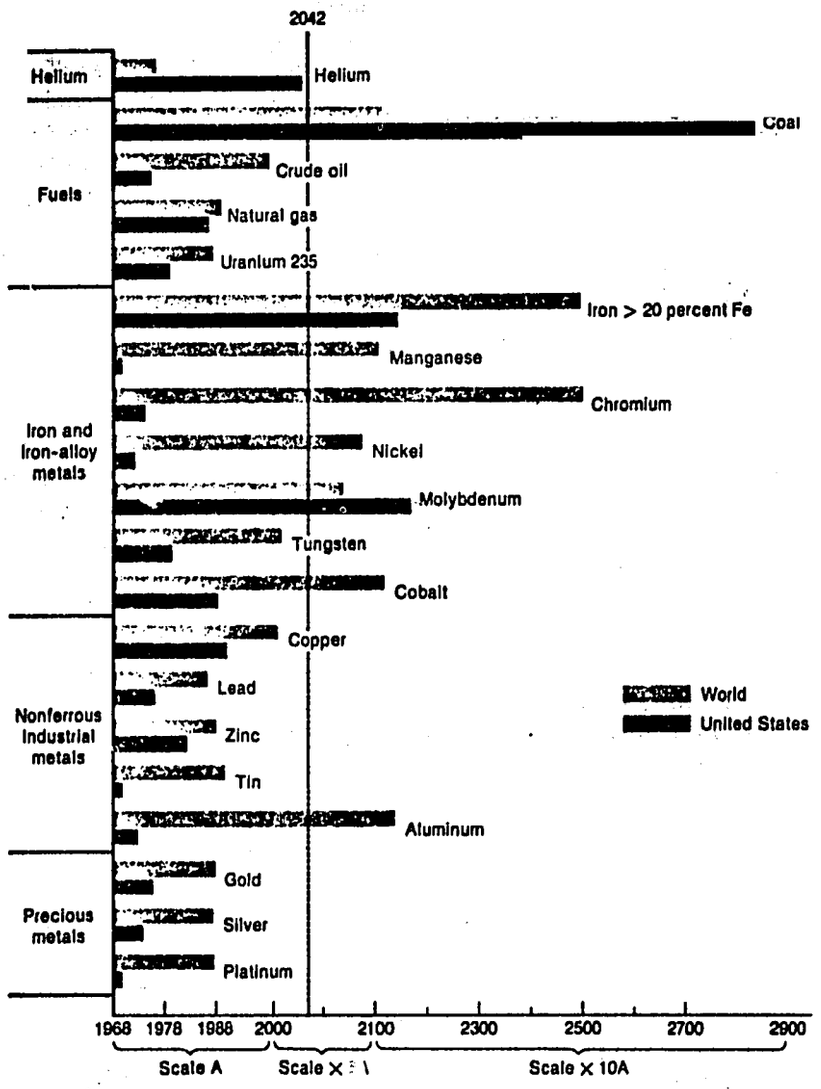

FIGURE 1.
Mineral reserve lifetimes. Apparent lifetimes of known recoverable reserves of twenty mineral commodities at currently minable grades and existing rates of consumption. (Except for helium, whose lifetime is estimated from U.S. Bureau of Mines data on reserves, conservation practices, and expected increases in demand.) Such lifetimes tend to increase with new discoveries and technological advances and to decrease with increasing population and per capita consumption rates, but resources to left of vertical dashed line are in obvious danger of depletion.

books, as summarized by Flawn.[1] The light bars represent lifetimes of world reserves for a stable population of roughly 3.5×10^9 at current rates of use. The heavy bars represent similar data for a United States population of about 200 million. Actual availability of some such commodities to the United States will, of course, be extended by imports from abroad, just as that of others will be reduced by population growth, increased per capita demands, and perhaps by political changes. The dashed vertical line represents the year 2042. This is chosen as a reference line because it marks that point in the future which is just as distant from the present as the invention of the airplane and the discovery of radioactivity are in the past.

The prospect is hardly conducive to unrestrained optimism. Of the commodities considered some are in very short supply. Only eleven for the world and four for the United States persist beyond the turn of the century; and only eight for the world and three for the United States extend beyond 2042. I do not suggest that we equate these lines with revealed truth. Time will prove some too short and others perhaps too long. New reserves will be found, lower-grade reserves will become minable for economic or technological reasons, substitutes will be discovered or synthesized, and some critical materials can be conserved by waste control and recycling. The crucial questions are: (1) How do we reduce these generalities to specifics? (2) Can we do so fast enough to sustain current rates of consumption? (3) Can we increase and sustain production of industrial materials at a rate sufficient to meet the rising expectations of a world population of three-and-a-half billion, growing with a doubling time of about thirty to thirty-five years, and for how long? (4) If the answer to the last question is no, what then?

A more local way of viewing the situation is to compare the position of the United States or North America with other parts of the world. Figures 2 to 4 show such a comparison for sixteen commodities with our favorite measuring stick, the USSR plus China. Figure 2 shows the more cheerful side of the coin. The United States is a bit ahead in petroleum, lignite, and phosphate, and neither we nor Asia have much chromium—known reserves are practically all in South Africa and Rhodesia. Figure 3, however, shows the USSR plus China to have a big lead in zinc, mercury, potash, and bauxite. And Figure 4 shows similar leads in tungsten, copper, iron, and coal.

Again there are brighter aspects to the generally unfavorable picture. Ample local low-grade sources of alumina other than bauxite are available with metallurgical advances and at a price. The U.S. coal supply is not in danger of immediate shortage. Potassium can be extracted from sea water. And much of the world's iron is in friendly hands, including

1. References and suggestions for further reading will be found on page 74-75.

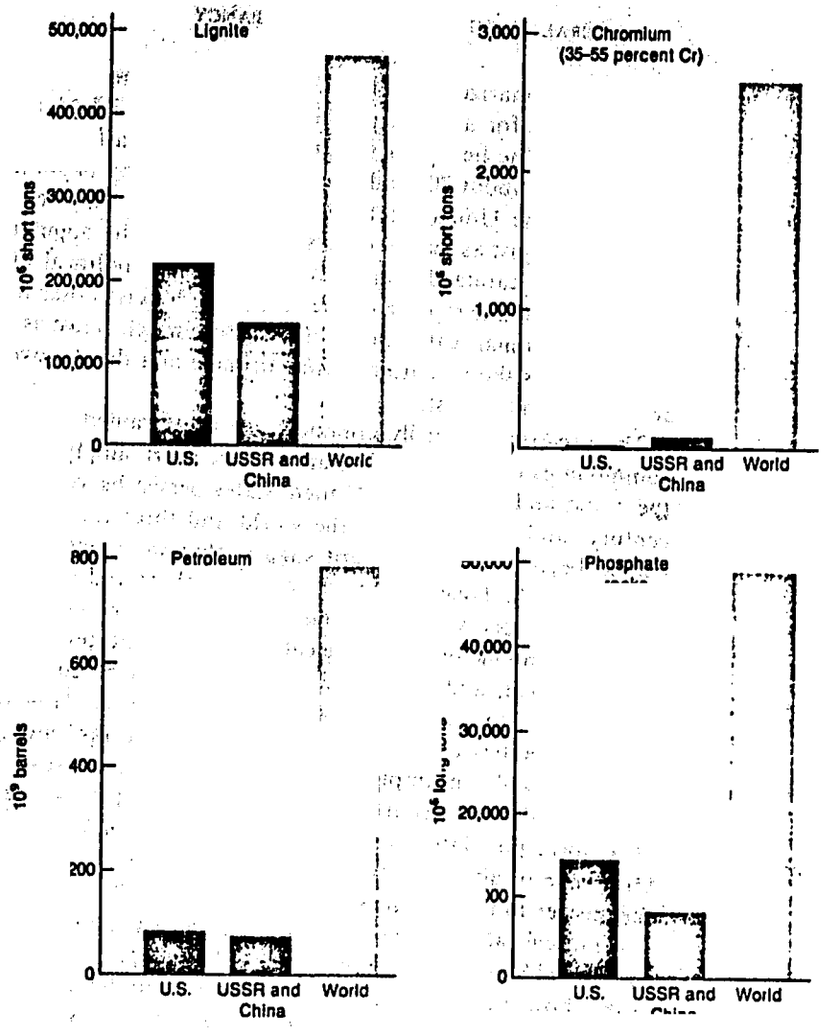

FIGURE 2.
Distribution of recoverable mineral resources. Estimated recoverable reserves of minerals (above sea level) for which U.S. reserve estimates exceed, equal, or fall only slightly below those of the USSR plus Mainland China. [Source: Data on lignite, chromium, phosphate from Flawn, *Mineral Resources* (see reference 1), on petroleum from M. K. Hubbert, *Resources and Man* (see reference 7).]

those of our good neighbor Canada and our more distant friend Australia.

No completely safe source is visible, however, for mercury, tungsten, and chromium. Lead, tin, zinc, and the precious metals appear to be in short supply throughout the world. And petroleum and natural gas will be exhausted or nearly so within the lifetimes of many of those alive today.

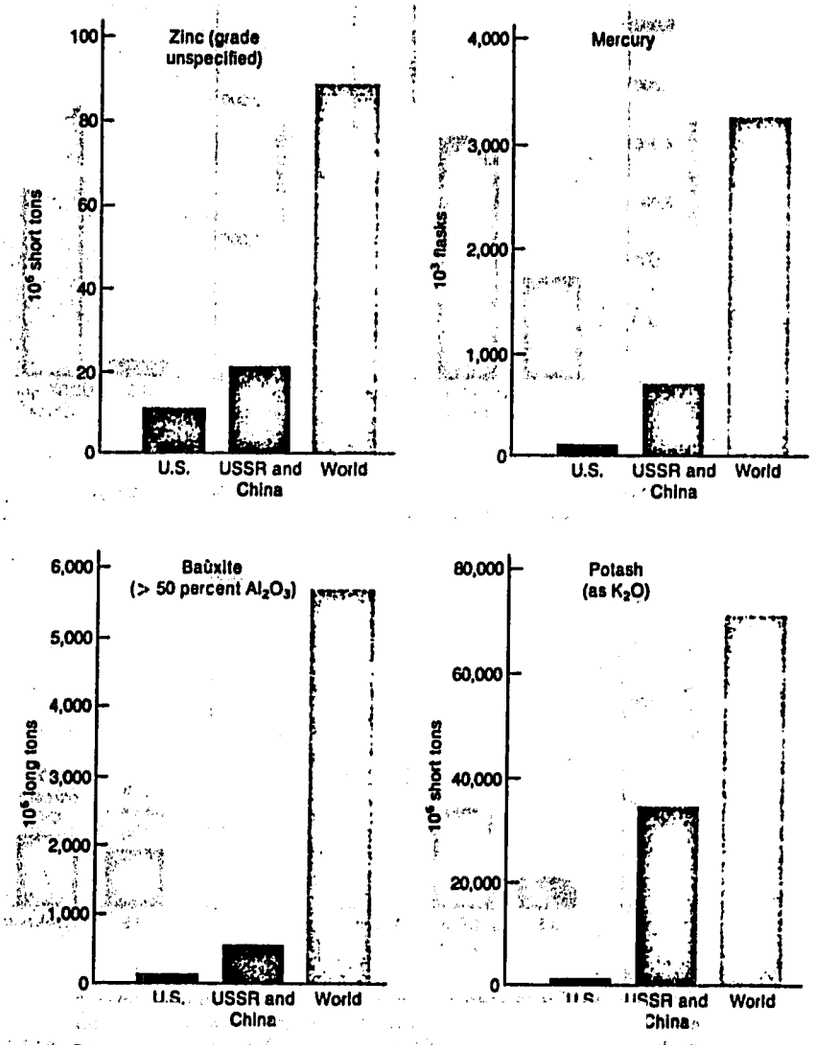

FIGURE 3.
Distribution of recoverable mineral resources. Estimated recoverable reserves of four minerals (above sea level) for which U.S. reserve estimates are less than those of the USSR plus Mainland China. [Source: Flawn, *Mineral Resources.*]

unless we decide to conserve them for petrochemicals and plastics. Even the extraction of liquid fuels from oil shales and "tar sands," or by hydrogenation of coal, will not meet energy requirements over the long term. If they were called upon to supply all the liquid fuels and other products now produced by the fractionation of petroleum, for instance, the sug-

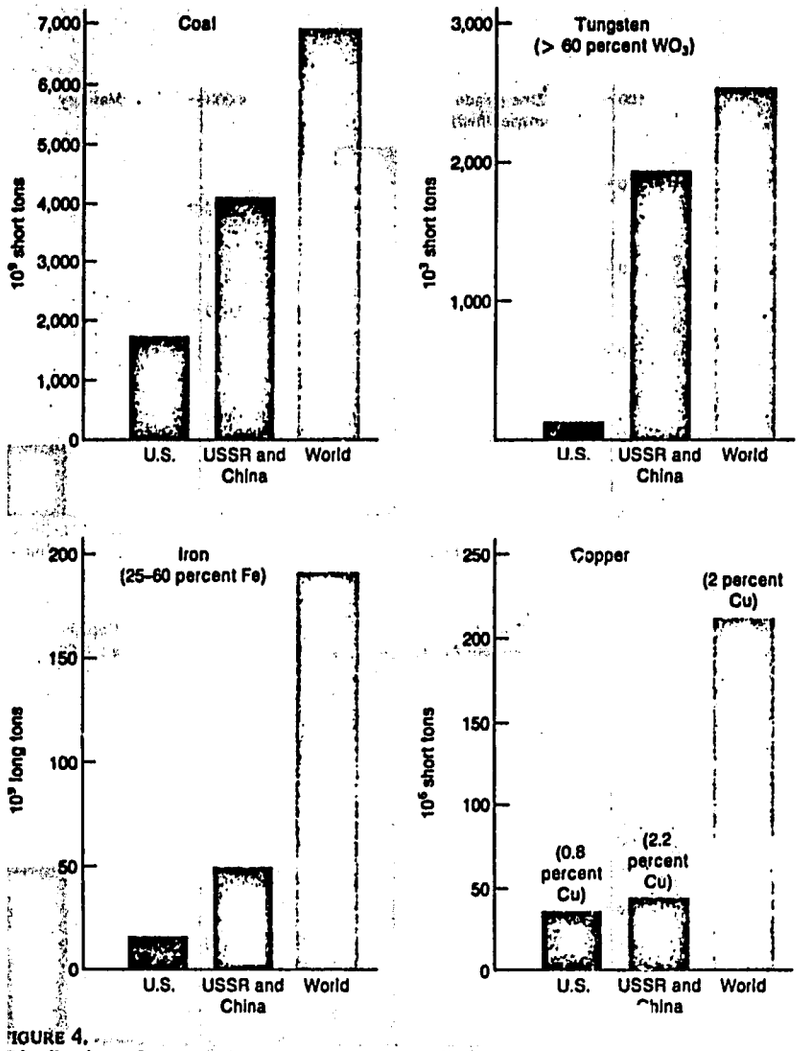

FIGURE 4.
Distribution of recoverable mineral resources. Estimated recoverable reserves of four additional minerals (above sea level) for which U.S. reserve estimates are less than those of the USSR plus Mainland China. [Source: Data on iron, tungsten, and copper from Flawn, *Mineral Resources*, on coal from Paul Averitt, 1969, *U.S. Geological Survey Bull.* 1275.]

gested lifetime for coal, the reserves of which are probably the most accurately known of all mineral products, would be drastically reduced below that indicated in Figure 1—and such a shift will be needed to a yet unknown degree before the end of the century.

THE CORNUCOPIAN PREMISES

In view of these alarming prospects, why do intelligent men of good faith seem to assure us that there is nothing to be alarmed about? It can only be because they visualize a completely nongeological solution to the problem, or because they take a very short-range view of it, or because they are compulsive optimists or are misinformed, or some combination of these things.

Let me first consider some of the basic concepts that might give rise to a cornucopian view of the earth's mineral resources and the difficulties that impede their unreserved acceptance. Then I will suggest some steps that might be taken to minimize the risks or slow the rates of mineral-resource depletion.

The central dilemma of all cornucopian premises is, of course, how to sustain an exponential increase of anything—people, mineral products, industrialization, or solid currency—on a finite resource base. This is, as everyone must realize, obviously impossible in the long run and will become increasingly difficult in the short run. For great though the mass of the earth is, well under 0.1 percent of that mass is accessible to us by any imaginable means (the entire crust is only about 0.4 percent of the total mass of the earth) and this relatively minute accessible fraction, as we have seen and shall see, is very unequally mineralized.

But the cornucopians are not naive or mischievous people. On what grounds do they deny the restraints and belittle the difficulties?

The six main premises from which their conclusions follow are:

Premise I. The promise of essentially inexhaustible cheap useful energy from nuclear sources.

Premise II. The thesis that economics is the sole factor governing availability of useful minerals and metals.

Premise III. The fallacy of essentially uninterrupted variation from ore of a metal to its average crustal abundance, which is inherent in Premise II; and from which emanates the strange and misleading notion that quantity of a resource available is essentially an inverse exponential function of its concentration.

Premise IV. The crucial assumption of population control, without which there can be no future worth living for most of the world (or, worse, the belief that quanitity of people is of itself the ultimate good, which, astounding as it may seem, is still held by a few people who ought to know better).[2]

Premise V. The concept of the "technological fix."

Premise VI. The naive and unsupported faith that if all else fails the sea will supply our needs.

Now these are appealing premises, several of which contain large elements of both truth and hope. Why do I protest their unreserved acceptance? I protest because, in addition to elements of truth, they also contain assumptions that are gross oversimplifications, outright errors, or are not demonstrated. I warn because their uncritical acceptance contributes to a dangerous complacency toward problems that will not be solved by a few brilliant technological breakthroughs, a wider acceptance of deficit economy, or fallout of genius from unlimited expansion of population. They will be solved only by intensive, wide-ranging, and persistent scientific and engineering investigation, supported by new social patterns and wise legislation.

I will discuss these premises in the order cited.

Premise I

The concept of essentially inexhaustible cheap useful energy from nuclear sources offers by all odds the most promising prospect of sweeping changes in the mineral resource picture.[3] We may be on the verge of developing a workable breeder reactor just in time to sustain an energy-hungry world facing the imminent exhaustion of traditional energy sources. Such a development, it has been persuasively stated, will also banish many problems of environmental pollution and open up unlimited reserves of metals in common crustal rocks. There are, unhappily, some flaws in this delightful picture, of which it is important to be aware.

Uranium 235 is the only naturally occurring spontaneously fissionable source of nuclear power. When a critical mass of uranium is brought together, the interchange of neutrons back and forth generates heat and continues to do so as long as the ^{235}U lasts. In the breeder reactor some of the free neutrons kick common ^{235}U over to plutonium 239, which is fissionable and produces more neutrons, yielding heat and accelerating the breeder reaction. Even in existing reactors some breeding takes place, and, if a complete breeding system could be produced, the amount of energy available from uranium alone would be increased about 140-fold. If thorium also can be made to breed, energy generated could be increased about 400-fold over that now attainable. This would extend the lifetime of visible energy resources at demands anticipated by 1980 by perhaps 1000 to 3000 years and gain time to work on contained nuclear fusion.

The problem is that it will require about 275,000 short tons of $6.00 to $10.00 per pound uranium oxide (U_3O_8) (not ore, not uranium) to fuel reactors now on order to 1980, plus another 400,000 tons to sustain them until the turn of the century, burning only ^{235}U with currently available

enrichments from slow breeding. Only about 310,000 of the 675,000 tons of uranium needed is known to be available at this price, although known geologic conditions indicate the possibility of another 350,000 tons. Thus we now appear to be somewhat short of the U_3O_8 needed to produce the hoped-for 150,000 megawatts of nuclear energy on a sustained basis from 1985 until the end of the century without a functioning breeder reactor. Unless we find more uranium, or pay more money for it, or get a functioning complete breeder reactor or contained nuclear fusion within ten or fifteen years, the energy picture will be far from bright, especially in view of the fact that other nations from whom we might purchase uranium are eager to develop their own nuclear energy plants. There is good reason to hope that the breeder will come, and after it, contained fusion, *if* the ^{235}U holds out—but there is no room for complacency.

If and when the breeder reactor or contained fusion does become available as a practicable energy source, however, how will this help with mineral resources? It is clear immediately that it will take pressure off the fossil fuels so that it will become feasible, and should become the law, to reserve them for petrochemicals, plastics, essential liquid propellants, and other special purposes not served by nuclear fuels. It is also clear that cheap massive transportation, or direct transmittal of large quantities of cheap electric power to, or its generation at, distant sources will bring the mineral resources of remote sites to the market place—either as bulk ore for processing or as the refined or partially refined product.

What is not clear is how this very cheap energy will bring about the extraction of thinly dispersed metals in large quantity from common rock. The task is very different from the recovery of liquid fuels or natural gas by nuclear fracturing. The procedure usually suggested is the breakup of rock in place at depth with a nuclear blast, followed by hydrometallurgical or chemical mining. The problems, however, are great. Complexing solutions in large quantity, also from natural resources, must be brought into contact with the particles desired. This means that the enclosing rock must be fractured to that particle size. Then other substances, unsought, may use up and dissipate valuable reagents. Or the solvent reagents may escape to ground waters and become contaminants. Underground electrolysis is no more promising in dealing with very low concentrations. And the bacteria that catalyze reactions of metallurgical interest are all aerobic, so that, in addition to having access to the particles of interest, they must also be provided with a source of oxygen underground if they are to work there.

Indeed the energy used in breaking rock for the removal of metals is not now a large fraction of mining cost in comparison with that of labor and capital. The big expense is in equipping and utilizing manpower, and, although cheap energy will certainly reduce manpower requirements, it will probably never adequately substitute for the intelligent man with

the pick at the mining face in dealing with vein and many replacement deposits, where the sought-after materials are irregularly concentrated in limited spaces. There are also limits to the feasible depths of open-pit mining, which would be by all odds the best way to mine common rock. Few open-pit mines now reach much below about 1500 feet. It is unlikely that such depths can be increased by as much as an order of magnitude. Moreover, the quantity of rock removable decreases exponentially with depth because pit circumference must decrease downward to maintain stable walls.

It may also not be widely realized by nongeologists that many types of ore bodies have definite floors or pinch-out downward, so that extending exploitative operations to depth gains no increase in ore produced. Even where mineralization does extend to depth, of course, exploitability is ultimately limited by temperature and rock failure.

Then there is the problem of reducing radioactivity so that ores can be handled and the refined product utilized without harm—not to mention heat dispersal (which in some but not all situations could itself be a resource) and the disposal of waste rock and spent reagents.

Altogether the problems are sufficiently formidable that it would be foolhardy to accept them as resolved in advance of a working efficient breeder reactor plus a demonstration that either cheap electricity or nucear explosions will significantly facilitate the removal of metals from any common rock.

A pithy comment from Peter Flawn's book on *Mineral Resources*[4] is appropriate here. It is to the effect that "average rock will never be mined." It is the uncommon features of a rock that make it a candidate for mining! Even with a complete nuclear technology, sensible people will seek, by geological criteria, to choose and work first those rocks or ores that show the highest relative recoverable enrichments in the desired minerals.

The reality is that even the achievement of a breeder reactor offers no guarantee of unlimited mineral resources in the face of geologic limitations and expanding populations with increased per capita demands, even over the middle term. To assume such for the long term would be sheer folly.

Premise II

The thesis that economics is the sole, or at least the dominant, factor governing availability of useful minerals and metals is one of those vexing part-truths which has led to much seemingly fruitless discussion between economists and geologists. This proposition bears examination.

It seems to have its roots in that interesting economic index known as

the Gross National Product (GNP). No one seems to have worked out exactly what proportion of the GNP is in some way attributable to the mineral resource base. It does, however, appear that the dollar value of the raw materials themselves is small compared to the total GNP, and that it has decreased proportionately over time to something like two percent of the present GNP. From this it is logically deduced that the GNP could, if necessary, absorb a severalfold increase in cost of raw materials. The gap in logic comes when this is confused with the notion that all that is necessary to obtain inexhaustible quantities of any substance is either to raise the price or to increase the volume of rock mined. In support of such a notion, of course, one can point to diamond, which in the richest deposit ever known occurred in a concentration of only 1 to 25 million, but which, nevertheless, has continued to be available. The flaw is not only that we cannot afford to pay the price of diamond for many substances, but also that no matter how much rock we mine we can't get diamonds out of it if there were none there in the first place.

Daniel Bell[5] comments on the distorted sense of relations that emerges from the cumulative nature of GNP accounting. Thus, when a mine is developed, the costs of the new facilities and payroll become additions to the GNP, whether the ore is sold at a profit or not. Should the mine wastes at the same time pollute a stream, the costs of cleaning up the stream or diverting the wastes also become additions to the GNP. Similarly if you hire someone to wash the dishes this adds to GNP, but if your wife does them it doesn't count.

From this it results that mineral raw materials and housework are not very impressive fractions of the GNP. What seems to get lost sight of is what a mess we would be in without either!

Assuming an indefinite extension of their curves and continuance of access to foreign markets, economists appear to be on reasonably sound grounds in postulating the relatively long-term availability of certain sedimentary, residual, and disseminated ores, such as those of iron, aluminum, and perhaps copper. What many of them do not appreciate is that the type of curve that can with some reason be applied to such deposits and metals is by no means universally applicable. This difficulty is aggravated by the fact that conventional economic indexes minimize the vitamin-like quality for the economy as a whole of the raw materials whose enhancement in value through beneficiation, fabrication, and exchange accounts for such a large part of the material assets of society.

In a world that wants to hear only good news some economists are perhaps working too hard to emancipate their calling from the epithet of "dismal science," but not all of them. One voice from the wilderness of hyperoptimism and over-consumption is that of Kenneth Boulding[6] who observes (as the reader will find on page 127 of this volume) that "the essential measure of the success of the economy is not production and

consumption at all, but the nature, extent, quality, and complexity of the total capital stock, including in this the state of the human bodies and minds included in the system." Until this concept penetrates widely into the councils of government and the conscience of society, there will continue to be a wide gap between the economic aspects of national and industrial policy and the common good, and the intrinsic significance of raw materials will remain inadequately appreciated.

Economic geology, which in its best sense brings all other fields of geology to bear on resource problems, is concerned particularly with questions of how certain elements locally attain geochemical concentrations that greatly exceed their crustal abundance and with how this knowledge can be applied to the discovery of new deposits and the delineation of reserves. Economics and technology play equally important parts with geology itself in determining what deposits and grades it is practicable to exploit. Neither economics, nor technology, nor geology can make an ore deposit where the desired substance is absent or exists in insufficient quantity.

The reality is that economics per se, powerful though it can be when it has material resources to work with, is not all powerful. Indeed, without material resources to start with, no matter how small a fraction of the GNP they may represent, economics is of no consequence at all. The current orthodoxy of economic well-being through obsolescence, overconsumption, and waste will prove, in the long term, to be a cruel and a preposterous illusion.

Premise III

Premise III, the postulate of essentially uninterrupted variation from ore to average crustal abundance, is seldom if ever stated in that way, but it is inherent in Premise II. It could almost as well have been treated under Premise II; but it is such an important and interesting idea, whether true or false, that separate consideration is warranted.

If the postulated continuous variation were true for mineral resources in general, volume of "ore" (not metal) produced would be an exponential inverse function of grade mined, the handling of lower grades would be compensated for by the availability of larger quantities of elements sought, and reserve estimates would depend only on the accuracy with which average crustal abundances were known. Problems in extractive metallurgy, of course, are not considered in such an outlook.

This delightfully simple picture would supplant all other theories of ore deposits, invalidate the foundations of geochemistry, divest geology of much of its social relevance, and place the fate of the mineral industry squarely in the hands of economists and nuclear engineers.

Unfortunately this postulate is simply untrue in a practical sense for many critical minerals and is only crudely true, leaving out metallurgical problems, for particular metals, like iron and aluminum, whose patterns approach the predicted form.[7] Sharp discontinuities exist in the abundances of mercury, tin, nickel, molybdenum, tungsten, manganese, cobalt, diamond, the precious metals, and even such staples as lead and zinc, for example. But how many prophets of the future are concerned about where all the lead or cadmium will come from for all those electric automobiles that are supposed to solve the smog problem?

Helium is a good example of a critical substance in short supply. Although a gas which has surely at some places diffused in a continuous spectrum of concentrations, particular concentrations of interest as a source of supply appear from published information to vary in a stepwise manner. Here I draw mainly on data summarized by H. W. Lipper.[8] Although an uncommon substance, helium serves a variety of seemingly indispensable uses. A bit less than half of the helium now consumed in the United States is used in pressurizing liquid fueled missiles and space ships. Shielded-arc welding is the next largest use, followed closely by its use in producing controlled atmospheres for growing crystals for transistors, processing fuels for nuclear energy, and cooling vacuum pumps. Only about 5.5 percent of the helium consumed in the United States is now being used as a lifting gas. It plays an increasingly important role, however, as a coolant for nuclear reactors and a seemingly indispensable one in cryogenics and superconductivity. In the latter role, it could control the feasibility of massive long-distance transport of nuclear-generated electricity. High-helium low-oxygen breathing mixtures may well be critical to man's long-range success in attempting to operate at great depths in the exploration and exploitation of the sea. Other uses are in research, purging, leak detection, chromatography, and so on.

Helium thus appears to be a very critical element, as the Department of the Interior has recognized in establishing its helium-conservation program. What are the prospects that there will be enough helium in 2042?

The only presently utilized source of helium is in natural gas, where it occurs at a range of concentrations from as high as 8.2 percent by volume to zero. The range, however, in particular gas fields of significant volume, is apparently not continuous. Dropping below the one field (Pinta Dome) that shows an 8.2 percent concentration, we find a few small isolated fields (Mesa and Hogback, New Mexico) that contain about 5.5 percent helium, and then several large fields (for example, Hugoton and Texas Panhandle) with a range of 0.3 to 1.0 percent helium. Other large natural gas fields contain either no helium or show it only in quantities of less than 5 parts per 10,000. From the latter there is a long junip down to the atmosphere with a concentration of only 1 part per 200,000.

Present annual demand for helium is about 900 million cubic feet, with a projected increase in demand approaching 2 billion cubic feet annually by about 1990. It will be possible to meet such an accelerated demand for a limited time only as a result of Interior's current purchase and storage program, which will augment recovery from natural gas then being produced. As now foreseen, if increases in use do not outrun estimates, conservation and continued recovery of helium from natural gas reserves will meet needs to somewhat beyond the turn of the century. When known and expected discoveries of reserves of natural gas are exhausted, the only potential sources of new supply will be from the atmosphere, as small quantities of ^3He from nuclear reactor technology, or by synthesis from hydrogen—a process whose practical feasibility and adequacy remain to be established.

Spending even a lot more money to produce more helium from such sources under existing technology just may not be the best or even a very feasible way to deal with the problem. Interior's conservation program should be enlarged and extended, under compulsory legislation if necessary. New sources must be sought. Research into possible substitutions, recovery and reuse, synthesis, and extraction from the atmosphere must be accelerated—now while there is still time. And we must be prepared to curtail, if necessary, activities which waste the limited helium reserves. Natural resources are the priceless heritage of all the people, including those yet to be born; their waste cannot be tolerated.

Problems of the adequacy of reserves obtain for many other substances, especially under the escalating demands of rising populations and expectations, and it is becoming obvious to many geologists that time is running out. Dispersal of metals which could be recycled should be controlled. Unless industry and the public undertake to do this voluntarily, legislation should be generated to define permissible mixes of material and disposal of "junk" metal. Above all the wastefulness of war and preparation for it must be terminated if reasonable options for posterity are to be preserved.

The reality is that a healthy mineral resource industry, and therefore a healthy industrial economy, can be maintained only on a firm base of geologic knowledge, and geochemical and metallurgical understanding of the distribution and limits of metals, mineral fuels, and chemicals in the earth's crust and hydrosphere.

Premise IV

The assumption that world populations will soon attain and remain in a state of balance is central to all other premises. Without this the rising expectations of the poor are doomed to failure, and the affluent can

remain affluent only by maintaining existing shameful discrepancies. Taking present age structures and life expectancies of world populations into account, it seems certain that, barring other forms of catastrophe, world population will reach six or seven billion by about the turn of the century, regardless of how rapidly family planning is accepted and practiced.

On the most optimistic assumptions, this is probably close to the maximum number of people the world can support on a reasonably sustained basis, even under strictly regularized conditions, at a general level of living roughly comparable to that now enjoyed in Western Europe. It would, of course, be far better to stabilize at a much smaller world population. In any case, much greater progress than is as yet visible must take place over much larger parts of the world before optimism on the prospects of voluntary global population control at any level can be justified. And even if world population did level off and remain balanced at about seven billion, it would probably take close to 100 years of intensive, enlightened, peaceful effort to lift all mankind to anywhere near the current level of Western Europe or even much above the level of chronic malnutrition and deprivation.

This is not to say that we must therefore be discouraged and withdraw to ineffectual diversions. Rather it is a challenge to focus with energy and realism on seeking a truly better life for all men living and yet unborn and on keeping the latter to the minimum. On the other hand, an uncritical optimism, just for the sake of that good feeling it creates, is a luxury the world cannot, at this juncture, afford.

A variation of outlook on the population problem which, surprisingly enough, exists among a few nonbiological scholars is that quantity of people is of itself a good thing. The misconception here seems to be that frequency of effective genius will increase, even exponentially, with increasing numbers of people and that there is some risk of breeding out to a merely high level of mediocrity in a stabilized population. The extremes of genius and idiocy, however, appear in about the same frequency at birth from truly heterogeneous gene pools regardless of size. What is unfortunate, among other things, about overly dense concentrations of people is that this leads not only to reduced likelihood of the identification of mature genius, but to drastic reductions in the development of potential genius, owing to malnutrition in the weaning years and early youth, accompanied by retardation of both physical and mental growth. If we are determined to turn our problems over to an elite corps of mental prodigies a more sure-fire method is at hand. Nuclear transplant from various adult tissue cells into fertilized ova whose own nuclei have been removed has already produced identical copies of amphibian nucleus-donors and can probably do the same in man.[9] Thus we appear

to be on the verge of being able to make as many "xerox" copies as we want or need of any particular genius as long as we can get a piece of his or her nucleated tissue and find eggs and incubators for the genome aliquots to develop in. Female geniuses would be the best because (with a little help) they could copy themselves!

The reality is that without real population control and limitation of demand all else is drastically curtailed, not to say lost. And the prospect that such limitations may take place voluntarily is not bright. The most fundamental freedom should be the right not to be born into a world of want and smothering restriction. I am convinced that we must give up (or have taken away from us) the right to have as many children as we want, or see all other freedoms lost for them. Nature, to be sure, will restore a dynamic balance between our species and the world ecosystem if we fail to do so ourselves—by famine, pestilence, plague, or war. It seems, but is not, unthinkable that this should happen. If it does, of course, mineral resources may then be or appear to be relatively unlimited in relation to demand for them.

Premise V

The notion of the "technological fix" expresses a view that is at once full of hope and full of risk. It is a gripping thought to contemplate a world set free by nuclear energy. Imagine soaring cities of aluminum, plastic, and thermopane where all live in peace and plenty at unvarying temperature and without effort, drink distilled water, feed on produce grown from more distilled water in coastal deserts, and flit from heliport to heliport in capsules of uncontaminated air. Imagine having as many children as you want, who, of course, will grow up seven stories above the ground and under such germ-free conditions that they will need to wear breathing masks if they ever do set foot in a park or a forest. Imagine a world in which there is no balance of payments problem, no banks, or money, and such mundane affairs as acquiring a shirt or a wife are handled for us by central computer systems. Imagine, if you like, a world in which the only problem is boredom, all others being solved by the state-maintained system of genius-technologists produced by transfer of nuclei from the skin cells of certified gene donors to the previously fertilized ova of final contestants in the annual ideal-pelvis contest. Imagine the problem of getting out of this disease-free world gracefully at the age of 110 when you just can't stand it any longer!

Of course this extreme view may not appeal to people not conditioned to think in those terms. But the risk of slipping bit by bit into such a smothering condition as one of the better possible outcomes is inherent

in any proposition that encourages or permits people or industries to believe that they can leave their problems to the invention of technological fixes by someone else.

Although the world ecosystem has been in a constant state of flux throughout geologic time, in the short and middle term it is essentially homeostatic. That is to say, it tends to obey Le Châtelier's general principle—when a stress is applied to a system such as to perturb a state of near equilibrium, the system tends to react in such a way as to restore the equilibrium. But large parts of the world ecosystem have probably already undergone or are in danger of undergoing irreversible changes. We cannot continue to plunder and pollute it without serious or even deadly consequences.

Consider what would be needed in terms of conventional mineral raw materials merely to raise the level of all 3.6 billion people now living in the world to the average of the 200 million now living in the United States. In terms of present staple commodities, it can be estimated[10] that this would require a "standing crop" of about 30 billion tons or iron, 500 million tons of lead, 330 million tons of zinc, and 50 million tons of tin. This is about 100 to 200 times the present annual production of these commodities. Annual power demands would, of course, increase proportionately. To support the doubled populations expected by the year 2000 at the same level would require, of course, a doubling of all the above numbers or substitute measures. The iron needed could probably be produced over a long period of time, perhaps even by the year 2000, given a sufficiently large effort. But once in circulation, merely to replace losses due to oxidation, friction, and dispersal, not counting production of new iron for larger populations, would take around 200,000 tons of new iron every year, or a drastic curtailment of losses below the present rate of one percent every two or three years. And the molybdenum needed to convert the iron to steel could become a serious limiting factor. The quantities of lead, zinc, and tin also called for far exceed all measured, indicated, and inferred world reserves of these metals.

This exercise gives a crude measure of the pressures that mineral resources will be under. It seems likely, to be sure, that substitutions, metallurgical research, and other technological advances will come to our aid, and that not all peoples of the world will find a superfluity of obsolescing gadgets necessary for the good life. But this is balanced by the equal likelihood that world population will not really level off at six-and-a-half or seven billion and that there will be growing unrest to share the material resources that might lead at least to an improved standard of living. The situation is also aggravated by the attendant problems of disposal of mine wastes and chemically and thermally polluted waters on a vast scale.

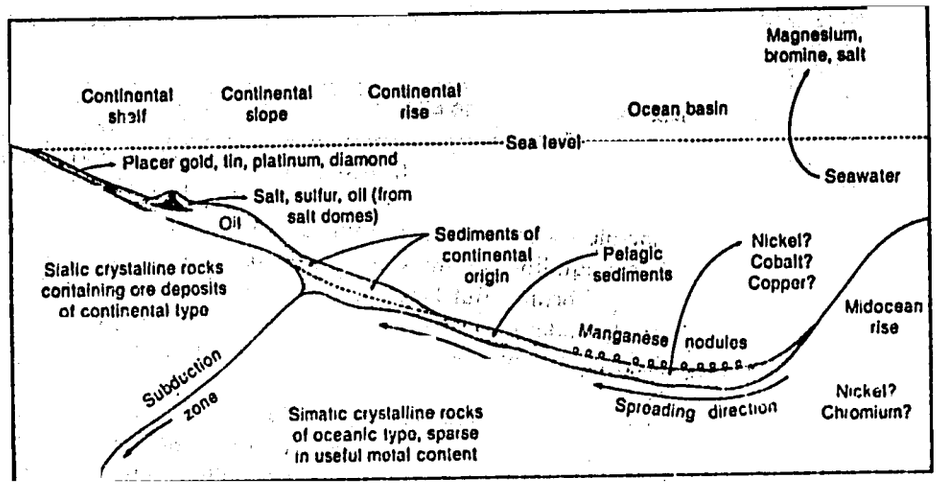

FIGURE 5.
Marine mineral resources. Sites of possible marine mineral resources. Chart is highly diagrammatic and not to scale.

Mineral and chemical resources from the sea may be found among the following (see also Figure 5).

1. Seawater.
2. Placer deposits within or beneath now-submerged beach or stream deposits.
3. Sediments other than placers, and sedimentary rocks that overlie crystalline rocks (a) on the continental shelves and slopes (about fifteen percent of the total sea floor), and (b) beyond the continental margins (about eighty-five percent of the total sea floor; the truly oceanic realm).
4. Crystalline rock exposed at the sea floor or lying beneath sediments (a) on the continental margins, and (b) beyond the continental margins.

Seawater. The sea contains about 1.3 billion cubic kilometers of seawater —an amount so large that quantities of dissolved substances are large even where their concentrations are small. Yet recovery of such substances accounts for little more than two percent of current production of marine minerals and chemicals. Only magnesium, bromine, and common salt are now being extracted in substantial quantities, and, for them, the seas do contain reserves that can be considered to be "inexhaustible" under any foreseeable pressures.

At the other extreme of accessibility is the 10 billion metric tons of gold in seawater—about 0.0013 troy ounce of gold in every million liters of

water. Although capable people and corporations have worked intensively at the problem, the amount of gold so far reported to have been extracted from seawater is trivial.

Sixty-four of the ninety naturally occurring elements now known on earth have been detected in seawater. Of these only fifteen occur in quantities of more than 1.8 kilograms per million liters. Only nine, all of them among the first fifteen in abundance, represent 1965 values of more than $2.50 per million liters (chlorine, sodium, magnesium, sulfur, calcium, potassium, bromine, lithium, and rubidium). These nine (or their salts), plus boron, fluorine, and iodine, offer the best promise for direct recovery from seawater through ion exchange, biological concentration, or more novel processes.

Omitting these twelve, and very few others, the metal elements we are likely to have greatest need to extract from seawater offer little promise for direct recovery.

Placer deposits. Placer deposits now offshore were formed by gravitational segregation in and beneath former beach and stream deposits when the sea stood lower or the land higher. The outer limit at which such deposits can be expected is about 100 to 130 meters, the approximate position of the beach when Pleistocene glaciation was at its peak.

Diamonds, gold, and tin are being recovered from submarine placers (the diamonds, up to 1967 at least, at a cost in excess of their value). Approximate 1964 global values, omitting cost of recovery, were as follows: diamonds, $4 million; tin, about $21 million; gold, unknown.

Submarine placers of tough heavy metals such as gold, tin, and platinum offer the best prospects for the practicable recovery of mineral resources from the sea other than magnesium (from seawater) and oil and gas (from continental shelf sediments).

Sediments. Continental-shelf sediments and salt-dome structures that penetrate them account for nearly ninety-eight percent of the mineral and chemical wealth currently produced from within and beneath the sea—by far the greater part of this being oil and gas. About seventeen percent of the world's petroleum and natural gas now comes from offshore, nearly half the fields and about one-fourth the production being adjacent to the United States.

From data available in 1965, it has been estimated that about 700 to 1000 billion barrels of liquid fuels are potentially recoverable from offshore areas worldwide, which is about equal to or somewhat more than that remaining to be discovered and produced on land.

The oil-producing salt domes in the Gulf of Mexico also yield sulfur. More than five percent of the world's sulfur now comes from such sources.

Current reserves, however, will have been depleted by about 1990, and new discoveries or other sources will have to take up the slack.

Sediments and sedimentary rocks beyond the continental shelves and slopes are strikingly different from those that mantle and comprise the continental margins. Here is where we find the curious and geologically interesting manganese nodules and crusts. Despite the extravagant claims that have been made, however, their prospects for future mineral production remain to be established.

Crystalline rocks. Finding and exploiting mineralized crystalline rocks on the sea floor—even on the continental shelves—involves the same problems as on land, and many more. Although it is clear from geological data that the substructure of the shelf and slope is of a continental rather than an oceanic type, and that mineral deposits comparable to those found on the adjacent land are to be expected, problems peculiar to the region hamper their discovery and exploitation. Nevertheless, it seems statistically certain that ore deposits exist in crystalline rocks somewhere on or beneath the continental shelves. How many of them will eventually be discovered and worked is another question.

Beyond the continental margins the difficulties increase. The crystalline rocks of the ocean basins appear to be mainly basalts, probably limited both in the variety of included minerals and in the degree of enrichment to be found. Nickel, chromium, copper, and platinum may be present, but the first submarine ore of any is yet to be found. Iron and magnesium are probably the most abundant metal elements in the oceanic rocks, but such ores, if any, could not compete with sources from dry land and from seawater.

Mineral and chemical resources of the sea that will be significant for man over the next half century are those that can be extracted from seawater or recovered from the seabed of the continental shelf (and perhaps the oceanic rises). About five percent of the world's known production of geological wealth came from the shelves and seawater in 1964 and the trend is upwards. Oil and gas are by far the most important products, although their duration at expected rates of consumption will be limited. Seawater can supply ample magnesium and bromine, as well as common salt and some other substances. It will, however, supply few important metal elements other than magnesium, sodium, potassium, iodine, and perhaps strontium and boron. Oyster shells (used in the recovery of magnesium and for road metal, and by no means an inexhaustible resource) are being taken from the shallower parts of the shelves in relatively large quantities. The use of nearshore submarine sand and gravel, not yet large, will probably increase as coastal cities expand over and use up other local sources.

The sediments of the continental shelves and the crystalline rocks beneath them can be expected to produce mineral commodities similar to those of the immediately adjacent land. One way of guessing the magnitude of such resources is to reflect the hundred-fathom depthline across the shoreline. It then defines an onshore area equivalent to the continental shelf and having roughly similar geology. For the equivalent on-shore area in the United States (in 1966 dollars), the total cumulative value of minerals extracted since the beginning of the U.S. mineral industry, is about $160 billion, exclusive of oil and gas, or $240 billion with oil and gas. Because of geological differences from the land, and other obstacles that complicate discovery and recovery in the subsea environment, however, this figure is doubtless considerably larger than what we can expect from the continental shelves.

The ocean basins beyond the continental margin are not promising places to seek mineral resources.

A "mineral cornucopia" beneath the sea exists only in hyperbole. What is actually won from it will be the result of persistent imaginative research, inspired invention, bold and skillful experiment, and intelligent application and management—and such resources as are found will come mostly from the continental shelves, slopes, and rises. Whether they will be large or small remains to be seen. It is a fair guess that they will be substantial; but if present concepts of earth structure and of seafloor composition and history are correct, minerals from the seabed are not likely to compare with those yet to be recovered from the emerged lands. As for seawater itself, despite its volume and the quantities of dissolved salts it contains, it can supply few of the substances considered essential to modern industry.

THE NUB OF THE MATTER

The realities of mineral distribution, in a nutshell, are that it is neither inconsiderable nor limitless, and that we just don't know yet, in the detail required for considered weighting of comprehensive long-range alternatives, where or how the critical lithophilic elements are concentrated. Stratigraphically controlled substances such as the fossil fuels, and, to a degree, iron and alumina, we can comprehend and estimate within reasonable limits. Reserves, grades, locations, and recoverability of many critical metals, on the other hand, are affected by a much larger number of variables. We in North America began to develop our rich natural endowment of mineral resources at an accelerated pace before the rest of the world. Thus it stands to reason that, to the extent we are unable to meet needs by imports, we will feel the pinch sooner than countries like the USSR with a larger component of virgin mineral lands.

In some instances nuclear energy or other technological fixes may buy time to seek better solutions or will even solve a problem permanently. But sooner or later man must come to terms with his environment and its limitations. The sooner the better. The year 2042, by which time even current rates of consumption will have exhausted presently known recoverable reserves of perhaps half the world's now useful metals, is only as far from the present as the invention of the airplane and the discovery of radioactivity. In the absence of real population control or catastrophe there could be fifteen billion people on earth by then! Much that is difficult to anticipate can happen in the meanwhile, to be sure, and to center faith in a profit-motivated technology and refuse to look beyond a brief "foreseeable future" is a choice widely made. Against this we must weigh the consequences of error or thoughtless inaction and the prospects of identifying constructive alternatives for deliberate courses of long-term action, or inaction, that will affect favorably the long-range future. It is well to remember that to do nothing is equally to make a choice.

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ELECTRIC POWER, EMPLOYMENT, AND ECONOMIC GROWTH: A CASE STUDY IN GROWTHMANIA

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ELECTRIC POWER, EMPLOYMENT, AND ECONOMIC GROWTH: A CASE STUDY IN GROWTHMANIA

Herman E. Daly

Every living thing is a sort of imperialist, seeking to transform as much as possible of the environment into itself and its seed.
Bertrand Russell

INTRODUCTION

The salient fact about electric power production is that it is growing at seven percent annually, doubling every ten years. Even ardent supporters of energy growth recognize the absurdity of projecting such a rate very far into the future, lest the entire environment be transformed into electric power and electric power generators. For example, John W. Simpson, president of Westinghouse Power Systems Company, says:

> At some point in time, well before plants crowd us into the ocean or we change the climate of the earth through the rejection of heat into the atmos-

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"Electric Power, Employment, and Economic Growth: A Case Study in Growthmania." Presented at the 1971 AAAS Convention "Symposium on the Energy Crisis," and previously published in the Congressional Record, February 8, 1972, at the request of Senator Hart.

> phere, we will reach an energy plateau, a level at which our technology will have placed us through the super-efficient utilization of power. In other words we will have learned to do so much more with so much less power that more power plants as we know them today probably would be superfluous.[1]

How many more years before we reach this "energy plateau"? Simpson says only that "well before that hypothetical 200 years from now, we will have seen a leveling off in the rate of increase of power consumption."[2] A "leveling off in the rate of increase" within 200 years? Presumably this means a zero rate of increase rather than some constant positive rate. But he leaves a date for the achievement of the important concept of an energy plateau vague, arguing that for the "forseeable future" (thirty to fifty years?) more power plants as we now know them will be necessary. Congressman Chet Holifield, of the Joint Committee on Atomic Energy, puts a minimum figure of thirty years on the forseeable future in stating that ". . . the doubling factor every decade for the next thirty years is basic to our standard of living, now and in the future."[3] According to this point of view, one can make the loose inference that at the minimum, eight times our present electric power output might be enough—then we can begin to talk seriously about an energy plateau, not before. But certainly we could not abruptly decelerate from seven percent to zero growth immediately at the end of thirty years. Indeed, it would most probably be necessary to double electric power output at least once more over a longer period in order to overcome the inertia of growth without shaking up the economy too badly. Thus the "energy plateau" appears to be at least sixteen times the present output! Furthermore we are to grow as rapidly as we can (at least at seven percent) for the next thirty years, which is to say, for the next generation, or sufficiently far into the future not to affect the capitalized market values of electric utility "growth" stocks. After us, the energy plateau—or is it perhaps, after us, the deluge?

For the regulated electric utilities, growth and profitability are closely related. The regulated "fair rate of return on capital" has been interpreted by the courts to be based on three criteria. The rate of return must be (1) commensurate with returns on investments in other enterprises having commensurate risks, (2) sufficient to insure the financial integrity of the enterprise, (3) able to maintain the credit of the enterprise and attract capital. For those of us who study growth the criterion most relevant is the last. In order to attract the capital needed to finance the rapid expansion of capacity, the rate of return must be *higher* than in other investments of equal risk. The need for rapid growth, if established to the satisfaction of regulatory agencies, leads to requests for a higher allowable rate of return, and it is notable that higher rates have already been

1. Notes for this reading will be found on pages, 276–277.

granted to some utilities and that many petitions for other rate increases are now pending. Furthermore, even if the regulated rate of return is held constant, the utilities have abundant incentive to expand productive capacity in order to increase the base to which the regulated rate is applied, and thus to increase total profits. If the rate of return must be raised to attract capital, so much the better. But in order to expand and to raise the rate, utilities must convince the regulatory commission of the need for expansion. To do this, the utilities must be able to point to a "shortage," which they can by showing that demand is increasing faster than supply. To increase demand it is necessary to advertise and to give lower rates for use in large quantities. Perhaps this explains the curious fact that the electric utilities, a public monopoly, spend eight dollars on advertising for every one dollar spent on research and development.[4] Another incentive to growth beyond the optimum is that a large part of the cost of increased electric power is the social cost of environmental deterioration, which is paid by society in general, rather than by the parties directly responsible for the costs. Although one is not accustomed to thinking of electric utilities as a "growth stock," Standard and Poor now inform the investor that "electric power is not only the backbone of the American economy [!], it is also a vigorous growth industry."[5]

Electric power is now used to illuminate advertising signs during daylight hours, to run electric toothbrushes, and to convey shoppers through parking lots on movable sidewalks. With so many trivial uses of electricity in present vogue, one wonders just what we will possibly do with twice as much electricity in 1980, four times as much in 1990, etc. It is not my intention to belittle the tremendous importance of electrical energy or of production in general. The French economist de Jouvenel has put the issue very well:

> But if I do not at all object to the much enhanced status of production, I may point out that production has come to embrace so much that it would be foolish to grant any and every productive activity the moral benefit of an earnestness not to be found in so-called "nonproductive activities." When popular newspapers propose to bring out their comic strips in color, I find it hard to regard such "progress in production" as something more earnest than planting flowering shrubs along the highways. I am quite willing to regard poetry as a frivolous occupation as against the tilling of the soil but not as against the composing of advertisements.
>
> When organizers of production have to relieve a situation of hunger, efficiency is the one and only virtue. But when this virtue has been thoroughly developed and comes to be applied to less and less vital objects, the question surely arises of the right choice of objects.[6]

The importance of this declining intensity of needs for increased production to satisfy is recognized also by advocates of growth, but as an

obstacle to be overcome in order to increase the flow of output and employment. For example, economist Joseph N. Froomkin explains:

> The big challenge to the U.S. and other Western economies is to bring out cheaply, through automation or otherwise, new products that will tempt the consumer's jaded tastes. These new products in turn will stimulate investment.[7]

Again, if the "big challenge" presently is to tempt the consumer's "jaded tastes," what are we going to do with sixteen times as much electricity? Population growth will absorb only a small and declining part of it. The big increase will be, and has been recently, in per capita consumption. Perhaps we must all learn to imitate President Nixon's idiosyncracy of turning the air conditioner on full blast so that he can enjoy warming himself by the fireplace in midsummer![8] The President's idea is rather logical: central heating in the winter warms the White House too much to make a hearth fire—something man has loved from earliest times—enjoyable, but in the summer air conditioning chills the air too much, and thus makes it possible to enjoy a fire. Such self-cancelling uses are capable of absorbing great amounts of electric power, and perhaps of jading consumer's tastes to the very limit. But is such "production" more earnest than weeding a flower garden? The question of electric power for the poor—whose tastes have not had the opportunity to become jaded—is considered later.

What we've considered so far raises doubts that advocates of increased power growth take the impossibility of growing forever at seven percent seriously; perhaps they mention the notion of an "energy plateau" just in passing in order to fend off an easy *reductio ad absurdum* by opponents. At least they do not develop the concept. As one reads four main arguments most often used as reasons defending the growth position in the media and in congressional hearings, the doubts increase. The *Congressional Record* contains fuller statements of these arguments, which are summarized below.[9] Examining them critically, we find them to be grossly deficient both in their logic and premises.

The growth advocates state that we must have continued rapid growth in energy:

A. To increase the standard of living (level of consumption) of the present population and to extend that rising standard of living to some 70–100 million more Americans by the year 2000.

B. To clean up the pollution and recycle the waste which has resulted from past production and consumption, and which will accumulate with current and increased production and consumption.

C. To maintain an acceptable level of employment, because (1) labor is used directly in the production of electric power, and more importantly because (2) power indirectly affects employment, being an

input in most production processes which also use labor and being necessary in order to operate many consumer goods produced through employment of people.

D. To produce the devices that give us the capacity for military defense and deterrence "upon which world peace depends."

Our attention will mainly be directed to reasons A and C, but it is important by way of introduction to realize that the four reasons are part of a whole point of view and are not independent of one another. The tacit, unifying point of view, the unarticulated preconception, is that of open ended growth, which, though sometimes obscured by refusing to project the growth of the energy sector beyond one generation, remains an implicit assumption of each of the four arguments for the "temporary" necessity of continued rapid growth. Reason A postulates the goal of an increasing level of consumption without reference to a "consumption plateau." Even the growth-oriented President's Council of Economic Advisers has told us that "growth of GNP has its costs, and beyond some point they are not worth paying."[10] Is some such point evident to those who cite reason A in defense of growth in energy production? No. Although many suspect that we in the United States may have already passed the critical point, defenses of the type illustrated by reason A fail to recognize even the existence of such a point.

Total output continues to grow and grow, and so does total waste and pollution. Reason B—that more energy is needed to clean up—is thus guaranteed by reason A, as well as by a backlog of accumulated pollution. Since matter and energy can be neither created nor destroyed but only transformed, the more we "consume," the more waste we must clean up. Thus the first round of matter-energy degradation (production) requires a second round to clean up after the first, and in turn the second round of matter-energy degradation requires a third round to clean up after it, etc. There are infinite rounds of clean-up uses of energy. Granted the residue of each round, like the dirt remaining after each sweep into the dust pan, probably diminishes rapidly, nevertheless there is something of a vicious circle in using resources to power industry, and then having to use more resources to produce the energy to power the industry called for to remove the soot or repair the effects of chemical corrosion brought about by the increased industrial production. What is ultimately scarce in the physical world is not energy but low entropy. The more energy we use, even for the purpose of cleaning up, the more rapidly we use up the stock of low entropy—i.e., the more rapidly we degrade the total environment. Thus, reason B derives from reason A and also reinforces reason A by falsely suggesting that cleaning up *cancels* the environmental cost of production growth. Cleaning up is *part* of the environmental cost of production, necessary but certainly not an activity to be pursued beyond

some limits. At some point the degradation cost of energy needed for cleaning up will be greater than the cost of the pollution it cleans up.

Reason C argues for more energy in order to provide more employment. But the labor done by energy is a *substitute* for human labor as well as a complement to it. Given a total output, an increasing supply of non-human energy will surely be used to substitute for human labor (what else could it be used for?) and will result in higher productivity per worker, but *less* employment. The reduced hours of employment would probably result in the employment of fewer men, although it could result in the same number of men working fewer hours. But since power-growth advocates seldom mention reducing the hours worked per man, a plan that could increase the number of men employed independently of changes in the uses of energy, it is clear that reason C assumes that total output is growing faster than the rate at which energy is becoming a substitute for human labor. In other words we are back to reason A and unlimited growth in the total product.

Reason D says energy growth is needed for national defense or deterrence of enemies. But military deterrence has become a self-escalating process of open-ended growth, by which military strength remains balanced, but only if each side achieves the defensive might available to the other. Both sides grow continually in tandem, and reason D seems to have less pertinence to actual warfare than to the growthmania assumption of reason A, with which it meshes perfectly. The more the military depletes the civilian economy of resources and technical personnel, the lower will be growth of output per input that is the important measure of the productivity of the civilian economy. The slower the growth in civilian productivity the greater must be the growth in raw material and energy inputs to maintain a given rate of increase in total product. And so the depletion of the civilian economy by burgeoning military needs has reduced possibilities of the one kind of growth we all welcome, growth in productivity—less input per output. The "energy plateau" becomes much harder to attain.

The counter-arguments above leave the strong impression that merely to mention limits or plateaus in the growth of energy needs is nothing more than a digression, a debating parry, and that the paradigm underlying the four principal arguments advanced by advocates of growth in the energy utilities remains one of "growthmania." In addition to recognizing the absurdities of projecting high growth rates of electric power into the future, we must recognize the absurdity also of projecting high rates of growth of total output, now that we have taken the four arguments at their logical face value. To paraphrase Westinghouse's President Simpson, it seems that at some time in the future, well before power plants crowd us into the ocean, we will have already been driven into the

ocean by our commodities, the pollution they have caused, and their corpses. Our economy, as Bertrand Russell describes "every living thing," is succeeding too well in its imperialist drive to "transform as much as possible of the environment into itself"—i.e. into commodities and people. The electric power industry has simply been more successful in doing what all other industries are striving to do—namely, to grow, and when possible, to avoid paying the full social cost of the increased production. This points to serious irrationalities at the overall systems level of our economy, some radical implications of which will be treated in the last section of this reading.

But now, further attention must be given, in the next section, to reason C—that increased energy production is necessary to maintain employment—since in a period of unemployment it is both particularly influential and particularly fallacious. The key argument, however, is A, open-ended growth in consumption. If A falls the other arguments fall with it, so it will merit our special attention in the last section.

ENERGY AND EMPLOYMENT

Bernard de Mandeville, in his "Fable of the Bees," argued in favor of the most extravagant luxury consumption by the upper class on the grounds that it provided employment for the poor. Frédéric Bastiat, in his "Petition of the Candlemakers . . ." proposed blocking sunlight from all houses and buildings in order to increase employment among candlemakers, who in turn, through their increased expenditures, would stimulate employment in whaling, match making, wick production—in effect, in all industries—to the immense benefit of all the classes of the realm. These two writers were of course telling tongue-in-cheek tales with the object of analogizing, through satire, proposals their contemporaries had made in sincere attempts at special pleading. Whether special pleading is at the heart of the employment rationale put forth by today's electric power interests I will leave for the reader to judge, presuming only to list a number of considerations that might be relevant in making such a judgment.

The Confusion, through Crude Empiricism, of Substitutes and Complements for Labor

Physical labor is, at the margin, a negative factor in the enjoyment of life and leisure is, at the margin, a positive factor. Thousands of years ago man domesticated animals to relieve his toil, substituting the labor

of animals for that of humans as the source of energy for production. Later, man harnessed inanimate energy and made a further substitution of it for human labor, deriving leisure previously unavailable when human labor was needed for production. It might appear that historically such substitutions dominate the relation of human energy to nonhuman energy: the more of one, the less of the other—a negative correlation. Yet what we find is a positive correlation—throughout history the number of men employed has increased as use of nonhuman energy has increased—and one is therefore tempted to argue that more employment necessitates more use of inanimate energy. But expose this crude empiricism to simple rational analysis and it will not stand up. The increase of nonhuman energy along with human employment means instead that energy use and employment both correlate to some other factors that have been increasing historically, namely total output and total population. The positive indirect correlations via the growth of these other factors has outweighed the negative direct correlation of energy and employment. For constant output and population we know that the correlation between energy and employment is bound to be negative, for as we asked in the previous section, what conceivable use does nonhuman energy have other than as a substitute for human labor in producing the same or a smaller quantity of goods, or as a complement to human labor in producing a greater quantity of goods? If we rule out the second use we are left with the first. If we insist on more employment and more nonhuman energy we must also insist on more output. The real world uses nonhuman energy as both a substitute and a complement simultaneously. Only if total product growth creates more jobs for humans than are eliminated by the growth of nonhuman energy will employment increase. This is self evident.

Congressman Chet Holifield, a supporter of energy growth, came dangerously close to defeating the logic of his own argument recently while extolling the importance of energy:

> Our standard of living is the highest of any nation in the world because we use the highest ratio of mechanical power versus manpower. . . . One man can do the work of 350 men.[11]

This is a clear recognition of the overwhelming importance of increasing substitution as the major factor in increasing the standard of living. Furthermore, for one man to do the work of 350 men means that 349 men are doing something else. If they are employed doing something else, total product will increase. If total product does not increase they must remain unemployed. Clearly what is responsible for increasing total employment is the increase in total product, not the increase in inanimate power consumption which in fact, taken by itself, must *decrease* employment.

The Least Energy-Intensive Sector Accounts for Nearly All New Employment

As nonhuman energy replaced human energy in agriculture it was not possible to increase employment in this sector even with vast increases in total agricultural product. Instead, employment was provided by growth in a new sector, industry. As nonhuman energy now replaces men in industry, even with large increases in the total output of the industrial sector the major source of new employment has been another new sector, service, rather than industry. The total employment within the service sector has grown from approximately forty percent in 1929 to over fifty-five percent in 1967. Of the total net increment of fourteen million jobs between 1947 and 1965, the service sector accounted for an increase of thirteen million, industry accounted for an increase of four million, but agriculture accounted for a decrease of three million.[12] Services, using less energy than the other two sectors, have provided nearly the entire net increase in employment since 1947. Service institutions, such as banks, hospitals, retail stores, schools, insurance companies, and others, now provide the new employment, and they require energy for lighting, space heating and cooling, and office machines—needs perhaps no more energy intensive than are found, on a per capita basis, in the average household. The most energy-intensive sectors are also the most highly capitalized and automated sectors, and consequently do not provide significant increases in new employment. Thus, to allege that large increases in energy input are needed to provide new jobs seems to presuppose that the average new worker will work in a steel or aluminum plant, a counterfactual presupposition, inasmuch as it is likely he will work in a service institution.

What is the reason for the drastic shift of employment toward the service sector? Victor Fuchs's authoritative study, *The Service Economy*, considers three hypotheses: (1) a more rapid growth of final demand for services, (2) a relative increase in the intermediate demand for services, and (3) a relatively slow increase in output per man in services. Hypothesis 1 could not be very important since the percentage of total output accounted for by the service sector was the same in 1965 as it was in 1929, measured in constant dollars. Measured in current dollars it increased only from forty-seven percent of fifty percent. Hypothesis 2 was examined statistically by Fuchs and found to account for less than ten percent of the total change. The major explanation is hypothesis 3, that output per man grew much more slowly in the service sector than in the other sectors. This means that the amount of labor required for a given output fell more rapidly in agriculture and industry than in the service sector. In other words, services employ relatively more people

because agriculture and industry need relatively less labor year after year.

But *why* has productivity per man risen more slowly in the services than in industry? Are services inherently less subject to technological improvement than manufacturing? Fuchs suggests perhaps this is so, but there is another reason that should not be overlooked. The industrial sector of the economy is characterized by much greater monopoly power than is the services sector. This power tends to be countervailing, the oligopolistic managements of the industrial sector being offset by the monopolistic labor unions. Although more than half the persons employed in industry are union members, only about ten percent of service sector employees are unionized.[13] Unionized labor succeeds in temporarily pushing wages above MRP_L, the marginal revenue product of labor. Management reacts by seeking to reestablish the equality in order to keep short run profits at a maximum.[14] Thus higher wages lead to a higher marginal revenue product of labor, and consequently, to a higher average revenue product of labor. Since the latter is the statistical measure of labor productivity it is clear that union-induced wage increases tend to increase measured labor productivity in the short run. In the long run, management reacts to union power by seeking to substitute capital for labor, thus further increasing the productivity of labor and reducing the number of laborers needed. By contrast with industry, in the service sector we witness neither much unionization nor much monopoly power, since entry into services is not blocked by the high initial capital outlays found in industry. Such cartelization as does exist in services (as, for example, among physicians and lawyers) involves no conflict between labor and management and results in no upward pressure on productivity per man. It seems, therefore, that at least a part of the difference in productivity and employment between industry and services has its origin in different market power rather than in different susceptibility to technological progress.

One third of service sector employment is in nonprofit institutions, where the profit-maximizing, employment-limiting rule of wage equal to MRP_L loses its rationale from the very beginning. The service sector also has a much higher rate of self-employment, where the rule of wage equal to MRP_L applies with less force and where a decline in employment often takes the form of work sharing, with fewer hours worked by the same number of people. Many small entrepreneurs in services are also, however unintentionally, "nonprofit institutions," and are providing temporary employment while in the process of slowly going out of business. Retail gasoline stations are a case in point. Finally, for many services, output is so hard to measure that it is estimated for national income purposes by the value of input (e.g., government services), with the result that productivity loses all meaning. Often productivity in services, even

when it can be roughly measured, depends as much on the consumer as on the producer. For example, a physician's productivity is influenced by the patient's ability to supply an accurate medical history, and the teacher's productivity varies according to the interest and intelligence of the student. In sum, the whole notion of productivity in the service sector is often very vague, or completely meaningless (as when we estimate the value of output by the value of input), or of little consequence in determining employment (as in both intentionally and unintentionally nonprofit institutions). The upshot is that service sector employment is much less strictly limited by productivity considerations than is industrial employment.

On the demand side ever rising standards of minimum consumption for certain services (in education, medical care, legal counsel, insurance, and government welfare services) have helped demand to keep up with supply and to make growing employment possible in these areas. But there is a limit to the amount of services people will voluntarily consume. Much service consumption is already involuntary—e.g., compulsory schooling, quasi-compulsory college attendance in order to get a job, compulsory insurance and retirement services and related medical exams, compulsory psychiatric care for the mentally ill, etc. How far such forced consumption is justifiable is now becoming a hotly debated issue. Books are written on "deschooling society" and on "how to avoid probate" and associated legal fees. The notion of legal insanity and forced consumption of psychiatric services is also under attack.

It has long been argued that in underdeveloped countries the service sector, particularly the government itself, acts as a sponge to absorb the unemployed, a policy that serves distribution more than it serves production. Might not the same apply to the United States?

Little Employment Is Created Directly by Energy Transformation

One must recognize, of course, that men are employed directly in energy extraction, in refining, pipeline transportation, and energy utilities. This employment amounted to 2.6 percent of total employment in 1947, 2.3 percent in 1955, and 1.8 percent in 1965. The energy industry accounted for a much larger percentage of total investment: 16.1 percent in 1947, 22.0 percent in 1955, and 19.4 percent in 1965. The percentage of GNP originating in the energy industry was 4.5 percent in 1947, 4.7 percent in 1955, and 3.8 percent in 1965. Note that the percentage of energy industry investment is very high relative to its percentage of total product. Note also that energy's percentage of employment is low relative to its percentage of the total product. Thus a relatively large invest-

ment in energy produces a relatively small amount of employment.[15] Energy transformation is probably the most capital-intensive, labor-saving part of the economy, and direct employment from its growth will be very small.

Indirect Employment and Special Pleading

Indirect employment is another matter, and in the previous section we mentioned that advocates of growth in energy output believe such growth will indirectly create employment. We may consider two kinds of indirect employment effects: those arising from the interdependence of supplies, of which energy is one, and those arising from demand. Undeniably, energy is a necessary input to the supplies of nearly all sectors. But it does not necessarily follow that increasing the production of energy will increase the number of jobs in these sectors. In fact, to the extent that an increased supply of it lowers the price of energy, the result is more likely to be a reduction in employment as cheaper energy replaces human labor. Nor does it always follow that other sectors cannot expand employment without an increase in energy input (though increased energy is needed to increase employment when coefficients of production are fixed). In general, increasing the input of energy to the supply side of the economy is neither a necessary nor a sufficient condition for increasing employment. The same would apply to many other inputs, not just energy. Minerals are necessary inputs to most production; to that extent, the jobs of all people in all sectors are influenced by the supply of minerals. Water is a necessary input; to that extent, jobs are influenced by water. For some production processes a ¾ inch no. 8 countersunk chromium-plated-brass wood screw is a necessary input. And though the jobs of all people in all sectors may depend on the availability of this type of screw, or of minerals, or of water, a surplus of countersunk chromium-plated-brass wood screws or minerals or water does not usually send a personnel manager to his job-applicant file.

On the demand side, indirect employment effects do result from new investment in energy production. As we have seen, energy accounts for some twenty percent of new investment, a significant amount. This high percentage of investment results from rapid growth and the high capital-intensity of energy production. These investments generate a chain of respending, or multiplier effects, throughout the economy, stimulating output and employment (and inflation). But once again, this Keynesian argument is perfectly general and can be applied to new investment in any industry. Indeed, it can be applied to increased expenditure of any kind (increased welfare payments, unemployment compensation, or

military spending), not just to investment. Arguments claiming indirect employment effects, either by way of supply or demand, are therefore obvious cases of special pleading of a condition that applies to all industries, not just energy. Such arguments, relying on the need for investment, are also premised on open-ended growth in total product—reason A on the list advanced by its advocates as evidence for the need of energy growth.

Power for the Poor

An occasional variant of the argument that energy growth increases employment is what might be called the "power for the poor" argument. To quote John Simpson again, "If we were to freeze our rate of power generation and consumption, we would effectively deny those millions who are below the average any chance to improve their lot in the future."[16] The statement is a non sequitur. Improving the lot of those below the average does not depend on electric power alone, and even if it did their lot could still be improved by cutting down the consumption of those who are above average—evidently a thought too horrible to contemplate! But the claim that in effect the increment in power would go largely to the poor has never been supported by evidence. Indeed, there is reason to expect, on the basis of evidence, that just the reverse would happen.

Consider the "power for the poor" argument expressed in the "Energy Marketing" section of a recent issue of *Electrical World*.[17] An article entitled "Zero Growth Power Advocates Ignore Effect on the Poor" argues that zero growth in power is a policy "which, by a sort of grandfather clause, would seek to prevent those of lower income and darker skin from sharing in the not-inconsiderable comforts and conveniences afforded by modern electric appliances . . ." As "evidence" the article presents us with Table 1, which shows that a much larger percentage of wealthy and white people own major electric appliances than do low-income and nonwhite people. The "conclusion" that the reader is encouraged to draw from these statistics is that "future growth will consist of gradual accumulation by lower income families of the more modern appliances first accumulated by their wealthier cousins." But if gradual accumulation by the poor comes about it will be because of general economic growth and the resulting growth in employment, not from growth in electric power, by itself something likely to have the opposite effect, as we have already seen. More importantly, the conclusion following from the fact that the rich own more appliances than the poor is that the rich use more electricity than the poor. How can the poor use much

TABLE 1
Appliance ownership by income and race in New York City (by percent)

Ownership	Air conditioner	Dish washer	Vacuum cleaner
Income			
$ 0–3,000	12	1	40
3–5,000	11	2	46
5–10,000	28	5	69
10–15,000	48	15	89
15,000 and over	58	36	95
Race			
White	40	12	81
Nonwhite	8	3	41

Source: Electrical World, *March 15, 1971, p. 148.*

more electricity without buying air conditioners, dish washers, vacuum cleaners, frost-free refrigerators, washers, dryers, color TVs, etc.? And how can they buy these applicances if they are poor? If the increment in electric power were truly directed to the poor, one would expect to find the energy-marketing people striving to promote mainly simple, low-priced appliances with low operating and maintenance costs, designed to be advantageous for the poor. One would expect to see research and development receive eight times as much as advertising instead of one-eighth as much, as is now the case, and one would also expect to see rate discrimination in favor of the small rather than the large users.

That the energy marketeers prefer to concentrate on production for those who can pay high prices is obvious from other articles appearing in the "Energy Marketing" section of *Electrical World.* Consider two other articles in this section of the very issue I just cited. One extols the virtues of a moving sidewalk projected for Boston, the object of which is to convey consumers from a parking area to an adjacent shopping area more quickly. Since conveyor belts have speeded up production, bringing the commodity to the market more rapidly, apparently we must speed up consumption also by putting the consumer on conveyor belts. Does *Electrical World* really think moving sidewalks will be a boon to the inner-city ghettos? A second new dimension in energy marketing is described in another article, about a Gold Medallion home, all electric (so as to avoid pollution!), with central vacuum cleaning systems and electronic security systems, the latter no doubt to safeguard the considerable wealth represented by all the other electric appliances, appliances available to everyone, rich and poor alike, provided he has the

money! Sandwiched as it is between these two articles on the latest technological advance toward trivial energy consumption for the jaded tastes of the affluent, the article defending the poor against the selfishness of the zero growth advocates raises the suspicion of trumpery. Needless to add, none of the articles warns readers that production of power causes pollution, and that though the benefits of power production go mainly to the rich, the external costs fall mainly on the poor. For example, consider the giant Four Corners power complex in the desert of northeastern Arizona. The electricity generated there is used mainly in Southern California and other distant places more affluent than the Four Corners area. The nearby Navajo hogans do not have air conditioners and other major electrical appliances. The Indians and other local residents are subjected to the air pollution and the strip mining that accompany electricity production, and the benefits of "clean" electricity go to affluent suburban Americans.

Increasing Costs and Decreasing Benefits per Kilowatt

It should be clear that growth in efficiency is not being questioned. If we can get more service from the same physical fund, that is all to the good. But increasing the physical fund is clearly a limited process. No one objects to getting more satisfaction per kilowatt or more kilowatts per BTU of primary fuel. But if kilowatts keep on growing we will witness a decline in the ratio of satisfaction per kilowatt. Although a trend in the ratio of energy to GNP fell until 1966, since 1966 the ratio has risen sharply, and in 1970 the actual ratio was thirteen percent greater than it would have been had the pre-1966 trend continued. (See Figure 1.) Thus a dollar's worth of satisfaction now costs more kilowatts than in 1966, and the new trend seems to be rising. Furthermore, new products and quality improvements notwithstanding, the amount of satisfaction represented by a dollar's worth of GNP is itself probably falling. We satisfy our most pressing wants first, and each extra dollar of income is dedicated to the satisfaction of a less important want. Furthermore, GNP increases currently overstate welfare increases since more and more of what is counted in GNP is the cost of defending ourselves from the unwanted side effects of production. Therefore the fact that GNP per capita has been growing means that the incremental dollars represent less satisfaction. With decreases in both satisfaction per dollar and in dollars per kilowatt, it is very clear that satisfaction per kilowatt must also have fallen. This does not square very well with Mr. Simpson's prediction that "we will have learned to do so much more with so much less power. . . ."

It seems instead we are learning to use more power to do less, at

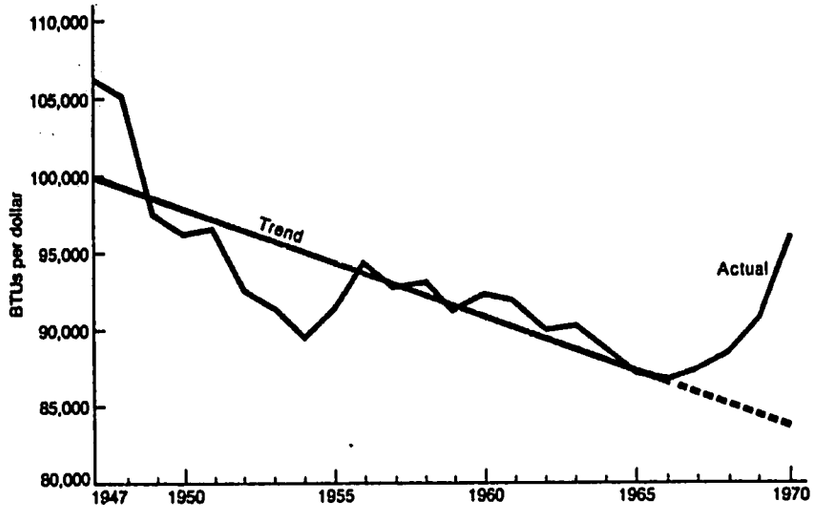

FIGURE 1.
The ratio of energy to Gross National Product, 1947–1970. [Source: National Economic Research Associates, "Energy Consumption and Gross National Product in the United States," March 1971. Also Earl Cook, "The Flow of Energy in an Industrial Society," *Scientific American*, September 1971, p. 140.]

least in terms of the significance of what is done. This by itself does not mean that we have overshot the optimum. Falling marginal benefits of kilowatts may still be greater than rising marginal costs. We do know that the marginal cost of a kilowatt, in terms of alternative satisfactions sacrificed, is bound to rise. There is a thermodynamic limit to the efficiency of converting energy, so improvement in kilowatts per BTU of primary fuel is limited. Continued increases will require more primary fuel, and more rivers and lakes to supply coolants, which implies the sacrifice of increasingly more important alternative satisfactions that could be derived from aquatic resources. We are now learning that the ecological value of the land and water that would be used for more kilowatt production is "invisible," and that the environmental services provided by the resource *in natura* are often far greater than the services they render within the economy of pecuniary calculation. Externalities have become so important relative to internalities that monetary price calculations have now become, if not blind, at least one-eyed guides, deficient in depth perception and less to be trusted than the common sense reasoning we have been using, reasoning that cannot prove, but does suggest, that one or two or three more doublings of electric power output will probably push marginal cost well above marginal benefits. In

any case, those who are proposing electric power increase need to undertake the burden of proving that such increases will not overshoot the optimum. The power growth arguments offered and analyzed earlier fall far short of establishing their presumption that the benefits of sixteen times as much electric power will outweigh the costs. Ironically, continued growth of electric output when marginal cost exceeds marginal benefit might well stimulate employment. Since we would, in view of this, in effect be getting poorer by producing more, power growth lobbies would likely combat our reduced well-being in the traditional way, proposing to increase production and employment even more, which would make us still worse off, and so forth. Indeed, this is painfully similar to reason B, the argument that we must grow more so that we will be rich enough to afford the cost of cleaning up. That neatly begs the question whether growth is not already making us poorer instead of richer!

ECONOMIC GROWTH

As noted in the introduction and demonstrated repeatedly in the previous section on energy and employment, arguments that employment will result from power growth (reason C) must, if they are to make any sense at all, presuppose continuing growth in total product (reason A). Reason A is in fact the linchpin of the whole case for continued power growth at current rates. But it is a linchpin that is rapidly wearing thin. The goal of increased employment itself raises a number of fundamental questions. After all, labor is a cost, and like all costs it is pushed to a minimum by the long run logic of technical and economic progress. Such long run behavior poses difficulties in the total economy, but since energy production has no reason for existence other than to function in the total economy, its attitude toward growth or nongrowth cannot be analyzed apart from the total context. Furthermore, the electric power industry is causing problems not because it is aberrant, but because it has succeeded so well in doing what all other industries are trying to do, namely, increase profits and growth.

Why, since labor is a cost of production, do we not rejoice instead of fret whenever jobs are eliminated, whenever one man can do the work of 350 men? Why, in the face of idle capacity do we insist on increased investment to create still more productive capacity? The answers to these questions, of course, have little to do with production but have everything to do with distribution. In a profit-maximizing capitalistic economy in which most people own no productive assets save those embodied in their own person, employment, or income through jobs, is the major institution for distribution. The possibility of a conflict between the

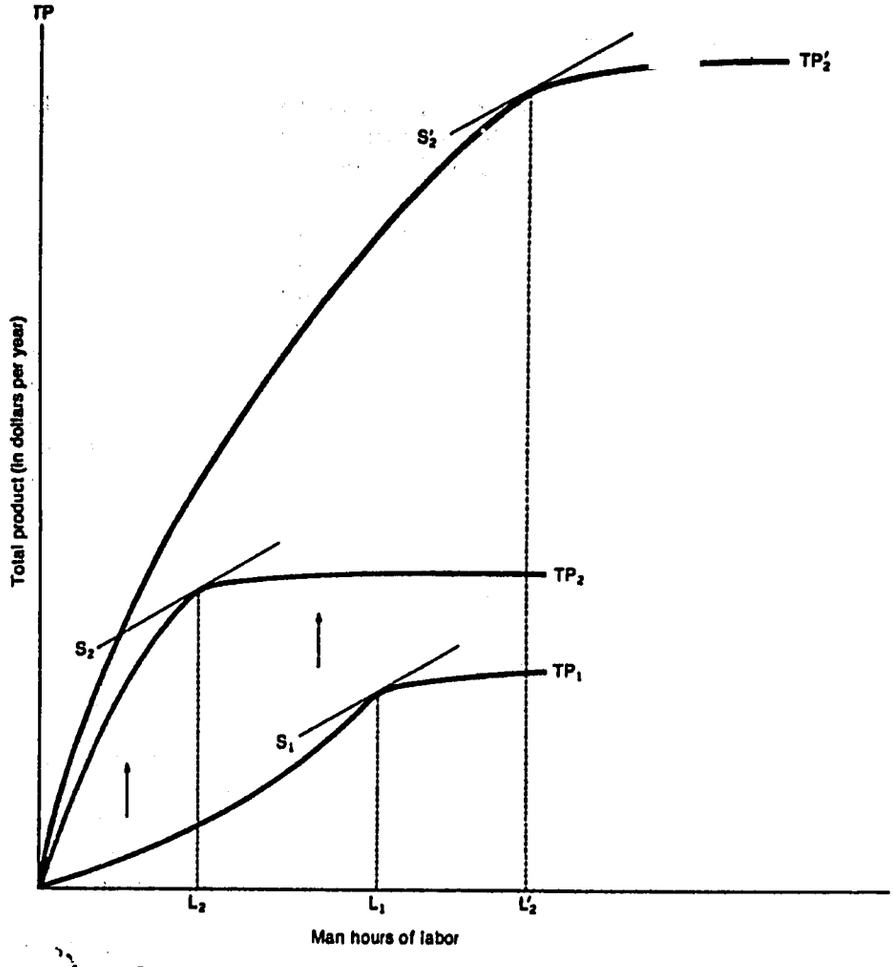

FIGURE 2.
Employment and total product in a low-energy, low-automation economy (TP_1) and a high-energy, high-automation economy (TP_2 and TP_2').

efficiency of production and the equity of distribution is a familiar theme in the history of economic thought. The goal of productive efficiency in a high-energy, automated economy conflicts very sharply with the goal of distributive efficiency and equity, given our present economic institutions. To see this conflict more clearly consider Figure 2.

Let TP_1 represent the total product of labor for an economy before it has access to high energy and automation (it rises and then levels off to reflect eventually diminishing returns to labor). TP_2 is the total product

curve after that economy has shifted to high-energy, automated kinds of production—a much higher total product is attained with a much smaller number of laborers, but again, beyond a certain limited number of laborers, further employment does not increase the total product. The slope of the total product curve at any point represents the productivity of labor at "the margin" where additional hours of labor are added. The corresponding quantity of labor employed is measured along L. Marginal productivity falls to zero more rapidly in the automated, high-energy economy, represented by the curve of TP_2, than on TP_1. In capitalistic profit-maximizing economies, the wages labor earns tend to be equal to the marginal product of labor. But wages—unlike interest, rent, and profit—cannot be zero. There is a positive limit to the basic wage, a minimum acceptable wage, or "subsistence." Let "subsistence" be the (equal) slopes of line S_1 and line S_2. The maximum number of jobs under the kind of production corresponding to TP_1 is L_1, and that corresponding to TP_2 is L_2. Assuming that L_1 represented full employment in an economy with little automation, then the distance L_2L_1 represents technological unemployment. The TP_2 kind of production supports fewer workers, even though total output is vastly greater. A smaller proportion of total output goes to wages, a larger proportion to interest, rent, and profit. Distribution of income becomes more concentrated, with a corresponding increase in luxury production.

How realistic is this "scenario"? If we apply it only to the transformation the agricultural sector has made from human labor to automation over the past fifty years, it is highly realistic. If we apply it to the current similar changes in industry, it also seems realistic. But if we apply it to the service sector the graph is unrealistic, a crucial fact since, as noted in the previous section, the service sector now accounts for over fifty-five percent of total employment and almost all net new employment. The ability of the service sector to absorb this quantity of employment indicates that so far the service sector has not experienced the kind of technical change that has occurred in agriculture and industry, and that employment is not so strictly limited by the rule that wage is equal to marginal revenue-product, for reasons discussed earlier. What this means is that we have maintained employment by bending the rule that wage is equal to marginal product in the service sector. We have also bent the income-through-jobs principle with an increase in the "grants economy" and in government transfer payments. Behaving the way it does, the service sector compensates for the mass unemployment that would otherwise be caused by the introduction of energy-using, labor-saving techniques in agriculture and industry. But what about the future? If one advocates the use of ever more energy, then one should, it appears, seek to reduce the very necessity of employment itself by advocating alternative distributive institutions, rather than by trying to make the case that

more energy means more employment. (Or we can hope that the service sector will continue to expand to provide jobs.) For automated sectors (those with total product curves shaped like TP_2) there is really only one way to increase employment, and that is through rapid growth in total product, represented in the diagram not by moving along the curve (TP_2) but by shifting the entire curve upward (to TP_2'). The shift cannot be only vertical, as this would reflect a marginal product of labor (slope of TP_2) unchanged at every L, and employment which has not increased with total product. The total product must not only shift upward, but must extend also to the right so that the marginal product will fall to subsistence only after achievement of greater employment (L_2'). In other words the employment-creating effect of further growth in total product must not be cancelled out by further advances in labor-saving technology. Therefore, we see that economic growth (growth in TP) does not by itself guarantee an increase in employment, though for future argument we will grant that one can always increase employment by increasing total product fast enough, for this assumption is, at basis, the proposition on which the power growth advocates rest their case. How realistic and how reasonable is it?

We already know that physical growth is a limited process, and long-run dependence on it is unrealistic. But there are shorter run dilemmas as well, such as those noted by Evesy Domar in his classic article on growth and employment:

> In a private capitalist society where the [marginal propensity to consume] cannot be readily changed, a higher level of income and employment at any given time can be achieved only through increased investment. But investment as an employment creating instrument is a mixed blessing because of its effect [in increasing productive capacity]. The economy finds itself in a serious dilemma: if sufficient investment is not forthcoming today, unemployment will be here today. But if enough is invested today, still more will be needed tomorrow. . . . So far as unemployment is concerned, investment is at the same time a cure for the disease and the cause of even greater ills in the future.[15]

The conventional way to employ unused capacity is to build still more capacity—to grow! But how to induce businessmen and corporations to invest more when they already have idle capacity? By giving all sorts of "bribes" such as lower interest rates and faster depreciation write-offs. But an alternative would be to encourage consumption by those at the bottom of the income pyramid rather than investment expenditures at the top. If, by way of tax reductions and negative income taxes, new expenditure is fed in from below, it will "trickle up" as the poor spend it without being bribed. Businessmen will then expand output and employment as they produce more of the things lower income people buy. This is indeed consumer sovereignty, subsidizing the consumer, not the

producer. In this way we escape the infinite regress of the ever increasing productive capacity needed to maintain full employment, at the same time we move the distribution of income toward equality. The remaining gap between private saving and private investment could be filled by public investment in social goods and services, and by government purchase and stockpiling of goods. The stockpile of goods could be saved for use in disaster, or until such time as we have discovered better institutions of distribution. The real counterpart to private monetary saving would then not be unused productive capacity, but a stockpile of unused commodities. Unused commodities can be used in the future, whereas unused productive capacity is irrevocably lost, since time cannot be accumulated. Selling from the commodity stockpile could be an effective form of antiinflation policy, something already done with some strategic materials. Under such a policy productive capacity would be increased only after all existing capacity had been used, and only in response to actual demand of the low income groups in the society. This truly would be growth for the poor, and those who are so anxious to sell more electric power to the poor should welcome such a plan.

But a continually growing economy offers further anomalies. To examine some of these, let us start from the premise that the legitimate goal of economic activity is the satisfaction of human wants. The satisfaction of wants is a nonmaterial service, a flow of psychic income that is rendered or yielded by the stock of all physical wealth. All goods and all people who perform services constitute the stock of wealth, i.e., physical capital. Maintenance of this nonphysical flow of services requires the maintenance of the physical stock of wealth, and maintenance of the physical stock of wealth requires a physical flow of production to offset the physical depreciation of the stock resulting from wear and tear, from the mere passage of time. Now we are in an area that will be somewhat familiar to those who have read the Introduction to this volume and Kenneth Boulding's "The Economics of the Coming Spaceship Earth." Let us think of the physical stock as being maintained in a steady state by a "maintenance throughput," i.e., by matching an outflow of high-entropy matter-energy with an equal inflow of low-entropy matter-energy (primary resources). That this maintenance throughput is a cost is clearly seen by looking at each end of the pipeline. Inputs necessitate depletion, outputs necessitate pollution. Furthermore the maintenance of the stock requires human labor, the sacrifice of leisure to production. Inasmuch as depletion, pollution, and labor are all costs, the flow of maintenance throughput (production) is also a cost; then production in the sense that it is a physical maintenance throughput is *not* something to be maximized.

In the steady-state economy any technological advance that allows

more service to be yielded by the same physical stock is always to be welcomed. Psychic income is nonmaterial, and its increase may be unlimited. Likewise, any technological advance that allows the same stock to be maintained by a smaller flow of throughput is also always to be welcomed. Limits to minimal throughput are imposed by the second law of thermodynamics. But to increase the throughput for its own sake makes no sense, and to increase it for the sake of building up and maintaining a larger stock is a limited process. It is limited physically by ecological interdependence and by spatial finitude, and it is limited economically by the laws of diminishing marginal utility and increasing marginal costs.

In the light of the above observations GNP becomes a largely irrelevant number. For the goods component of GNP we may interpret the number as an index of the annual flow of quantity of goods produced (something to be minimized for a given stock, not maximized). The services component presents problems. To be consistent logically we should not even try to count services but to count instead the new production of the physical things that yield the service, skilled people—just as we count durable consumer goods. But there is no market for buying and selling skilled people, only for renting them; therefore we do not know the price of, say, a physician, although we could use the present value of expected future earnings. The problem is that even though "service" in the sense of "psychic income" is nonphysical, service defined in the sense of the national income accountant measures something physical, a stock at one's disposal for a certain duration of time. Because of the physically accountable dimension of most services, we cannot say that because the "services" component is *wholly* nonphysical GNP could grow forever. A physician cannot sell a thirty minute consultation and then just leave his disembodied medical knowledge in his office, there to dispense medical advice to another patient while the physician's body is out playing golf. The doctor's services require the participation of his entire physical self. An increase in measured medical service for the GNP requires more physical bodies functioning as physicians, more hospitals, more X-ray machines, and on and on. Thus we do not escape physical limits on GNP by saying it is simply a matter of enlarging the service component.

Why is this flow-fetishism—this emphasis on the throughput, which eclipses the stock dimension from view—at present so important in economics? In a society in which the stock of wealth is very unequally distributed (see Table 2) demands for social justice are more conservatively dealt with by focusing on the flow of income, seeking to direct more of it to the poor without directing less of it to the rich, something possible only if the flow is growing. Since a stock is measured at some given point in time it must always be seen as a constant at the moment

TABLE 2
Wealth compared to income (1962)

Characteristic of population	Distribution through population	Extent of wealth (dollars), and distribution (percent)											
		Negative	Zero	$1–999	1,000–4,999	5,000–9,999	10,000–24,999	25,000–49,999	50,000–99,999	100,000–199,999	200,000–499,999	500,000–999,999	1,000,000 and over
Total	100 percent	2	8	16	19	16	23	11	4	1	1		
Income	$0–2,999	1	23	19	18	15	17	7	1				
	3,000–4,999	3	8	29	20	11	17	8	2	1			
	5,000–7,499	2	1	15	25	21	22	8	5				
	7,500–9,999	2		7	18	18	36	14	3	1	1		
	10,000–14,999	1		2	13	16	35	20	10	3	1		
	15,000–24,999				3	10	21	29	24	7	5	1	
	25,000–49,999						5	8	22	27	27	7	4
	50,000–99,999							1	9	7	45	20	17
	100,000 and over									1	5	56	38
Age	Under 35	5	9	36	26	14	8	2					
	35–44	2	7	14	20	21	25	8	4	1			
	45–54	1	7	10	20	10	31	14	5	1	1		
	55–64	1	8	7	12	16	28	16	8	3	2		
	65 and over		11	8	13	18	25	15	5	1	2	1	

Source: Dorothy S. Projector and Gertrude S. Weiss, Survey of Financial Characteristics of Consumers, *Board of Governors, Federal Reserve, 1966.*
Note: Some rows do not add to exactly 100 percent due to rounding. Blank entries signify values of less than 1/2 unit.

it is measured, and more of the stock to the poor must also mean less to the rich. Better to think, say those most influential in deciding economic policy, in terms of the flow, the additions to the stock, and to channel a bit more of the flow to the poor through our tax system (or at least let's pretend that is what we are doing). Once it seemed a good idea to make sure that the flow would grow year after year, so that even with the same proportional division of wealth, the poor would get absolutely more. Furthermore, welfare economics teaches us that a policy represents an unambiguous increase in social welfare only if it makes some people better off without making anyone worse off. Otherwise we are forced to make interpersonal comparisons of utility, and that is an ethical matter with which science cannot deal. Once again the policy of increasing A's income without diminishing B's income requires growth in total income.

We are used to hearing that we do not have enough, and that an even distribution of income would make all evenly poor, a view that has always been morally questionable since if there is really not enough for all, then it is all the more objectionable that the few should receive so much more than the average while the many receive much less. However, with current United States per capita disposable income in excess of $3,000, even this argument is no longer possible.[19] The average before-tax income for a family of four in 1971 was close to $16,000—not exactly poverty. Of course this is a very unrepresentative mean, since the distribution of income is so badly skewed. In 1968 the twenty million Americans in the top ten percent of income recipients got around twenty-seven percent of the total national income, and the twenty million in the lowest ten percent received about one percent of the total income. (See Table 3.) Contrary to the assumptions of growthmania, distribution is, at the margin, a more pressing issue than production. Nevertheless, there are strong vested interests in growth throughout our society. The growth aspirations of any one industry, such as electric power, cannot be properly understood apart from the context of the overall functioning of the economic system. Although an annual growth goal of seven percent is high compared to other industries, the case of electric power is important not because it is an exception, but because it so clearly illustrates the general rule of growthmania.

Our arguments against power growth have assumed continued use of a reasonably safe technology. Yet present commitments are to the development of fast breeder reactors, which represent a technology that is quite unsafe. Even if the considerable technical problems of nuclear power-generation are eventually solved, there will remain the nontechnical problems of safeguarding ever increasing stocks of plutonium and fissile isotopes. Once again it is growthmania that causes intemperate haste in commercializing an extremely dangerous technology—one which

TABLE 3
Percentage distribution of income in the United States through five-percentile divisions (1960–1968)

5-percent quantiles	1960	1961	1962	1963	1964	1965	1966	1967	1968
1 and 2 (lowest)	0.64	0.67	0.71	0.77	0.77	0.85	0.94	0.94	1.03
3	1.04	1.02	1.08	1.06	1.08	1.10	1.12	1.14	1.20
4	1.50	1.45	1.53	1.51	1.52	1.54	1.56	1.58	1.64
5	1.95	1.89	1.97	1.95	1.95	1.97	1.99	2.00	2.07
6	2.40	2.32	2.40	2.39	2.38	2.40	2.42	2.43	2.49
7	2.84	2.75	2.82	2.83	2.82	2.83	2.85	2.84	2.91
8	3.27	3.18	3.24	3.27	3.25	3.26	3.28	3.26	3.33
9	3.70	3.61	3.66	3.70	3.68	3.68	3.71	3.67	3.74
10	4.13	4.04	4.08	4.14	4.12	4.12	4.14	4.09	4.16
11	4.57	4.48	4.32	4.58	4.56	4.55	4.58	4.52	4.58
12	5.00	4.92	4.97	5.03	5.01	5.00	5.01	4.96	5.00
13	5.44	5.37	5.45	5.49	5.46	5.45	5.45	5.41	5.44
14	5.89	5.83	5.95	5.95	5.93	5.92	5.90	5.88	5.89
15	6.35	6.30	6.48	6.42	6.40	6.40	6.35	6.37	6.49
16	7.04	7.00	7.05	7.14	7.12	7.07	7.09	7.00	6.94
17	7.67	7.76	7.81	7.76	7.81	7.74	7.71	7.64	7.54
18	8.61	8.73	8.73	8.66	8.71	8.65	8.61	8.56	8.44
19	10.29	10.47	10.34	10.26	10.31	10.26	10.21	10.22	10.06
20	17.66	18.18	17.21	17.09	17.13	17.19	17.08	17.50	17.05
Top 1 percent	6.08	6.33	5.77	5.73	5.74	5.00	5.76	6.01	5.81

Source: Edward C. Budd, "Postwar Changes in the Size Distribution of Income in the U.S." American Economic Review, *Papers and Proceedings, May 1970, p. 253.*

is certain to increase vastly our vulnerability to sabotage, terrorism, and disasterous accidents.[20]

The alternative to growthmania is the steady-state economy, and the big task for physical and social scientists is to work out the technologies and institutions that will allow us to attain such a steady state. The even bigger task is for all citizens to find the moral resources necessary to overcome the vested interests and hag-ridden compulsions of growthmania.

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ENVIRONMENT DIRECTORATE

REPORT ON ENVIRONMENTAL IMPACT OF AIRPORT DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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5-243

REPORT ON ENVIRONMENTAL IMPACT OF AIRPORT DEVELOPMENT(x)

PREFACE

1. The Organisation for Economic Co-operation and Development, in carrying out its task of promoting economic development in Member countries, is concerned both with the qualitative and quantative aspects of economic growth. The Environment Committee of the O.E.C.D. is responsible for:

(i) investigating the problems of preserving or improving man's environment, with particular reference to their economic and trade implications;

(ii) reviewing and confronting actions taken or proposed in Member countries in the field of environment, together with their economic trade implications;

(iii) proposing solutions for environmental problems that would as far as possible take account of all relevant factors, including cost effectiveness;

(iv) ensuring that the results of environmental investigations can be effectively utilised in the wider framework of the Organisation's work on economic policy and social development.

In the implementation of its mandate, the Committee is assisted by a number of delegate groups concerned with policy development in specific sectors of the overall environment problem. Such groups are established in respect of Air, Water, Chemicals and Urban problems. Co-ordination and development of economic aspects are the responsibility of a Sub-Committee of Economic Experts.

2. The attached report is considered by the Sector Group on Urban Environment to be a valuable review of the different options open to Member governments to deal with the environmental problems raised by the location and development of major airports. The options identified in this report are based on an analysis of the most recent practical experience in 16 Member countries currently concerned with planning new, or expanding existing major airports.

3. In addition the report puts forward a number of principles which should be given important consideration in airport planning. It suggests that these principles should be adopted in order that the planning process may become more sensitive to environmental concerns than is possible with conventional benefit/cost analysis.

(x) The decision to derestrict the present document was taken on 22nd November, 1974; it will be reproduced as a publication at a later stage.

Introduction

Construction of a major international airport, like any major land use development, can have a wide variety of effects. Some of these effects are undoubtedly desirable, such as benefits to air travellers, business interests and industrial activities of the region. At the same time there are some effects which can be undesirable and which help to account for the growing opposition to airport development. For example, the construction or major expansion of an airport may structure the development of the region in ways which are inconsistent with regional objectives. There will be higher noise levels in the communities surrounding the airport, increased traffic on the local road network, increased demand for local public services such as water and sewage disposal. Possible harm to wildlife, damage to fragile ecology, loss of agricultural land and open spaces are other reasons why new airports are increasingly unwelcome in rural areas as well as in urbanised regions.

The task of airport planning is further complicated by uncertainties concerning the future development of air transportation and the prospect of future development in aircraft technology. For example, much quieter equipment capable of using shorter runways and steeper angles on take-off and approach (QRTOL aircraft) could significantly modify the present requirements for airport location, and could open up hitherto unusable sites within metropolitan areas. But will such aircraft be developed, and if so, on what time scale? Many countries faced with an urgent need to expand airport capacity feel they cannot afford to wait until these questions are resolved.

Compounding the difficulties are uncertainties in areas over which the aviation sector has little control. For example, will the trend toward increasing decentralisation of employment and residence continue, and if so, what implications will it have for airport size and location? What is the prospect for high-speed surface transport and what is its likely impact on short-haul air travel demand between metropolitan areas? Will the growing scarcity of fuel resources and the cost of environmental protection affect the economics of air transport sufficiently to dampen future growth of the air travel market? What might be user response to changes in marketing and the prevailing patterns of service?

The growth of aviation has been sustained, the number of passengers doubling every five years for the past twenty-five. Growth may continue in the immediate future, but in the longer term it seems unlikely that air transport demand and provision of transport facilities can continue to expand along the same exponential curve. Demand forecasts tend to be self-sustaining. So the important thing is to set independently determined goals for the future supply of airport facilities. Obviously, even a reduced rate of growth will demand serious efforts if rising levels of congestion, noise and other disamenities are to be avoided. In the following pages the Sector Group considers

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what options are open to Member governments to accommodate future changes in air transport and examines the key policy issues that must be addressed in the airport planning process. For purposes of this report these options have been grouped under five headings. In practice many combinations of these basic choices can be and are used within the various OECD countries. Governments are invited to look carefully and continuously at all these options; their decisions must, however, depend on a variety of national and local conditions.

1. The New Airport

In 1973 some twelve Member countries* were planning or building new, very large "third generation" international airports. Because large tracts of undeveloped land near big cities are increasingly difficult to find and assemble, and because the insertion of an airport into an already established densely settled area would be politically and environmentally unacceptable, most of these airports are being located in more or less remote areas, away from population centres. Only in a very few countries are convenient and environmentally compatible sites, like the undeveloped island of Saltholm, some 20 km. from Copenhagen, available for a large new airport.

A long distance between city and airport, however, creates an economic disadvantage and an inconvenience to the users of the airport. To compensate for this physical separation, arrangements are therefore made to provide the airport with superior motorway access and, increasingly, with a direct rail link to the city centre. This is the strategy which is being considered by a number of countries, among them the United Kingdom, Canada, Sweden, the Netherlands, United States, Denmark Japan and Norway. An advantage of this strategy is that a larger airport can be built capable of accommodating the anticipated needs of a metropolitan region for many decades while providing an opportunity to control land use in the surrounding area on a scale and to a degree not possible in a more urbanised region.

Although this policy minimises the impact of airport noise and problems of land acquisition, it can have a major impact on the local ecology and, in most cases, on the urban development patterns of the surrounding region. Inserting a new airport into a hitherto undeveloped area may seriously affect wildlife, disturb the sensitive ecological balance of wetlands and destroy the peaceful character of the countryside. In addition, major new airports become growth centres. The airport itself, a a major employer, generates a demand for housing and supporting services. A number of related activities find it convenient to be near their markets and settle nearby, thus contributing to the development. The superior roadway system, built to serve the airport, will tend to attract additional development unrelated to the airport, which if uncontrolled could further increase the urbanisation of the

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*Australia, Canada, Denmark, Germany, Greece, Italy, Japan, the Netherlands, Norway, Portugal, the United Kingdom, the United States.

surrounding areas. The positive and negative impacts of these urbanisation effects are discussed further below.

2. Expanding the Capacity of Existing Airports

Another option is to expand the capacity of an existing airport through additional investment in runways, terminals and supporting facilities.

In expanding existing airports, environmental concerns, community opposition and the scarcity of land emerge as the major constraints. Most existing airports are either surrounded by densely populated areas or located in greenbelts perpetually free of development. Thus, opportunities for the extension of runways, construction of new runways and addition of terminal facilities are often limited.

Airport expansion will often lead to higher noise levels in the vicinity of the airport. Increased runway and terminal capacity will attract additional traffic, subjecting local population to higher levels of annoyance. For this reason airport expansion plans have often met with spirited opposition on the part of the neighbouring communities. Re-zoning of the areas most severely exposed to noise, or the outright purchase of land is a possible solution. However, since it is not always practical to consider re-zoning large, densely populated areas surrounding existing airports, secondary measures must be considered aimed at minimising or reducing the level of annoyance, such as sound-proofing or compensation.

Regional development impacts of airport expansion are generally less pronounced than those of a new airport. More intensive use of an existing site has not always demonstrated a large jump in the level of urbanisation or in the demands placed on public services such as water or sewage disposal, although it has sometimes imposed some strain on the local economy, for instance creating pressure on the local labour and housing market. It has also sometimes generated additional vehicular traffic, putting additional strain on the existing road network. The scale of these local and regional impacts may be much greater in the future because the activities most responsible for the urbanisation impacts - activities such as hotels, warehousing and conventions - are likely to expand faster than in the past.

With the introduction of larger aircraft the primary strain on capacity may first be felt by the terminal and access facilities rather than by the runway system. Giving priority to establishing more efficient transportation to and from airports, such as rail links to the central city, may therefore prove to be the most effective method of solving the immediate airport capacity problems.

3. Development of a Regional Airport System

While expansion of existing major airports and the construction of new hub airports represent essentially a continuation of the traditional airport planning philosophy, development of a regional airport system requires some modification to the prevailing concept of air service.

A regional airport system involves an effort both to disperse air traffic to a number of points within a region and to introduce a certain specialisation in the nature of services offered by different airports. For example, the hub airport might primarily serve scheduled international services and long-distance traffic while private aviation, short-haul charters and cargo services (i.e., those not requiring large aircraft and long runways) and certain scheduled domestic flights are removed to smaller airports. More importantly, the concept of a regional airport system acknowledges the current trend toward metropolitan decentralisation and the increasing dispersal of trip origins and destinations by offering direct short-haul service to and from a number of points within metropolitan areas. San Francisco/Los Angeles, Tokyo/Osaka and Toronto/Montreal are three city pairs exploring ways of expanding air services to a number of points between their metropolitan areas. In Scandinavia two new secondary airports Roskilde west of Copenhagen, and Sturup east of Malmoe in Sweden - already act as regional airports for the Sound Region around Copenhagen. Careful attention should be paid to the type of services that can be shifted to the regional airports. For example, long-distance charters, heavy cargo and other air services that use large planes should be kept at the hub airport so as not to increase the noise footprints at the secondary airports.

The practicality of a regional airport system is dependent upon the availability of sufficiently large undeveloped parcels of land in metropolitan areas or of facilities (e.g., military bases) that could be converted at reasonable cost to service short-range aircraft including perhaps charters, and the willingness of communities to accept small airports as neighbours. This willingness, in turn, may largely depend on the development of the quiet reduced take-off and landing airplane (QRTOL)*. Even if these conditions were met, the regional airport system would still raise a number of questions. For example, could the air traffic control handle the complex pattern of aircraft movements? How much investment would be necessary to improve the road access to the secondary airports and how much additional land would have to be included in the buffer zones? Above all, is it desirable to spread the negative effects of airport activity over a wide area and thus expose additional communities to noise annoyance, or is it preferable to concentrate environmentally disrupting activities in as few locations as possible? The answer to these questions will depend upon the objectives and constraints of a particular comprehensive regional plan into which the airport development must be integrated, in particular on the compatibility of the airport site with the present and intended land use around it.

* Such aircraft require runways of 4-5000 feet instead of the 8-12,000 foot runways needed by conventional aircraft.

4. Improving the Efficiency of Existing Facilities

Alternatively or in parallel to investment in a new airport or in expanding an existing airport, steps can be taken to ease the pressure on the existing airport facilities. Much of the congestion at major airports has a simple and basic cause: too many aircraft compete for the use of limited facilities at peak hours, mostly occurring in early morning and in late afternoon. Such mode of operation will continue as long as airline operations are not restricted or given incentives to shift to off-peak hours.

A rational policy of alleviating peak-hour congestion and related capacity problems might include restrictions against charter flights during peak hours, removal of general aviation to secondary airports, encouragement of flight consolidation and increased pooling between airlines, and a differential landing fee policy, consisting of higher fees during peak hours and increased minimum fees for general aviation. With the help of such methods commercial operations could be distributed more evenly throughout the day and private planes diverted away from busy airports. The result could be a significant decrease in airport congestion, providing longer term relief from saturation, and reducing premature investment in additional ground facilities.

5. Standing Still

The final strategy is the converse of all those mentioned above - a standstill policy which allows only for continued operation of the existing airport without any additional investment in runways or new terminal facilities, and which lets congestion and noise standards regulate the ultimate level of activity. While this may be inappropriate in most countries as a national policy, it may be acceptable as a strategy for an individual airport either because further growth would drastically reduce its working efficiency or because public opposition has foreclosed virtually every other option. In 10 or 20 years time this option may be given serious consideration by some governments.

Data on the effects of the null or do-nothing alternative should be developed to a level of detail consistent with that for other alternatives, and the null alternative can serve as a reference point for identifying on a relative or comparative basis the adverse and beneficial effects of any other alternative proposal.

Conclusions on Airport Planning Options

A review of country experience suggests that there is a range of alternatives available to accommodate rising air transport demand while providing for an acceptable urban environment. One of the critical needs is to determine when the increased use of existing runways, terminals and access systems will come into conflict with standards for acceptable environment, and what costs will be involved in maintaining those standards

Exactly which course of action to pursue is a decision involving delicate trade-offs between on the one hand the objectives of transport efficiency and convenience, and on the other hand considerations external to the aviation sector: regional development objectives; competing claims on the use of land, noise impact, effect on the local ecology, and public attitudes in the communities affected by the existing airport and its possible expansion or by the construction of a new airport.

The trade-offs and the uncertainties about future air transport demand, patterns of urban development, aircraft technology and user response to changes in patterns of service will be perceived differently in different countries, making it impossible to single out any one of the alternatives as the preferred or most "rational" strategy. For each large international airport the government will have to make an independent decision in the light of its best assessment of the competing considerations and weighing the conflicting interests of different groups after full consultations with the public.

MAIN ENVIRONMENTAL AND PLANNING ISSUES IN AIRPORT DEVELOPMENT POLICY

Whatever strategy a given region or nation may adopt, there are certain issues common to all nations, concerning which the Group believes it can offer some constructive suggestions. Three issues stand out as warranting particular attention: the problem of airport noise; the growing scarcit of land suitable for airports and problems surrounding its acquisition; and the need to consider airport planning in the wider context of comprehensive transport, regional and environmental planning.

The Problem of Airport Noise

Noise from aircraft is by far the most serious constraint facing airports today. It is the source of mounting complaints and litigation on the part of people living in the neighbourhood of airports; it is the main reason for organised protest against the expansion of existing airports; it is the cause of the growing trend to close major airports at night (with the attendant repercussions for air transport industry such as loss of freight revenue, forced idleness of equipment on the ground, problems of transcontinental flight scheduling, etc.); and it is a major factor in public opposition to the building of new airports. Ways to deal with aircraft and airport noise, therefore, should be accorded priority attention.

Recommendations to limit aircraft noise at the source have been adopted by the International Civil Aviation Organisation (ICAO) in 1971. This initiative has already resulted in some concrete improvements. New types of aircraft emit 10 to 15 EPNdB (effective perceived noise decibels) less than earlier jet equipment. As an illustration of the impact these noise reduction improvements have had, the 90 EPNdB noise footprint of a long-range jet aircraft of the first generation (B-707) was 120 km^2; the 90 EPNdB footprint of the latest long-range jet complying with ICAO recommendations (e.g. DC-10 or Tristar) has been reduced to 20-30 km^2. Efforts to produce even quieter aircraft are being pursued in the United States, the United Kingdom and France.

Present noise emission requirements apply to new type subsonic aircraft and, in 1976, will apply to all production aircraft whenever originally designed. There are, however, no proposals to apply the ICAO rules to all existing aircraft in service. Although the use of the new, large-capacity aircraft may reduce the number of noisy overflights around airpor the older, noisy equipment will continue in existence in sufficient numbers to constitute a nuisance for many years to com Only retrofitting of the older aircraft would help to improve the noise situation in the short and medium term.

Attention, therefore, should be focussed on the possibilities of improving the airport noise environment at the local level - where measures can have a more immediate effect. Three sets of measures can serve this end: operational measures designed to limit the production of noise by aircraft; measures aimed at changing the land use in areas exposed to heavy noise; and measures aimed at reducing the impact of noise at the point of reception.

Included in the first set are special take-off and landing procedures, restrictions on the total number of noisy aircraft, banning night traffic, partial diversion of traffic (especially at night) to more isolated airports, and establishment and enforcement of local airport noise regulations. Many such measures are already in use. For example, some European airports have imposed night curfews. Schiphol and the major German airports permit night operations only to those aircraft that meet the ICAO noise standards; while the London airports permit more nightflights to airlines whose aircrafts meet the ICAO requirements. Another approach - which so far is only in the discussion stage - would impose an overall limit on the total noise emitted by all aircraft of a given airline during a given period of time. The virtue of this concept - known as "Fleet Noise Level" - is that it would provide airlines with more flexibility. They could switch to quieter equipment or reduce the number of movements,

whichever seemed more advantageous, so long as they remained within the overall noise emission ceiling. All these measures would tend to promote the commercial introduction of quiet aircraft.

A second approach consists in minimising the contact between human activities and airport noise through the co-ordination of airport planning with regional and local land use policy. This approach can be implemented most easily in the case of new airports situated in areas which are not yet intensively developed. However, even around existing airports within metropolitan areas possibilities arise to re-zone heavily noise-impacted areas over a period of time so as to minimise the exposure to airport noise of private dwellings, schools, hospitals and recreation areas. Re-zoning may involve heavy costs in purchase and clearance of residential houses; in some cases it may be possible to convert existing structures and areas, for instance into airport-related activities. industrial parks or sports stadiums.

Land can be acquired or restrictions on the construction of private housing can be imposed at the outset in such a manner as to establish a buffer zone between a new airport and the surrounding development. This has been done in the case of the new Montreal airport, where an area of 360 km^2 was acquired although only 82 km^2 were needed for the airport itself; and in the case of the new Paris airport at Roissy, where a prohibition has been imposed on the construction of private dwellings, schools and hospitals within the zone of the most intense noise. At existing airports, such as Zuric and Geneva, the problem of incompatible land uses near the airport has been dealt with by legislation. In addition, around these airports as well as around the Los Angeles and Roissy airports, large numbers of dwellings have been bought from their owners at considerable expense rather than risk a continuing threat of legal action. In the Scandinavian countries certain criteria have been laid down by the Ministries of the Environment as to existing and future land uses and their compatibility with different noise levels.

The third approach - which must be regarded as secondary one compared to the first and second sets of measures - concentrates on providing protection against noise at its point of reception.

Sound-proofing of private dwellings, hotels, offices, etc. may prove to be the only way of dealing rapidly with noise disturbance around existing airports where land development has already seriously encroached upon the buffer zone. This technique has been used in connection with Heathrow (United Kingdom) and, more recently, Schiphol (Netherlands) and the German Federal airports. In the case of Heathrow 4,000 dwellings have been sound-proofed since 1966 in the most exposed areas. However, sound-proofing remains an incomplete measure as it does nothing to improve the outdoor environment.

A practical programme of noise abatement requires a two-pronged approach, co-ordinating anticipated improvements in noise reduction at the source with protective measures carried out around the airport. In most situations there will be a need to modify to some extent the use of land where it does not comply with the proposed zoning plan. Priority could be given to those properties which could not expect significant relief from noise even under the most optimistic projections of future reductions in aircraft noise. Such a plan would provide a systematic basis for negotiation and action between the various interests involved. Zurich airport has been the first to experiment with such an approach as a basis for reconciling land use and noise impact in the long run, after 1980.

Where noise levels still remain unacceptably high in spite of all remedial efforts, a solution of last resort is to provide compensation to home owners for the property's loss in value due to noise. In return, the airport acquires a "noise easement" on the property. In the United States, where compensation has been used it has amounted to roughly 20 per cent of the value of the property. Although there is much virtue in the principle of compensation, it should be stressed that it is regarded as the final means of redress when other positive measures to minimise the adverse effects of noise have all been taken. Monetary compensation does not guarantee that the money will be spent on remedial measures and that the tenants living in the affected dwellings will therefore be protected. For them, as well as for those who do not qualify for compensation, sound insulation and noise abatement zoning are the only effective solutions. The issue of compensation is already being addressed by the Sector Group in another context.

The Use of Economic Instruments

The possibility of using economic instruments to promote aircraft noise abatement also deserves attention. Airlines are already subject to landing charges, although today these charges are based on aircraft weight. Landing surcharges could also be assessed on noisy aircraft. Such charges could provide an important source of revenue which may be earmarked for financing airport noise abatement programmes, e.g. sound-proofing of exposed dwellings, hospitals and schools; land acquisition for buffer zones; and compensation grants. The use of such taxes as a source of revenue for airport noise abatement is still the subject of considerable debate.

It has also been argued that, set at a proper level and generally applied by the large airports, noise surcharges would act as a continuous incentive for airlines to minimise the noise impact of their activities. For instance, at operational level, charges would prompt the airlines to make the most rational use of their existing fleets of aircraft by diverting noisy equipment to long-haul runs and to airports where noise causes little disturbance (and where noise charges, therefore, would be set low), while concentrating the quiet aircraft on the heavily travelled short-haul routes characterised by

frequent landings and take-offs at noise-sensitive airports. At the same time, the noise tax could act as a continuous inducement for airlines to retrofit existing aircraft, or to accelerate their retirement and their replacement with quieter models, and to purchase the quietest aircraft available on the market. All this, in turn, would provide an incentive to aircraft and engine manufacturers to devote maximum effort to the development of quieter engines and more effective retrofit devices and techniques.

Some problems remain to be resolved before a surtax on aircraft noise could be introduced. However, the use of charges to finance local noise protection programmes and to induce airlines to shift to quieter equipment already in production deserves serious attention. This issue is already being addressed by the Group in another context.

Airports and Comprehensive Planning

There is a need to integrate airport planning with the larger problems of land use, ground transportation, regional development and environmental protection. Only in this way can air transport objectives be reconciled with other pressing national and local needs. Issues concerning the planning process are dealt with toward the end of this paper.

Evidence examined by the Group indicates that the zone under the airport's influence is much larger than the area of the airport itself. It includes the surrounding noise buffer zones, associated service areas, large-scale residential development for airport employees and a network of access roads. Because of the size of the area involved, it is becoming difficult to find suitable sites for airports. It is increasingly important, therefore, to reserve sufficient land in advance of development to cover both the needs for the airport itself, its possible later expansion and the buffer zones needed to minimise noise annoyance.

Urbanisation Effects of Airports

There is general agreement that the construction and expansion of a large international airport and of its access links to the metropolitan agglomeration can have a substantial impact on urban development patterns in the surrounding sub-region. The airport itself is a major employment centre in the region, attracting a number of related services - airline companies, aircraft workshops, warehouses, car-hire agencies, catering firms hotels, convention and exhibition centres, as well as public services and internationally oriented service firms. Similarly, employees of the airport and of the airport-related activities will follow to a considerable extent the short journey-to-work tradition and settle in relative proximity to their work - inducing further development of secondary and tertiary activities.

Whether this is to be regarded as a positive or a negative effect will depend upon the general goals of national and regional planning. Where the policy is to stimulate the growth

of a hitherto under-developed area, a new airport can serve as a powerful tool of that policy. Where, on the other hand - as has been the case in recent years in a growing number of countries the goals is to slow down the further expansion of an already highly urbanised region or to preserve the area as a valuable agricultural, open space or recreational resource, the construction of a new major airport or a major expansion of an existing airport cannot but be viewed as going counter to that goal.

Airport Planning in the Context of a Comprehensive Transport Policy

One aspect of aviation's success is its ability to drastically shorten journeys over long distances; another is its ability to serve in an economic way dispersed locations between which the density of passenger traffic is not heavy enough to justify fast and frequent rail service. On the other hand, over short distances, in heavily travelled corridors traversing densely populated, congested urban regions, improved rail service will be offering an increasingly viable alternative to flying. This observation is supported by evidence. Where fast, frequent and reliable rail service has been introduced, as for example between London and Manchester and between Tokyo and Osaka, people have switched from air to rail travel in impressive numbers. Since the introduction of high-speed trains on the London to Manchester run, the proportion of travellers going by air has decreased by more than 40 per cent while rail travellers more than doubled. In Japan, the Tokaido line has had a similar effect on travel behaviour between Tokyo and Osaka: air traffic has dropped from 22 per cent to 8 per cent of the total in a period of eight years.

Improvements in rail transport thus offer another significant way in which relief could be sought from future airport saturation problems. But to bring about major modifications in the prevailing patterns of travel will require some readjustment in the ways of thinking. All too often the relationship between the different modes of transport is viewed as one of competition rather than of partnership. Each mode is regarded as sufficient unto itself whereas, in fact, they should be considered as complementing each other and functioning as parts of a total transportation system. In such an integrated transport system rail, road and air transport do not vie for traffic but co-operate to give the traveller and the shipper the best possible service from origin to destination. Such intermodal co-operation can take many forms: joint reservation services, co-ordinated timetables, inter-connection of rail and air terminals as is proposed in the Netherlands and Switzerland. Underlying this philosophy is recognition of the fact that no one transport mode could possibly satisfy the many diverse needs of transport users or combine all of the attributes desired by the traveller. Each form of transport has certain unique features enabling it to serve particularly well certain transport needs. The goal

of a national transport policy should be to exploit each mode for the purpose for which it is best suited: to assure, in other words, that the right kind of transportation is available in the right place for the right purpose.

This approach to transport planning could be widely applied. In a growing number of countries sufficient space for major airports is increasingly difficult to find. At the same time, improvements in high-speed ground transport are extending the acceptable distance for access travel to airports. These conditions suggest that there might be value in considering airport provision at an international or at least bilateral level. The Group believes that more attention should be devoted to examining the possibilities of developing shared airport facilities.

Environmental Issues and the Planning Process

The traditional technique for evaluating alternative plans for airports, as indeed for any major public facility, has been that of benefit/cost analysis. In this procedure positive and negative effects of each alternative are evaluated in monetary terms, the direct and indirect social benefits and costs are added up separately and a benefit/cost ratio is computed. The alternative whose ratio of benefits to costs comes out highest is ranked as the preferred alternative. Although rather sophisticated methods have been developed in recent years to assess the value of seemingly unquantifiable matters, such as historical landmarks or the visual beauty of a landscape, the benefit/cost approach still contains serious shortcomings. To begin with, it employs monetary valuation of items that are not subject to the influence of the market mechanism. Secondly, it uses discount rates and amortisation periods for public investments, whose lifetime, benefits, and possible technical evolution are arbitrarily fixed; thirdly, it aggregates all the impacts of the analysis and in so doing it conceals the essential fact that the impacts will not fall evenly on all the groups concerned: some people will benefit from the proposed project while others will be affected adversely.

The Group feels that methods of evaluation need to be improved so that the planning process may become more sensitive to social and environmental issues and more responsive to community concerns than is possible with the conventional benefit, cost analysis. In particular, the evaluation should deal not only with costs and benefits that can be quantified in monetary terms but also with a full range of other impacts, such as health, safety, amenity, equity, freedom of choice and attractiveness of the physical environment. In such a planning process several principles are of importance:

(i) There must be a range of alternatives available. The range of alternatives must be sufficiently broad to represent real choices, including the option of not doing anything.

(ii) There must be information on the effects of the alternatives. This information must include both the beneficial and the adverse effects of the alternatives; it must include all effects that any particular segment of the public thinks are important, whether or not those effects are readily quantifiable; and it must identify explicitly which groups are benefited and which groups are hurt by any proposed alternative.

(iii) There must be full opportunity for public involvement in the process so that every group which may be potentially affected by the proposed project has access to all relevant information and has the opportunity to influence the process.

(iv) Where adverse impacts result for some groups in order that benefits may be provided to other groups, consideration must be given to how those adversely affected can be compensated.

(v) Environmental damages and benefits must be evaluated not in monetary terms but in terms of their falling above or below certain conventionally fixed threshold values expressed in non-economic units - e.g. noise levels, pollution levels or acres of recreational land consumed. The weighting of these factors is of necessity a political act carried out in the context of the total planning process. It is possible to list all money value factors and environmental factors in a total "evaluation scheme", but not to add up all factors into one grand total.

(vi) Sensitivity analyses should be used as supplementary tools in the assessment of alternative policies, location decisions and investment choices in order to test the effects of varying the assumptions in the benefit/cost analysis and in assessing the influence of levels chosen for environmental and other threshold values.

A N N E X I

LIST OF CASE-STUDY PAPERS(1)

An Example of a Programme of Studies to Determine the Location of an Airport in a Region: Stockholm and Malar-Hjalmar
Reinar PERSSON, Stockholm County Council, Sweden.

Arlanda and Marsta - Airport and Town Planning
C. F. AHLBERG and Reinar PERSSON, Stockholm County Council Regional Planning Bureau, Sweden.

Regional Impact of Airports: Problems to be Solved: Some General Remarks
R. P. VAN DER KIND, Planning Group, Second Airport Department of Civil Aviation, The Hague, Netherlands.

Urban Impact of a New Principal Airport for the Oslo Region
Aage DANIELSON, Head of Economic and Planning Studies, Nordland Regional College, Bødo, Norway.

The Maplin Project, Impacts and Objectives
Stanley SMITH, Principal Planner, Third London Airport Directorate, Department of the Environment, London, U.K.

Anticipated Economic and Urbanisation Impacts Generated by Frankfurt International Airport Expansion
K. DEHN, Flughafen Frankfurt-Main Aktiengesellschaft and J. MEISE, Batelle-Institut, Frankfurt-Main, Germany.

Location Problems of Kansai International Airport
Masao HIRAI, Deputy Head, Kansai International Airport Research Office and Kasuo YODA, Deputy Head, City Planning Division, Tokyo, Japan.

Potential Environmental Impacts Generated by the Location of Major Airports near Montreal and Toronto: A Review of Studies to Date
Peter J. MARRIOTT, Policy Branch and Bryan D. COOK, Research Policy and Co-ordination Branch, Department of the Environment, Ottawa, Canada.

The Environmental Impacts of Airport Siting in the Copenhagen Region
Kai LEMBERG, Director of General Planning, City of Copenhagen, Denmark.

The Planning of Aircraft Noise Zones
Hans REINHARD, Zurich Cantonal Planning Authority, Switzerland.

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(1) The full text of these case-studies will appear in the publication (see footnote page 1).

Management of Airport Planning: Montreal. A Prototype
P. BEINHAKER and J. M. CHOUKROUN, Canada.

Airport Siting and the Environment, Jamaica Bay and J. F. Kennedy International Airport
Steven EBBIN, Former Study Director of the Jamaica Bay/Kennedy Airport Study, U.S.A.

The Airport's Impact on Residential Development and Economic Growth in the Canton of Zurich
V. TOUZIN, Cantonal Planning Authority, Zurich, Switzerland.

Rapport du Groupe de Travail "Paris-Nord"

BACKGROUND PAPERS

Social and Economic Impact of Aircraft Noise
Ariel ALEXANDRE, O.E.C.D. Secretariat, and
Hans OPSCHOOR, Vrije-Universiteit, Amsterdam, Netherlands.

Trends and Developments in Airport Provision
Anthony E. PEARCE, Consultant, O.E.C.D.

Economic and Urbanisation Impacts of International Airports: An Assessment of Methodological Issues and Policy Implications
Elliott A. MEDRICH, Consultant, O.E.C.D.

Factors to be Considered in the Siting of Major Airports
F. A. SHARMAN, Partner, Sir William Halerow and Partners, London.

How to Reduce the Noise of Aircraft
Ariel ALEXANDRE, O.E.C.D. Secretariat.

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UNEP, Geneva, Switzerland

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United Nations Industrial Development Organization (UNIDO) - Vienna (1)

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	Bureau of the UNDP/WHO Project Poland 40-832 Katowice - Poland ul. Jamka Krasickiego-L Attn: Mr. C. Ferullo, Proj. Mgr.	American Embassy Dept. of State - Poland Washington, D. C. 20521

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EGYPT - None

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Common Environmental Terms

A Glossary

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Foreword

The words and terms included in this glossary are used in discussing and writing about the environment. We have excepted household words generally understood and defined elsewhere, such as water or air, but have included certain common words which, while not peculiar to the environment, occur frequently in environmental literature and are important to a student's understanding of pollution problems—words like adsorption or rodenticide. The glossary also explains the meaning of words such as dust and abatement as they apply to the environment even though definitions of such words are found in ordinary dictionaries.

In sum, we have endeavored in a single listing to compile and define the most common words and terms essential to the study, understanding and solution of environmental problems. Where so many words and terms are concerned, it is sometimes difficult to settle upon definitions acceptable to users who represent a great variety of pursuits and interests. This is particularly true of the newer words generated by science and technology. It may be recalled that Dr. Samuel Johnson once described a compiler of dictionaries as a "harmless drudge" and observed: "Dictionaries are like watches; the worst is better than none, and the best cannot be expected to go quite true."

We do not expect this glossary to be used extensively by technicians and professionals in environmental control. It was not designed for that purpose. Rather, it is our hope that it will stimulate and improve a student's understanding of man's environment and the interrelationship of the forces and elements that comprise it.

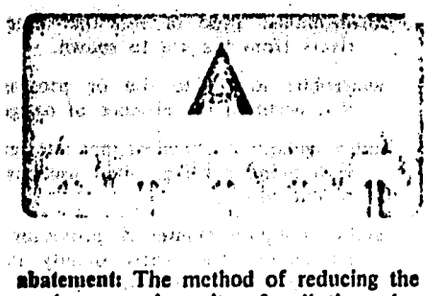
Acknowledgements

So many good people helped compile this glossary it would be impossible to list them all, but sincere thanks go to each. Employees of EPA's Region IV deserve special mention for contributing words for inclusion.

Specific credit should be given to my major sources: Paul Sarnoff's delightful *The New York Times Encyclopedic Dictionary of the Environment*, Herbert Hanson's *Dictionary of Ecology*, the American Society of Civil Engineers' *Glossary—Water and Sewage Control Engineering*, Veatch and Humphrys' *Water and Water Use Terminology* and a myriad of other equally good, but untraceable sources.

My especial thanks go to Charles Pou for his patience and moral support, to Dr. Walter Bishop, my mentor, and to Daisy Sawicki for her beautiful typing and for uncomplainingly correcting my misspelling of "eutrophication" all the way through.

G. J. S.



abatement: The method of reducing the degree or intensity of pollution, also the use of such a method.

absorption: The penetration of a substance into or through another. For example, in air pollution control, absorption is the dissolving of a soluble gas, present in an emission, in a liquid which can be extracted.

accelerator: In radiology, a device for imparting high velocity to charged particles such as electrons or protons. These fast particles can penetrate matter and are known as radiation.

acclimation: The physiological and behavioral adjustments of an organism to changes in its immediate environment.

acclimatization: The acclimation or adaptation of a particular species over several generations to a marked change in the environment.

activated carbon: A highly adsorbent form of carbon, used to remove odors and toxic substances from gaseous emissions. In advanced waste treatment, activated carbon is used to remove dissolved organic matter from waste water.

activated sludge: Sludge that has been aerated and subjected to bacterial action, used to remove organic matter from sewage.

activated sludge process: The process of using biologically active sewage sludge to hasten breakdown of organic matter in raw sewage during secondary waste treatment.

acute toxicity: Any poisonous effect produced within a short period of time, usually up to 24-96 hours, resulting in severe biological harm and often death.

adaptation: A change in structure or habit of an organism that produces better adjustment to the environment.

adsorption: The adhesion of a substance to the surface of a solid or liquid. Adsorption is often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Hydrophobic, or water-repulsing adsorbents, are used to extract oil from waterways in oil spills.

adulterants: Chemicals or substances that by law do not belong in a food, plant, animal or pesticide formulation. Adulterated products are subject to seizure by the Food and Drug Administration.

advanced waste treatment: Waste water treatment beyond the secondary or biological stage that includes removal of nutrients such as phosphorus and nitrogen and a high percentage of suspended solids. Advanced waste treatment, known as tertiary treatment, is the "polishing stage" of waste water treatment and produces a high quality effluent.

aeration: The process of being supplied or impregnated with air. Aeration is used in waste water treatment to foster biological and chemical purification.

aerobic: This refers to life or processes that can occur only in the presence of oxygen

aerosol: A suspension of liquid or solid particles in the air.

afterburner: An air pollution abatement device that removes undesirable organic gases through incineration.

agricultural pollution: The liquid and solid wastes from all types of farming, including runoff from pesticides, fertilizers and feedlots; erosion and dust from plowing, animal manure and carcasses and crop residues and debris. It has been estimated that agricultural pollution in the U.S. has amounted to more than 2½ billion tons per year.

air curtain: A method for mechanical containment of oil spills. Air is bubbled through a perforated pipe

causing an upward water flow that retards the spreading of oil. Air curtains are also used as barriers to prevent fish from entering a polluted body of water.

air mass: A widespread body of air with properties that were established while the air was situated over a particular region of the earth's surface and that undergoes specific modifications while in transit away from that region.

air monitoring: See monitoring.

air pollution: The presence of contaminants in the air in concentrations that prevent the normal dispersive ability of the air and that interfere directly or indirectly with man's health, safety or comfort or with the full use and enjoyment of his property.

air pollution episode: The occurrence of abnormally high concentrations of air pollutants usually due to low winds and temperature inversion and accompanied by an increase in illness and death. See inversion.

air quality control region: An area designated by the Federal government where two or more communities—either in the same or different states—share a common air pollution problem.

air quality criteria: The levels of pollution and lengths of exposure at which adverse effects on health and welfare occur.

air quality standards: The prescribed level of pollutants in the outside air that cannot be exceeded legally during a specified time in a specified geographical area.

algal bloom: A proliferation of living algae on the surface of lakes, streams or ponds. Algal blooms are stimulated by phosphate enrichment.

alpha particle: A positively charged particle emitted by certain radioactive materials. It is the least penetrating of the three common types of radiation (alpha, beta and gamma) and usually not dangerous to plants, animals or man.

ambient air: Any unconfined portion of e atmosphere; the outside air.

anadromous: Type of fish that ascend rivers from the sea to spawn.

anaerobic: Refers to life or processes that occur in the absence of oxygen.

anticoagulant: A chemical that interferes with blood clotting, often used as a rodenticide.

anti-degradation clause: A provision in air quality and water quality laws that prohibits deterioration of air or water quality in areas where the pollution levels are presently below those allowed.

aquifer: An underground bed or stratum of earth, gravel or porous stone that contains water.

aquatic plants: Plants that grow in water either floating on the surface, growing up from the bottom of the body of water or growing under the surface of the water.

area source: In air pollution, any small individual fuel combustion source, including any transportation sources. This is a general definition; area source is legally and precisely defined in Federal regulations. See point source.

asbestos: A mineral fiber with countless industrial uses; a hazardous air pollutant when inhaled.

A-Scale sound level: The measurement of sound approximating the auditory sensitivity of the human ear. The A-Scale sound level is used to measure the relative noisiness or annoyance of common sounds.

assimilation: Conversion or incorporation of absorbed nutrients into protoplasm. Also refers to the ability of a body of water to purify itself of organic pollution.

atmosphere: The layer of air surrounding the earth.

atomic pile: A nuclear reactor.

attractant: A chemical or agent that lures insects or other pests by olfactory stimulation.

attrition: Wearing or grinding down by friction. One of the three basic con-

tributing processes of air pollution, the others are vaporization and combustion.

audiometer: An instrument for measuring hearing sensitivity.

autotrophic: Self-nourishing; denoting those organisms capable of constructing organic matter from inorganic substances.

B

backfill: The material used to refill a ditch or other excavation. or the process of doing so.

background level: With respect to air pollution, amounts of pollutants present in the ambient air due to natural sources.

background radiation: Normal radiation present in the lower atmosphere from cosmic rays and from earth sources.

bacteria: Single-celled microorganisms that lack chlorophyll. Some bacteria are capable of causing human, animal or plant diseases, others are essential in pollution control because they break down organic matter in the air and in the water.

baffle: Any deflector device used to change the direction of flow or the velocity of water, sewage or products of combustion such as fly ash or coarse particulate matter. Also used in deadening sound.

baghouse: An air pollution abatement device used to trap particulates by filtering gas streams through large fabric bags, usually made of glass fibers.

baling: A means of reducing the volume of solid waste by compaction.

ballistic separator: A machine that separates inorganic from organic matter in a composting process.

band application: With respect to pesticides, the application of the chemical over or next to each row of plants in a field.

bar screen: In waste water treatment, a screen that removes large floating and suspended solids.

basal application: With respect to pesticides, the application of the pesticide formulation on stems or trunks of plants just above the soil line.

basin: See river basin.

benthic region: The bottom of a body of water. This region supports the benthos, a type of life that not only lives upon, but contributes to the character of the bottom.

benthos: The plant and animal life whose habitat is the bottom of a sea, lake or river.

beryllium: A metal that when airborne has adverse effects on human health; it has been declared a hazardous air pollutant. It is primarily discharged by operations such as machine shops, ceramic and propellant plants and foundries.

beta particle: An elementary particle emitted by radioactive decay that may cause skin burns. It is easily stopped by a thin sheet of metal.

bioassay: The employment of living organisms to determine the biological effect of some substance, factor or condition.

biochemical oxygen demand (BOD): A measure of the amount of oxygen consumed in the biological processes that break down organic matter in water. Large amounts of organic waste use up large amounts of dissolved oxygen, thus the greater the degree of pollution, the greater the BOD.

biodegradable: The process of decomposing quickly as a result of the action of microorganisms.

biological control: A method of controlling pests by means of introduced

or naturally occurring predatory organisms, sterilization or the use of inhibiting hormones, etc., rather than by mechanical or chemical means.

biological oxidation: The process by which bacterial and other microorganisms feed on complex organic materials and decompose them. Self-purification of waterways and activated sludge and trickling filter waste water treatment processes depend on this principle. The process is also called biochemical oxidation.

biomonitoring: The use of living organisms to test the suitability of effluent for discharge into receiving waters and to test the quality of such waters downstream from a discharge.

biosphere: The portion of the earth and its atmosphere capable of supporting life.

biostabilizer: A machine used to convert solid waste into compost by grinding and aeration.

biota: All the species of plants and animals occurring within a certain area.

bloom: A proliferation of living algae and/or other aquatic plants on the surface of lakes or ponds. Blooms are frequently stimulated by phosphate enrichment.

BOD: See biochemical oxygen demand.

BOD_5: The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter in an effluent. See biochemical oxygen demand.

bog: Wet, spongy land usually poorly drained, highly acid and rich in plant residue.

boom: A floating device that is used to contain oil on a body of water.

botanical pesticide: A plant-produced chemical used to control pests; for example, nicotine, strychnine or orpyrethrun.

brackish water: A mixture of fresh and salt water.

breeder: A nuclear reactor that produces more fuel than it consumes.

broadcast application: With respect to pesticides, the application of a chemical over an entire field, lawn or other area.

burial ground (graveyard): A place for burying unwanted radioactive materials to prevent radiation escape, the earth or water acting as a shield. Such materials must be placed in water-tight, noncorrodible containers so the radioactive material cannot leach out and invade underground water supplies.

C

cadmium: See heavy metals.

carbon dioxide (CO_2): A colorless, odorless, nonpoisonous gas that is a normal part of the ambient air. CO_2 is a product of fossil fuel combustion, and some researchers have theorized that excess CO_2 raises atmospheric temperatures.

carbon monoxide (CO): A colorless, odorless, highly toxic gas that is a normal byproduct of incomplete fossil fuel combustion. CO, one of the major air pollutants, can be harmful in small amounts if breathed over a certain period of time.

carcinogenic: Cancer producing.

catalytic converter: An air pollution abatement device that removes organic contaminants by oxidizing them into carbon dioxide and water through chemical reaction. Can be used to reduce nitrogen oxide emissions from motor vehicles.

caustic soda: Sodium hydroxide (NaOH), a strongly alkaline, caustic substance used as the cleaning agent in some detergents.

cells: With respect to solid waste dis-

posal, earthen compartments in which solid wastes are dumped, compacted and covered over daily with layers of earth.

centrifugal collector: Any of several mechanical systems using centrifugal force to remove aerosols from a gas stream.

cfs: Cubic feet per second, a measure of the amount of water passing a given point.

channelization: The straightening and deepening of streams to permit water to move faster, to reduce flooding or to drain marshy acreage for farming. However, channelization reduces the organic waste assimilation capacity of the stream and may disturb fish breeding and destroy the stream's natural beauty.

chemical oxygen demand (COD): A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the BOD test, is used to determine the degree of pollution in an effluent.

chemosterilant: A pesticide chemical that controls pests by destroying their ability to reproduce.

chilling effect: The lowering of the earth's temperature due to the increase of atmospheric particulates that inhibit penetration of the sun's energy.

chlorinated hydrocarbons: A class of generally long-lasting, broad-spectrum insecticides of which the best known is DDT, first used for insect control during World War II. Other similar compounds include aldrin, dieldrin, heptachlor, chlordane, lindane, endrin, mirex, benzene hexachloride (BHC), and toxaphene. The qualities of persistence and effectiveness against a wide variety of insect pests were long regarded as highly desirable in agriculture, public health and home uses. But later research has revealed that these same qualities may represent a potential hazard through accumulation in the food chain and persistence in the environment.

chlorination: The application of chlorine to drinking water, sewage or industrial waste for disinfection or oxidation of undesirable compounds.

chlorinator: A device for adding a chlorine-containing gas or liquid to drinking or waste water.

chlorine-contact chamber: In a waste treatment plant, a chamber in which effluent is disinfected by chlorine before it is discharged to the receiving waters.

chlorosis: Yellowing or whitening of normally green plant parts. It can be caused by disease organisms, lack of oxygen or nutrients in the soil or by various air pollutants.

chromium: See heavy metals.

chronic: Marked by long duration or frequent recurrence, as a disease.

clarification: In waste water treatment, the removal of turbidity and suspended solids by settling, often aided by centrifugal action and chemically induced coagulation.

clarifier: In waste water treatment, a settling tank which mechanically removes settleable solids from wastes.

coagulation: The clumping of particles in order to settle out impurities; often induced by chemicals such as lime or alum.

coastal zone: Coastal waters and adjacent lands that exert a measurable influence on the uses of the sea and its ecology.

COD: See chemical oxygen demand.

coefficient of haze (COH): A measurement of visibility interference in the atmosphere.

coffin: A thick-walled container (usually lead) used for transporting radioactive materials.

COH: See coefficient of haze.

coliform index: An index of the purity of water based on a count of its coliform bacteria.

coliform organism: Any of a number of organisms common to the intestinal tract of man and animals whose

presence in waste water is an indicator of pollution and of potentially dangerous bacterial contamination.

combined sewers: A sewerage system that carries both sanitary sewage and storm water runoff. During dry weather, combined sewers carry all waste water to the treatment plant. During a storm, only part of the flow is intercepted because of plant overloading; the remainder goes untreated to the receiving stream.

combustion: Burning. Technically, a rapid oxidation accompanied by the release of energy in the form of heat and light. It is one of the three basic contributing factors causing air pollution, the others are attrition and vaporization.

comminution: Mechanical shredding or pulverizing of waste, a process that converts it into a homogeneous and more manageable material. Used in solid waste management and in the primary stage of waste water treatment.

comminutor: A device that grinds solids to make them easier to treat.

compaction: Reducing the bulk of solid waste by rolling and tamping.

compost: Relatively stable decomposed organic material.

composting: A controlled process of degrading organic matter by microorganisms. (1) mechanical—a method in which the compost is continuously and mechanically mixed and aerated. (2) ventilated cell—compost is mixed and aerated by being dropped through a vertical series of ventilated cells. (3) windrow—an open-air method in which compostable material is placed in windrows, piles or ventilated bins or pits and occasionally turned or mixed. The process may be anaerobic or aerobic.

contact pesticide: A chemical that kills pests on contact with the body, rather than by ingestion (stomach poison).

contrails: Long narrow clouds caused by the disturbance of the atmosphere during passage of high-flying jets. Proliferation of contrails may cause changes in the weather.

coolant: A substance, usually liquid or gas, used for cooling any part of a reactor in which heat is generated, including the core, the reflector, shield and other elements that may be heated by absorption of radiation.

cooling tower: A device to remove excess heat from water used in industrial operations, notably in electric power generation.

core: The heart of a nuclear reactor where energy is released.

cover material: Soil that is used to cover compacted solid waste in a sanitary landfill.

cultural eutrophication: Acceleration by man of the natural aging process of bodies of water.

curie: A measure of radioactivity.

cutie-pie: A portable instrument equipped with a direct reading meter used to determine the level of radiation in an area.

cyclone collector: A device used to collect large-size particulates from polluted air by centrifugal force.

D

DDT: The first of the modern chlorinated hydrocarbon insecticides whose chemical name is 1,1,1-tricholoro-2,2-bis (p-chloriphenyl)-ethane. It has a half-life of 15 years, and its residues can become concentrated in the fatty tissues of certain organisms, especially fish. Because of its persistence in the environment and its ability to accumulate and magnify in the food chain, EPA has banned the registration and interstate sale of DDT for nearly all uses in the United States effective December 31, 1972.

decibel (dB): A unit of sound measurement.

decomposition: Reduction of the net energy level and change in chemical composition of organic matter because of the actions of aerobic or anaerobic microorganisms.

dermal toxicity: The ability of a pesticide chemical to poison an animal or human by skin absorption.

desalinization: Salt removal from sea or brackish water.

desiccant: A chemical agent that may be used to remove moisture from plants or insects causing them to wither and die.

detergent: Synthetic washing agent that, like soap, lowers the surface tension of water, emulsifies oils and holds dirt in suspension. Environmentalists have criticized detergents because most contain large amounts of phosphorus-containing compounds that contribute to the eutrophication of waterways.

diatomaceous earth (diatomite): A fine siliceous material resembling chalk used in waste water treatment plants to filter sewage effluent to remove solids. May also be used as inactive ingredients in pesticide formulations applied as dust or powder.

diffused air: A type of sewage aeration. Air is pumped into the sewage through a perforated pipe.

digester: In a waste water treatment plant, a closed tank that decreases the volume of solids and stabilizes raw sludge by bacterial action.

digestion: The biochemical decomposition of organic matter. Digestion of sewage sludge takes place in tanks where the sludge decomposes, resulting in partial gasification, liquefaction and mineralization of pollutants.

dilution ratio: The ratio of the volume of water of a stream to the volume of incoming waste. The capacity of a stream to assimilate waste is partially dependent upon the dilution ratio.

disinfection: Effective killing by chemical or physical processes of all organisms capable of causing infectious disease. Chlorination is the disinfection method commonly employed in sewage treatment processes.

dispersant: A chemical agent used to break up concentrations of organic material. In cleaning oil spills, dispersants are used to disperse oil from the water surface.

dissolved oxygen (DO): The oxygen dissolved in water or sewage. Adequately dissolved oxygen is necessary for the life of fish and other aquatic organisms and for the prevention of offensive odors. Low dissolved oxygen concentrations generally are due to discharge of excessive organic solids having high BOD, the result of inadequate waste treatment.

dissolved solids: The total amount of dissolved material, organic and inorganic, contained in water or wastes. Excessive dissolved solids make water unpalatable for drinking and unsuitable for industrial uses.

distillation: The removal of impurities from liquids by boiling. The steam, condensed back into liquid, is almost pure water; the pollutants remain in the concentrated residue.

dose: In radiology, the quantity of energy or radiation absorbed.

dosimeter (dosemeter): An instrument used to measure the amount of radiation a person has received.

dredging: A method for deepening streams, swamps or coastal waters by scraping and removing solids from the bottom. The resulting mud is usually deposited in marshes in a process called filling. Dredging and filling can disturb natural ecological cycles. For example, dredging can destroy oyster beds and other aquatic life; filling can destroy the feeding and breeding grounds for many fish species.

dry limestone process: A method of controlling air pollution caused by sulfur oxides. The polluted gases are exposed to limestone which combines with oxides of sulfur to form manageable residues.

dump: A land site where solid waste is disposed of in a manner that does not protect the environment.

dust: Fine-grain particulate matter that is capable of being suspended in air.

dustfall jar: An open-mouthed container used to collect large particles that fall out of the air. The particles are measured and analyzed.

dystrophic lakes: Lakes between eutrophic and swamp stages of aging. Such lakes are shallow and have high humus content, high organic matter content, low nutrient availability and high BOD.

E

ecological impact: The total effect of an environmental change, either natural or man-made, on the ecology of the area.

ecology: The interrelationships of living things to one another and to their environment or the study of such interrelationships.

economic poisons: Those chemicals used to control insects, rodents, plant diseases, weeds and other pests, and also to defoliate economic crops such as cotton.

ecosphere: See biosphere.

ecosystem: The interacting system of a biological community and its nonliving environment.

effluent: A discharge of pollutants into the environment, partially or completely treated or in its natural state. Generally used in regard to discharges into waters.

electrodialysis: A process that uses electrical current and an arrangement of permeable membranes to separate soluble minerals from water. Often used to desalinize salt or brackish water.

electrostatic precipitator: An air pollution control device that removes particulate matter by imparting an electrical charge to particles in a gas stream for mechanical collection on an electrode.

emergency episode: See air pollution episode.

emission: See effluent. (Generally used in regard to discharges into air.)

emission factor: The average amount of a pollutant emitted from each type of polluting source in relation to a specific amount of material processed. For example, an emission factor for a blast furnace (used to make iron) would be a number of pounds of particulates per ton of raw materials.

emission inventory: A list of air pollutants emitted into a community's atmosphere, in amounts (usually tons) per day, by type of source. The emission inventory is basic to the establishment of emission standards.

emission standard: The maximum amount of a pollutant legally permitted to be discharged from a single source, either mobile or stationary.

enrichment: The addition of nitrogen, phosphorus and carbon compounds or other nutrients into a lake or other waterway that greatly increases the growth potential for algae and other aquatic plants. Most frequently, enrichment results from the inflow of sewage effluent or from agricultural runoff.

environment: The sum of all external conditions and influences affecting the life, development and, ultimately, the survival of an organism.

environmental impact statement: A document prepared by a Federal agency on the environmental impact of its proposals for legislation and other major actions significantly affecting the quality of the human environment. Environmental impact statements are used as tools for decision making and are required by the National Environmental Policy Act.

epidemiology: The study of diseases as they affect populations.

erosion: The wearing away of the land surface by wind or water. Erosion occurs naturally from weather or runoff but is often intensified by man's land-clearing practices.

estuaries: Areas where the fresh water meets salt water. For example, bays, mouths of rivers, salt marshes and lagoons. Estuaries are delicate ecosystems; they serve as nurseries, spawning and feeding grounds for a large group of marine life and provide shelter and food for birds and wildlife.

eutrophication: The normally slow aging process by which a lake evolves into a bog or marsh and ultimately assumes a completely terrestrial state and disappears. During eutrophication the lake becomes so rich in nutritive compounds, especially nitrogen and phosphorus, that algae and other microscopic plant life become superabundant, thereby "choking" the lake, and causing it eventually to dry up. Eutrophication may be accelerated by many human activities.

eutrophic lakes: Shallow lakes, weed-choked at the edges and very rich in nutrients. The water is characterized by large amounts of algae, low water transparency, low dissolved oxygen and high BOD.

evaporation ponds: Shallow, artificial ponds where sewage sludge is pumped, permitted to dry and either removed or buried by more sludge.

F

fabric filters: A device for removing dust and particulate matter from industrial emissions much like a home vacuum cleaner bag. The most common use of fabric filters is the baghouse.

fecal coliform bacteria: A group of organisms common to the intestinal tracts of man and of animals. The presence of fecal coliform bacteria in water is an indicator of pollution and of potentially dangerous bacterial contamination.

feedlot: A relatively small, confined land area for raising cattle. Although an economical method of fattening beef, feedlots concentrate a large amount of animal wastes in a small area. This excrement cannot be handled by the soil as it could be if the cattle were scattered on open range. In addition, runoff from feedlots contributes excessive quantities of nitrogen, phosphorus and potassium to nearby waterways, thus contributing to eutrophication.

fen: A low-lying land area partly covered by water.

filling: The process of depositing dirt and mud in marshy areas to create more land for real estate development. Filling can disturb natural ecological cycles. See dredging.

film badge: A piece of masked photographic film worn like a badge by nuclear workers to monitor an exposure to radiation. Nuclear radiation darkens the film.

filtration: In waste water treatment, the mechanical process that removes particulate matter by separating water from solid material usually by passing it through sand.

floc: A clump of solids formed in sewage by biological or chemical action.

flocculation: In waste water treatment, the process of separating suspended solids by chemical creation of clumps or flocs.

flowmeter: In waste water treatment, a meter that indicates the rate at which waste water flows through the plant.

flue gas: A mixture of gases resulting from combustion and emerging from a chimney. Flue gas includes nitrogen

oxides, carbon oxides, water vapor and often sulfur oxides or particulates.

fluorides: Gaseous, solid or dissolved compounds containing fluorine, emitted into the air or water from a number of industrial processes. Fluorides in the air are a cause of vegetation damage and, indirectly, of livestock damage.

flume: A channel, either natural or man-made, which carries water.

fly ash: All solids, including ash, charred paper, cinders, dust, soot or other partially incinerated matter, that are carried in a gas stream.

fog: Liquid particles formed by condensation of vaporized liquids.

fogging: The application of a pesticide by rapidly heating the liquid chemical, thus forming very fine droplets with the appearance of smoke. Fogging is often used to destroy mosquitoes and blackflies.

food waste: Animal and vegetable waste resulting from the handling, storage, sale, preparation, cooking and serving of foods; commonly called garbage.

fossil fuels: Coal, oil and natural gas; so-called because they are derived from the remains of ancient plant and animal life.

fume: Tiny solid particles commonly formed by the condensation of vapors of solid matter.

fumigant: A pesticide that is burned or evaporated to form a gas or vapor that destroys pests. Fumigants are often used in buildings or greenhouses.

fungi: Small, often microscopic plants without chlorophyll. Some fungi infect and cause disease in plants or animals; other fungi are useful in stabilizing sewage or in breaking down wastes for compost.

fungicide: A pesticide chemical that kills fungi or prevents them from causing diseases, usually on plants of economic importance. See pesticide.

G

game fish: Those species of fish sought by sports fishermen; for example, salmon, trout, black bass, striped bass, etc. Game fish are usually more sensitive to environmental changes and water quality degradation than "rough" fish.

gamma ray: Waves of radiant nuclear energy. Gamma rays are the most penetrating of the three types of radiation and are best stopped by dense materials such as lead.

garbage: See food waste.

garbage grinding: A method of grinding food waste by a household disposal, for example, and washing it into the sewer system. Ground garbage then must be disposed of as sewage sludge.

Geiger counter: An electrical device that detects the presence of radioactivity.

generator: A device that converts mechanical energy into electrical energy.

germicide: A chemical or agent that kills microorganisms such as bacteria and prevents them from causing disease. Such compounds must be registered as pesticides with EPA.

grain: A unit of weight equivalent to 65 milligrams or 2/1,000 of an ounce.

grain loading: The rate of emission of particulate matter from a polluting source. Measurement is made in grains of particulate matter per cubic foot of gas emitted.

green belts: Certain areas restricted from being used for buildings and houses; they often serve as separating buffers between pollution sources and concentrations of population.

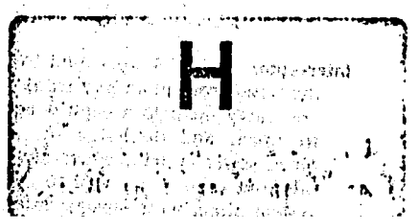
greenhouse effect: The heating effect of the atmosphere upon the earth. Light waves from the sun pass through the

air and are absorbed by the earth. The earth then reradiates this energy as heat waves that are absorbed by the air, specifically by carbon dioxide. The air thus behaves like glass in a greenhouse, allowing the passage of light but not of heat. Thus many scientists theorize that an increase in the atmospheric concentration of CO_2 can eventually cause an increase in the earth's surface temperature.

ground cover: Grasses or other plants grown to keep soil from being blown or washed away.

groundwater: The supply of freshwater under the earth's surface in an aquifer or soil that forms the natural reservoir for man's use.

groundwater runoff: Groundwater that is discharged into a stream channel as spring or seepage water.



habitat: The sum total of environmental conditions of a specific place that is occupied by an organism, a population or a community.

half-life: The time it takes certain materials, such as persistent pesticides or radioactive isotopes, to lose half their strength. For example, the half-life of DDT is 15 years; the half-life of radium is 1,580 years.

hammermill: A broad category of high-speed equipment that uses pivoted or fixed hammers or cutters to crush, grind, chip or shred solid wastes.

hard water: Water containing dissolved minerals such as calcium, iron and magnesium. The most notable characteristic of hard water is its inability to lather soap. Some pesticide chemicals will curdle or settle out when added to hard water.

hazardous air pollutant: According to law, a pollutant to which no ambient air quality standard is applicable and that may cause or contribute to an increase in mortality or in serious illness. For example, asbestos, beryllium and mercury have been declared hazardous air pollutants.

heat island effect. An air circulation problem peculiar to cities. Tall buildings, heat from pavements and concentrations of pollutants create a haze dome that prevents rising hot air from being cooled at its normal rate. A self-contained circulation system is put in motion that can be broken by relatively strong winds. If such winds are absent, the heat island can trap high concentrations of pollutants and present a serious health problem.

heating season: The coldest months of the year when pollution emissions are higher in some areas because of increased fossil-fuel consumption.

heavy metals: Metallic elements with high molecular weights, generally toxic in low concentrations to plant and animal life. Such metals are often residual in the environment and exhibit biological accumulation. Examples include mercury, chromium, cadmium, arsenic and lead.

herbicide: A pesticide chemical used to destroy or control the growth of weeds, bush and other undesirable plants. See pesticide.

herbivore: An organism that feeds on vegetation.

heterotrophic organism: Organisms dependent on organic matter for food.

high density polyethylene: A material often used in the manufacture of plastic bottles that produces toxic fumes if incinerated.

hi-volume sampler: A device used in the measurement and analysis of suspended particulate pollution. Also called a Hi-Vol.

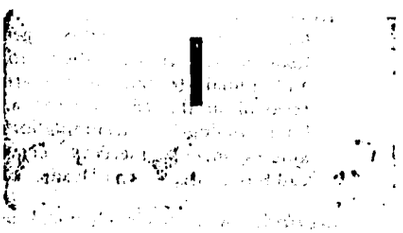
hot: A colloquial term meaning highly radioactive.

humus: Decomposed organic material.

hydrocarbons: A vast family of compounds containing carbon and hydrogen in various combinations, found especially in fossil fuels. Some hydrocarbons are major air pollutants, some may be carcinogenic and others contribute to photochemical smog.

hydrogen sulfide (H_2S): A malodorous gas made up of hydrogen and sulfur with the characteristic odor of rotten eggs. It is emitted in the natural decomposition of organic matter and is also the natural accompaniment of advanced stages of eutrophication. H_2S is also a byproduct of refinery activity and the combustion of oil during power plant operations. In heavy concentrations, it can cause illness.

hydrology: The science dealing with the properties, distribution and circulation of water and snow.



impedance: The rate at which a substance can absorb and transmit sound.

implementation plan: A document of the steps to be taken to ensure attainment of environmental quality standards within a specified time period. Implementation plans are required by various laws.

impoundment: A body of water, such as a pond, confined by a dam, dike, floodgate or other barrier.

incineration: The controlled process by which solid, liquid or gaseous combustible wastes are burned and changed into gases; the residue produced contains little or no combustible material.

incinerator: An engineered apparatus used to burn waste substances and in which all the combustion factors—temperature, retention time, turbulence and combustion air—can be controlled.

inert gas: A gas that does not react with other substances under ordinary conditions.

inertial separator: An air pollution control device that uses the principle of inertia to remove particulate matter from a stream of air or gas.

infiltration: The flow of a fluid into a substance through pores or small openings. Commonly used in hydrology to denote the flow of water into soil material.

inoculum: Material such as bacteria placed in compost or other medium to initiate biological action.

integrated pest control: A system of managing pests by using biological, cultural and chemical means.

interceptor sewers: Sewers used to collect the flows from main and trunk sewers and carry them to a central point for treatment and discharge. In a combined sewer system, where street runoff from rains is allowed to enter the system along with sewage, interceptor sewers allow some of the sewage to flow untreated directly into the receiving stream, to prevent the plant from being overloaded.

interstate carrier water supply: A water supply whose water may be used for drinking or cooking purposes aboard common carriers (planes, trains, buses and ships) operating interstate. Interstate carrier water supplies are regulated by the Federal government.

interstate waters: According to law, waters defined as: (1) rivers, lakes and other waters that flow across or form a part of State or international boundaries; (2) waters of the Great Lakes; (3) coastal waters — whose scope has been defined to include ocean waters seaward to the territorial limits and waters along the coastline (including inland streams) influenced by the tide.

inversion: An atmospheric condition

where a layer of cool air is trapped by a layer of warm air so that it cannot rise. Inversions spread polluted air horizontally rather than vertically so that contaminating substances cannot be widely dispersed. An inversion of several days can cause an air pollution episode.

Ionization chamber: A device roughly similar to a Geiger counter that reveals the presence of ionizing radiation.

Isotope: A variation of an element having the same atomic number as the element itself, but having a different atomic weight because of a different number of neutrons. Different isotopes of the same element have different radioactive behavior.

J, K, L

lagoon: In waste water treatment, a shallow pond usually man-made where sunlight, bacterial action and oxygen interact to restore waste water to a reasonable state of purity.

lateral sewers: Pipes running underneath city streets that collect sewage from homes or businesses.

LC_{50}: Median lethal concentration, a standard measure of toxicity. LC_{50} indicates the concentration of a substance that will kill 50 percent of a group of experimental insects or animals.

leachate: Liquid that has percolated through solid waste or other mediums and has extracted dissolved or suspended materials from it.

leaching: The process by which soluble materials in the soil, such as nutrients, pesticide chemicals or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

lead: A heavy metal that may be hazardous to human health if breathed or ingested.

life cycle: The phases, changes or stages an organism passes through during its lifetime

lift: In a sanitary landfill, a compacted layer of solid waste and the top layer of cover material.

limnology: The study of the physical, chemical, meteorological and biological aspects of fresh waters.

M

marsh: A low-lying tract of soft, wet land that provides an important ecosystem for a variety of plant and animal life but often is destroyed by dredging and filling.

masking: Covering over of one sound or element by another. Quantitatively, masking is the amount the audibility threshold of one sound is raised by the presence of a second masking sound. Also used in regard to odors.

mechanical turbulence: The erratic movement of air caused by local obstructions such as buildings.

mercury: A heavy metal, highly toxic if breathed or ingested. Mercury is residual in the environment, showing biological accumulation in all aquatic organisms, especially fish and shell fish. Chronic exposure to airborne mercury can have serious effects on the central nervous system.

methane: Colorless, nonpoisonous and flammable gaseous hydrocarbon. Methane, (CH_4), is emitted by marshes and by dumps undergoing anaerobic decomposition.

mgd: Millions of gallons per day. Mgd is commonly used to express rate of flow.

microbes: Minute plant or animal life. Some disease-causing microbes exist in sewage.

mist: Liquid particles in air formed by condensation of vaporized liquids. Mist particles vary from 500 to 40 microns in size. By comparison, fog particles are smaller than 40 microns in size.

mixed liquor: A mixture of activated sludge and water containing organic matter undergoing activated sludge treatment in the aeration tank.

mobile source: A moving source of air pollution such as an automobile.

monitoring: Periodic or continuous determination of the amount of pollutants or radioactive contamination present in the environment.

muck soils: Soils made from decaying plant materials.

mulch: A layer of wood chips, dry leaves, straw, hay, plastic strips or other material placed on the soil around plants to retain moisture, to prevent weeds from growing and to enrich soil.

N

natural gas: A fuel gas occurring naturally in certain geologic formation. Natural gas is usually a combustible mixture of methane and hydrocarbons.

natural selection: The natural process by which the organisms best adapted to their environment survive and those less well adapted are eliminated.

necrosis: Death of plant cells resulting in a discolored, sunken area or death of the entire plant.

nitric oxide (NO): A gas formed in great part from atmospheric nitrogen and oxygen when combustion takes place under high temperature and high pressure, as in internal combustion engines. NO is not itself a pollutant; however, in the ambient air, it converts to nitrogen dioxide, a major contributor to photochemical smog.

nitrogen dioxide (NO_2): A compound produced by the oxidation of nitric oxide in the atmosphere; a major contributor to photochemical smog.

nitrogenous wastes: Wastes of animal or plant origin that contain a significant concentration of nitrogen.

NO: A notation meaning oxides of nitrogen. See nitric oxide.

noise: Any undesired audible signal. Thus, in acoustics, noise is any undesired sound.

NTA: Nitrilotriacetic acid, a compound once used to replace phosphates in detergents.

nuclear power plant: Any device, machine or assembly that converts nuclear energy into some form of useful power, such as mechanical or electrical power. In a nuclear electric power plant, heat produced by a reactor is generally used to make steam to drive a turbine that in turn drives an electric generator.

nutrients: Elements or compounds essential as raw materials for organism growth and development; for example, carbon, oxygen, nitrogen and phosphorus.

O

oil spill: The accidental discharge of oil into oceans, bays or inland waters.

ways: Methods of oil spill control include chemical dispersion, combustion, mechanical containment and absorption.

oligotrophic lakes: Deep lakes that have a low supply of nutrients and thus contain little organic matter. Such lakes are characterized by high water transparency and high dissolved oxygen.

opacity: Degree of obscuration of light. For example, a window has zero opacity; a wall is 100 percent opaque. The Ringelmann system of evaluating smoke density is based on opacity.

open burning: Uncontrolled burning of wastes in an open dump.

open dump: See dump.

organic: Referring to or derived from living organisms. In chemistry, any compound containing carbon.

organism: Any living human, plant or animal.

organophosphates: A group of pesticide chemicals containing phosphorus, such as malathion and parathion, intended to control insects. These compounds are short-lived and, therefore, do not normally contaminate the environment. However, some organophosphates, such as parathion, are extremely toxic when initially applied and exposure to them can interfere with the normal processes of the nervous system, causing convulsions and eventually death. Malathion, on the other hand, is low in toxicity and relatively safe for humans and animals; it is a common ingredient in household insecticide products.

outfall: The mouth of a sewer, drain or conduit where an effluent is discharged into the receiving waters.

overfire air: Air forced into the top of an incinerator to fan the flame.

oxidant: Any oxygen containing substance that reacts chemically in the air to produce new substances. Oxidants are the primary contributors to photochemical smog.

oxidation: A chemical reaction in which oxygen unites or combines with other elements. Organic matter is oxidized by the action of aerobic bacteria; thus oxidation is used in waste water treatment to break down organic wastes.

oxidation pond: A man-made lake or pond in which organic wastes are reduced by bacterial action. Often oxygen is bubbled through the pond to speed the process.

ozone (O_3): A pungent, colorless, toxic gas. Ozone is one component of photochemical smog and is considered a major air pollutant.

P

package plant: A prefabricated or prebuilt waste water treatment plant.

packed tower: An air pollution control device in which polluted air is forced upward through a tower packed with crushed rock or wood chips while a liquid is sprayed downward on the packing material. The pollutants in the air stream either dissolve or chemically react with the liquid.

PAN: Peroxyacetyl nitrate, a pollutant created by the action of sunlight on hydrocarbons and nitrogen oxides in the air. PANS are an integral part of photochemical smog.

particulates: Finely divided solid or liquid particles in the air or in an emission. Particulates include dust, smoke, fumes, mist, spray and fog.

particulate loading: The introduction of particulates into the ambient air.

pathogenic: Causing or capable of causing disease.

PCBs: Polychlorinated biphenyls, a group of organic compounds used in the manufacture of plastics. In the en-

vironment, PCBs exhibit many of the same characteristics as DDT and may, therefore, be confused with that pesticide. PCBs are highly toxic to aquatic life, they persist in the environment for long periods of time, and they are biologically accumulative.

peat: Partially decomposed organic material.

percolation: Downward flow or infiltration of water through the pores or spaces of a rock or soil.

persistent pesticides: Pesticides that will be present in the environment for longer than one growing season or one year after application.

pesticide: An agent used to control pests. This includes insecticides for use against harmful insects; herbicides for weed control; fungicides for control of plant diseases; rodenticides for killing rats, mice, etc.; and germicides used in disinfectant products, algaecides, slimicides, etc. Some pesticides can contaminate water, air or soil and accumulate in man, animals and the environment, particularly if they are misused. Certain of these chemicals have been shown to interfere with the reproductive processes of predatory birds and possibly other animals.

pesticide tolerance: A scientifically and legally established limit for the amount of chemical residue that can be permitted to remain in or on a harvested food or feed crop as a result of the application of a chemical for pest-control purposes. Such tolerances or safety levels, established federally by EPA, are set well below the point at which residues might be harmful to consumers.

pH: A measure of the acidity or alkalinity of a material, liquid or solid. pH is represented on a scale of 0 to 14 with 7 representing a neutral state, 0 representing the most acid and 14, the most alkaline.

phenols: A group of organic compounds that in very low concentrations produce a taste and odor problem in water. In higher concentrations, they are toxic to aquatic life. Phenols are byproducts of petroleum refining, tanning and textile, dye and resin manufacture.

phosphorus: An element that while essential to life, contributes to the eutrophication of lakes and other bodies of water.

photochemical oxidants: Secondary pollutants formed by the action of sunlight on the oxides of nitrogen and hydrocarbons in the air; they are the primary contributors to photochemical smog.

photochemical smog: Air pollution associated with oxidants rather than with sulfur oxides, particulates, etc. Produces necrosis, chlorosis and growth alterations in plants and is an eye and respiratory irritant in humans.

phytoplankton: The plant portion of plankton.

phytotoxic: Injurious to plants.

pig: A container usually made of lead used to ship or store radioactive materials.

pile: A nuclear reactor.

plankton: The floating or weakly swimming plant and animal life in a body of water, often microscopic in size.

plume: The visible emission from a flue or chimney.

point source: In air pollution, a stationary source of a large individual emission, generally of an industrial nature. This is a general definition; point source is legally and precisely defined in Federal regulations. See area source.

pollen: A fine dust produced by plants; a natural or background air pollutant.

pollutant: Any introduced gas, liquid or solid that makes a resource unfit for a specific purpose.

pollution: The presence of matter or or energy whose nature, location or quantity produces undesired environmental effects.

polyelectrolytes: Synthetic chemicals used to speed flocculation of solids in sewage.

potable water: Water suitable for drinking or cooking purposes from both health and aesthetic considerations.

ppm: Parts per million. The unit commonly used to represent the degree of pollutant concentration where the concentrations are small. Larger concentrations are given in percentages. Thus BOD is represented in ppm while suspended solids in water are expressed in percentages. In air, ppm is usually a volume/volume ratio; in water, a weight/volume ratio.

precipitate—A solid that separates from a solution because of some chemical or physical change or the formation of such a solid.

precipitators: In pollution control work, any of a number of air pollution control devices usually using mechanical/electrical means to collect particulates from an emission.

pretreatment: In waste water treatment, any process used to reduce pollution load before the waste water is introduced into a main sewer system or delivered to a treatment plant for substantial reduction of the pollution load.

primary treatment: The first stage in waste water treatment in which substantially all floating or settleable solids are mechanically removed by screening and sedimentation.

process weight: The total weight of all materials, including fuels, introduced into a manufacturing process. The process weight is used to calculate the allowable rate of emission of pollutant matter from the process.

pulverization: The crushing or grinding of material into small pieces.

pumping station: A station at which sewage is pumped to a higher level. In most sewer systems pumping is unnecessary; waste water flows by gravity to the treatment plant.

putrescible: Capable of being decomposed by microorganisms with sufficient rapidity to cause nuisances from odors, gases, etc. For example, kitchen wastes or dead animals.

Q

quench tank: A water-filled tank used to cool incinerator residues.

R

rad: A unit of measurement of any kind of radiation absorbed by man.

radiation: The emission of fast atomic particles or rays by the nucleus of an atom. Some elements are naturally radioactive while others become radioactive after bombardment with neutrons or other particles. The three major forms of radiation are alpha, beta and gamma.

radiation standards: Regulations that include exposure standards, permissible concentrations and regulations for transportation.

radiobiology: The study of the principles, mechanisms and effects of radiation on living matter.

radioecology: The study of the effects of radiation on species of plants and animals in natural communities.

radioisotopes: Radioactive isotopes. Radioisotopes such as cobalt-60 are used in the treatment of disease.

rasp: A device used to grate solid waste into a more manageable material, ridding it of much of its odor.

raw sewage: Untreated domestic or commercial waste water.

receiving waters: Rivers, lakes, oceans or other bodies that receive treated or untreated waste waters.

recycling: The process by which waste materials are transformed into new products in such a manner that the original products may lose their identity.

red tide: A proliferation or bloom of a certain type of plankton with red-to-orange coloration, that often causes massive fish kills. Though they are a natural phenomenon, blooms are believed to be stimulated by phosphorus and other nutrients discharged into waterways by man.

refuse: See solid waste.

refuse reclamation: The process of converting solid waste to saleable products. For example, the composting of organic solid waste yields a saleable soil conditioner.

rem: A measurement of radiation dose to the internal tissues of man.

rep: A unit of measurement of any kind of radiation absorbed by man.

reservoir: A pond, lake, tank or basin, natural or man-made, used for the storage, regulation and control of water.

resource recovery: The process of obtaining materials or energy, particularly from solid waste.

reverberation: The persistence of sound in an enclosed space after the sound source has stopped.

Ringelmann chart: A series of illustrations ranging from light grey to black used to measure the opacity of smoke emitted from stacks and other sources. The shades of grey simulate various smoke densities and are assigned numbers ranging from one to five. Ringelmann No. 1 is equivalent to 20 percent dense; No. 5 is 100 percent dense. Ringelmann charts are used in the setting and enforcement of emission standards.

riparian rights: Rights of a land owner to the water on or bordering his property, including the right to prevent diversion or misuse of upstream water.

river basin: The total area drained by a river and its tributaries.

rodenticide: A chemical or agent used to destroy or prevent damage by rats or other rodent pests. See pesticide.

rough fish: Those fish species considered to be of poor fighting quality when taken on tackle or of poor eating quality; for example, gar, suckers, etc. Most rough fish are more tolerant of widely changing environmental conditions than are game fish.

rubbish: A general term for solid waste —excluding food waste and ashes— taken from residences, commercial establishments and institutions.

runoff: The portion of rainfall, melted snow or irrigation water that flows across ground surface and eventually is returned to streams. Runoff can pick up pollutants from the air or the land and carry them to the receiving waters.

S

salinity: The degree of salt in water.

salt water intrusion: The invasion of salt water into a body of fresh water, occurring in either surface or groundwater bodies. When this invasion is caused by oceanic waters, it is called sea water intrusion.

salvage: The utilization of waste materials.

sanitation: The control of all the factors in man's physical environment that exercise or can exercise a deleterious effect on his physical development, health and survival.

sanitary landfill: A site for solid waste disposal using sanitary landfilling techniques.

sanitary landfilling: An engineered method of solid waste disposal on land in a manner that protects the environment; waste is spread in thin layers, compacted to the smallest practical volume and covered with soil at the end of each working day.

sanitary sewers: Sewers that carry only domestic or commercial sewage. Storm water runoff is carried in a separate system. See sewer.

scrap: Discarded or rejected materials that result from manufacturing or fabricating operations and are suitable for reprocessing.

screening: The removal of relatively coarse floating and suspended solids by straining through racks or screens.

scrubber: An air pollution control device that uses a liquid spray to remove pollutants from a gas stream by absorption or chemical reaction. Scrubbers also reduce the temperature of the emission.

secondary treatment: Waste water treatment, beyond the primary stage, in which bacteria consume the organic parts of the wastes. This biochemical action is accomplished by use of trickling filters or the activated sludge process. Effective secondary treatment removes virtually all floating and settleable solids and approximately 90 percent of both BOD_5 and suspended solids. Customarily, disinfection by chlorination is the final stage of the secondary treatment process.

sedimentation: In waste water treatment, the settling out of solids by gravity.

sedimentation tanks: In waste water treatment, tanks where the solids are allowed to settle or to float as scum. Scum is skimmed off; settled solids are pumped to incinerators, digesters, filters or other means of disposal.

seepage: Water that flows through the soil.

selective herbicide: A pesticide intended to kill only certain types of plants, especially broad-leafed weeds, and not harm other plants such as farm crops or lawn grasses. The leading herbicide in the United States is 2,4-D. A related but stronger chemical used mostly for brush control on range, pasture, and forest lands and on utility or highway rights-of-way is 2,4,5-T. Uses of the latter chemical have been somewhat restricted because of laboratory evidence that it or a dioxin contaminant in 2,4,5-T can cause birth defects in test animals.

senescence: The process of growing old. Sometimes used to refer to lakes nearing extinction.

septic tank: An underground tank used for the deposition of domestic wastes. Bacteria in the wastes decompose the organic matter, and the sludge settles to the bottom. The effluent flows through drains into the ground. Sludge is pumped out at regular intervals.

settleable solids: Bits of debris and fine matter heavy enough to settle out of waste water.

settling chamber: In air pollution control, a low-cost device used to reduce the velocity of flue gases usually by means of baffles, promoting the settling of fly ash.

settling tank: In waste water treatment, a tank or basin in which settleable solids are removed by gravity.

sewage: The total of organic waste and waste water generated by residential and commercial establishments.

sewage lagoon: See lagoon.

sewer: Any pipe or conduit used to collect and carry away sewage or storm-water runoff from the generating source to treatment plants or receiving streams. A sewer that conveys household and commercial sewage is called a sanitary sewer. If it transports runoff from rain or snow, it is called a storm sewer. Often storm water runoff and sewage are transported in the same system or combined sewers.

sewerage: The entire system of sewage collection, treatment and disposal. Also applies to all effluent carried by sewers whether it is sanitary sewage, industrial wastes or storm water runoff.

shield: A wall that protects workers from harmful radiation released by radioactive materials.

silt: Finely divided particles of soil or rock. Often carried in cloudy suspension in water and eventually deposited as sediment.

sinking: A method of controlling oil spills that employs an agent to entrap oil droplets and sink them to the bottom of the body of water. The oil and sinking agent are eventually biologically degraded.

skimming: The mechanical removal of oil or scum from the surface of water.

sludge: The construction of solids removed from sewage during waste water treatment. Sludge disposal is then handled by incineration, dumping or burial.

smog: Generally used as an equivalent of air pollution, particularly associated with oxidants.

smoke: Solid particles generated as a result of the incomplete combustion of materials containing carbon.

SO_x: A symbol meaning oxides of sulfur.

soft detergents: Biodegradable detergents.

soil conditioner: A biologically stable organic material such as humus or compost that makes soil more amenable to the passage of water and to the distribution of fertilizing material, providing a better medium for necessary soil bacteria growth.

solid waste: Useless, unwanted or discarded material with insufficient liquid content to be free flowing. Also see waste. (1) agricultural—solid waste that results from the raising and slaughtering of animals, and the processing of animal products and orchard and field crops. (2) commercial—waste generated by stores, offices and other activities that do not actually turn out a product. (3) industrial—waste that results from industrial processes and manufacturing. (4) institutional — waste originating from educational, health care and research facilities. (5) municipal—residential and commercial solid waste generated within a community. (6) pesticide—the residue from the manufacturing, handling or use of chemicals intended for killing plant and animal pests. (7) residential—waste that normally originates in a residential environment. Sometimes called domestic solid waste.

solid waste disposal: The ultimate disposition of refuse that cannot be salvaged or recycled.

solid waste management: The purposeful, systematic control of the generation, storage, collection, transport, separation, processing, recycling, recovery and disposal of solid wastes.

sonic boom: The tremendous booming sound produced as a vehicle, usually a supersonic jet airplane, exceeds the speed of sound, and the shock wave reaches the ground.

soot: Agglomerations of tar-impregnated carbon particles that form when carbonaceous-material does not undergo complete combustion.

sorption: A term including both adsorbtion and absorption. Sorption is basic to many processes used to remove gaseous and particulate pollutants from an emission and to clean up oil spills.

spoil: Dirt or rock that has been removed from its original location, specifically materials that have been dredged from the bottoms of waterways.

stabilization: The process of converting active organic matter in sewage sludge or solid wastes into inert, harmless material.

stabilization ponds: See lagoon, oxidation pond.

stable air: An air mass that remains in the same position rather than moving in its normal horizontal and vertical directions. Stable air does not disperse pollutants and can lead to high buildups of air pollution.

stack: A smokestack; a vertical pipe or flue designed to exhaust gases and suspended particulate matter.

stack effect: The upward movement of hot gases in a stack due to the temperature difference between the gases and the atmosphere.

stagnation: Lack of wind in an air mass or lack of motion in water. Both cases tend to entrap and concentrate pollutants.

stationary source: A pollution emitter that is fixed rather than moving as an automobile.

storm sewer: A conduit that collects and transports rain and snow runoff back to the ground water. In a separate sewerage system, storm sewers are entirely separate from those carrying domestic and commercial waste water.

stratification: Separating into layers.

strip mining: A process in which rock and top soil strata overlying ore or fuel deposits are scraped away by mechanical shovels. Also known as surface mining.

sulfur dioxide (SO_2) A heavy, pungent, colorless gas formed primarily by the combustion of fossil fuels. SO_2 damages the respiratory tract as well as vegetation and materials and is considered a major air pollutant.

sump: A depression or tank that serves as a drain or receptacle for liquids for salvage or disposal.

surfactant: An agent used in detergents to cause lathering. Composed of several phosphate compounds, surfactants are a source of external enrichment thought to speed the eutrophication of our lakes.

surveillance system: A monitoring system to determine environmental quality. Surveillance systems should be established to monitor all aspects of progress toward attainment of environmental standards and to identify potential episodes of high pollutant concentrations in time to take preventive action.

suspended solids (SS): Small particles of solid pollutants in sewage that contribute to turbidity and that resist separation by conventional means. The examination of suspended solids and the BOD test constitute the two main determinations for water quality performed at waste water treatment facilities.

synergism: The cooperative action of separate substances so that the total effect is greater than the sum of the effects of the substances acting independently.

systemic pesticide: A pesticide chemical that is carried to other parts of a plant or animal after it is injected or taken up from the soil or body surface.

T

tailings: Second grade or waste material derived when raw material is screened or processed.

tertiary treatment: Waste water treatment beyond the secondary, or biological stage that includes removal of nutrients such as phosphorus and nitrogen, and a high percentage of suspended solids. Tertiary treatment, also known as advanced waste treatment, produces a high quality effluent.

thermal pollution: Degradation of water quality by the introduction of a heated effluent. Primarily a result of the discharge of cooling waters from industrial processes, particularly from electrical power generation. Even small deviations from normal water temperatures can affect aquatic life. Thermal pollution usually can be controlled by cooling towers.

threshold dose: The minimum dose of a given substance necessary to produce a measurable physiological or psychological effect.

tolerance: The relative capability of an organism to endure an unfavorable environmental factor. The amount of

topography

a chemical considered safe on any food to be eaten by man or animals. Also see pesticide tolerance.

topography: The configuration of a surface area including its relief, or relative elevations, and the position of its natural and man-made features.

toxicant: A substance that kills or injures an organism through its chemical or physical action or by altering its environment; for example, cyanides, phenols, pesticides or heavy metals. Especially used for insect control.

toxicity: The quality or degree of being poisonous or harmful to plant or animal life.

trickling filter: A device for the biological or secondary treatment of waste water consisting of a bed of rocks or stones that support bacterial growth. Sewage is trickled over the bed enabling the bacteria to break down organic wastes.

troposphere: The layer of the atmosphere extending seven to ten miles above the earth. Vital to life on earth, it contains clouds and moisture that reach earth as rain or snow.

turbidimeter: A device used to measure the amount of suspended solids in a liquid.

turbidity: A thick, hazy condition of air due to the presence of particulates or other pollutants, or the similar cloudy condition in water due to the suspension of silt or finely divided organic matter.

U

urban runoff: Storm water from city streets and gutters that usually contains a great deal of litter and organic and bacterial wastes.

V

vapor: The gaseous phase of substances that normally are either liquids or solids at atmospheric temperature and pressure; for example, steam and phenolic compounds.

vapor plume: The stack effluent consisting of flue gas made visible by condensed water droplets or mist.

vaporization: The change of a substance from the liquid to the gaseous state. One of three basic contributing factors to air pollution, the others are attrition and combustion.

variance: Sanction granted by a governing body for delay or exception in the application of a given law, ordinance or regulation.

vector: Disease vector—a carrier, usually an arthropod, that is capable of transmitting a pathogen from one organism to another.

volatile: Evaporating readily at a relatively low temperature.

W

waste: Also see solid waste. (1) bulky waste—items whose large size precludes or complicates their handling by normal collection, processing or disposal methods. (2) construction and demolition waste—building materials and rubble resulting from construction, remodeling, repair and demolition operations. (3) hazardous

waste — wastes that require special handling to avoid illness or injury to persons or damage to property. (4) special waste—those wastes that require extraordinary management. (5) wood pulp waste — wood or paper fiber residue resulting from a manufacturing process. (6) yard waste—plant clippings, prunings and other discarded material from yards and gardens. Also known as yard rubbish.

waste water: Water carrying wastes from homes, businesses and industries that is a mixture of water and dissolved or suspended solids.

water pollution: The addition of sewage, industrial wastes or other harmful or objectionable material to water in concentrations or in sufficient quantities to result in measurable degradation of water quality.

water quality criteria: The levels of pollutants that affect the suitability of water for a given use. Generally, water use classification includes: public water supply; recreation; propagation of fish and other aquatic life; agricultural use and industrial use.

water quality standard: A plan for water quality management containing four major elements: the use (recreation, drinking water, fish and wildlife propagation, industrial or agricultural) to be made of the water; criteria to protect those uses; implementation plans (for needed industrial-municipal waste treatment improvements) and enforcement plans, and an anti-degradation statement to protect existing high quality waters.

watershed: The area drained by a given stream.

water supply system: The system for the collection, treatment, storage and distribution of potable water from the sources of supply to the consumer.

water table: The upper level of ground water.

X, Y, Z

zooplankton: Planktonic animals that supply food for fish.