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Environmental Boundaries to Energy Development

Alvin W. Trivelpiece

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Abstract

Public concern about the environment, health and safety consequences of energy technology has been growing steadily for more than two decades in the United States. This concern forms an important boundary condition as the United States seeks to develop a new National Energy Strategy. Furthermore, the international aspects of the energy/environment interface such as acid rain, global climate change and stratospheric ozone depletion are very prominent in U.S. thinking. In fact, the energy systems of the world are becoming more closely coupled environmentally and otherwise. No where is this coupling more important than that between the industrialized and developing world; the choices made by each will have profound effects on the other.

The development of energy technologies compatible with both economic growth and improving and sustaining environmental quality represents a major R&D challenge to the U.S. and the USSR. Decisions about adoption of new technology and R&D priorities can be improved by better measurements of how energy sources and uses are changing throughout the world and better methods to project the potential consequences of these decisions. Such projections require understanding relative risks of alternative existing and evolving technologies. All of these R&D areas, technology improvement, energy system monitoring and projection and comparative risk assessment are the topics of this seminar. Progress in each may be enhanced by collaboration and cooperation between our two countries.

Environmental Boundaries to Energy Development
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1. Introduction

This paper is designed to set the stage for and put in context the seminar contributions by the other members of the U.S. National Academy of Sciences (NAS) team. This seminar might be considered an umbrella under which the other joint NAS/ASUSSR energy panels might fit. They are the ones on global climate change, energy efficiency R&D and nuclear power plant safety. In addition, the subject of this activity is relevant to the work of the Intergovernmental Panel on Climate Change (IPCC). What we are concerned about here is not only the environmental impacts of world energy development but also the development and deployment of improved energy technologies. These I define as technologies which will pose more acceptable risks to human health and safety and the environment while simultaneously achieving the goal of providing energy services needed everywhere for economic growth and social development at the lowest possible costs.

In the second section, the changing attitudes toward the environment are described and certain similarities between the U.S. and Soviet experiences are noted. For the past 25 years in the United States, the public concern about the environment has grown unabated, despite the energy crises of the seventies, and it is fair to say that this trend is observed in many countries, even in developing countries.

In section three, the ongoing effort to develop a new National Energy Strategy in the U.S. is discussed. Environmental concerns provide one set of boundary conditions within which the strategy is being formulated.

Finally, in section four, we discuss each of the four seminar topics, and how the U.S. papers fit into them.

2. Public Attitudes Toward the Environment

Attitudes toward technology and its interface with the environment have changed as dramatically as technology itself has changed over the years. As mechanization and industrial growth become prevalent throughout the United States, there was a beginning of change in public attitude away from the pioneer image of the unmanaged natural environment as a hostile domain to be conquered toward a view of the wilderness as a spiritual refuge— a view popularized by Henry David Thoreau and Ralph Waldo Emerson that continues as one of the mainstays of the present environmental movement in the United States.

George Catlin, the celebrated painter of American Indians was the first to propose the preservation of nature in national parks. In 1832 he wrote that Indians, buffaloes, and the wilderness in which they existed need not yield completely to the ravages of civilization if the government would protect them in a magnificent park.

The continuous tension between values of wilderness preservation and land utilization was illustrated in the work of George Perkins Marsh, author of "Man and Nature; or Physical Geography as Modified by Human Action" (1864), who observed the counter-productive effects of human dominance over nature. His principal illustration was the effects (e.g. floods, erosion, and climate change) of indiscriminate lumbering on the watersheds of rivers such as had occurred in the ancient Mediterranean empires. Because of Marsh, the idea of environmental preservation was seen to have utilitarian justifications. Marsh's work laid the foundation for a twenty-year campaign that culminated in the 1885 New York State bill to establish the Adirondacks as permanent wild forest lands.

The early impetus of American environmentalism was broad enough to unite many different viewpoints. Although initial exploitation of natural resources presented a common concern to environmentalists, it was not long before internal disagreements distinguished those who defined conservation as the planned use of resources from the preservationists who sought to safeguard the aesthetic and spiritual values of nature from the hands of mankind. A leader of the preservationists was the noted naturalist and founding president of the Sierra Club, John Muir. At the outset of his career, Muir had tried to reconcile the preservationists' inclinations with the utilitarian imperatives of the conservationists. However, the differences between the two groups is well illustrated by a meeting between Muir and the planned-forestry advocate, Gifford Pinchot when the latter advocated grazing sheep (described by Muir as "hoofed locusts") in the newly created federal forest reserves.

The American tradition of economic growth is strongly linked to continuing industrial expansion. Unfortunately, this growth has been accompanied by pressures on the environment from industrial discharges into the air and water. For many years the smoking factory stack was a symbol of the good life for many Americans who persisted in a cornucopian view of nature as the resilient provider of resources.

A major shock to this complacency came with the landmark publication of Rachel Carson's "Silent Spring" in 1962 (Houghton Mifflin, Boston). It was revealed that DDT, a major blessing in humanity's battles to feed the world and vanquish insect-borne diseases, was passing through the food chain with ecologically disastrous consequences for birds, small mammals, and even mankind. This sparked a new conflict; that between the cornucopians who believe in the resilience of nature and man's ability to invent technological fixes and the catastrophists who viewed nature as a fragile system susceptible to imminent irreversible damage from industrial society and economic development.

American society has steered a course between cornucopian and catastrophist extremes for more than twenty years now as we have debated the environmental limits to worldwide economic growth while beginning to put our own house into environmental order through the provisions of the Wilderness Act; the National Environmental Policy Act (requiring environmental impact statements and public hearings on major federal projects); the Clean Air Act; the Resource Conservation and Recovery Act (to deal with solid and hazardous waste); the Toxic Substance Control Act; and many more.

Figure 1 is a plot of environmental legislation versus time showing the explosion of laws over the past two decades. This is one indication of the fact that public concern about environmental issues has grown unabated since "Silent Spring".

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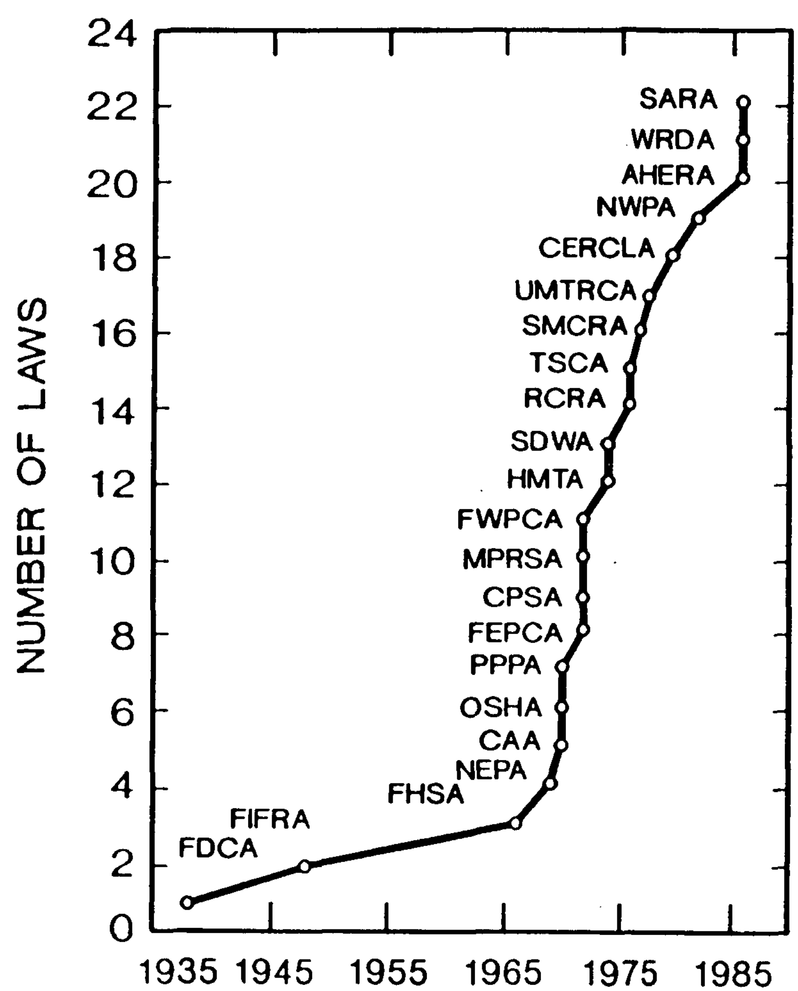
GROWTH OF HEALTH AND ENVIRONMENTAL PROTECTION LAWS



FDCA - FEDERAL DRUG AND COSMETICS (1938)
FIFRA - FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE (1948, 1972, 1975, 1983)
FHSA - FEDERAL HAZARDOUS SUBSTANCES (1966)
NEPA - NATIONAL ENVIRONMENT POLICY (1969)
PPPA - POISONOUS PACKAGING PREVENTION (1970)
OSHA - OCCUPATIONAL SAFETY AND HEALTH (1970)
CAA - CLEAR AIR (1970, 1977)
FWPCA - FEDERAL WATER POLLUTION CONTROL (CLEAN WATER) (NOW WATER QUALITY) (1972, 1977, 1987)
MPRSA - MARINE PROTECTION, RESEARCH, AND SANCTUARIES (1972)
CPSA - CONSUMER PRODUCT SAFETY (1972)
FWPCA - FEDERAL ENVIRONMENTAL POLLUTION CONTROL (1972)
SDWA - SAFE DRINKING WATER (1974, 1977, 1986)
HMTA - HAZARDOUS MATERIALS TRANSPORTATION (1974, 1984)
RCRA - RESOURCE CONSERVATION AND RECOVERY (1976, 1979)
TSCA - TOXIC SUBSTANCE CONTROL (1976)
SMCRA - SURFACE MINE CONTROL AND RECLAMATION (1977)
UMTRCA - URANIUM MILL TAILINGS RADIATION CONTROL (1978)
CERCLA - COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (1980)
NWPA - NUCLEAR WASTE POLICY ACT (1982)
AHERA - ASBESTOS HAZARD EMERGENCY RESPONSE ACT (1986)
WRDA - WATER RESOURCES DEVELOPMENT ACT (1986)
SARA - SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT (EXTENSION OF CERCLA) (1986)

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Fig. 1. Growth of health and environmental protection laws.

During this period, the Environmental Protection Agency (EPA) was established (1970) and the Council on Environmental Quality (CEQ) (1969). CEQ was formed to report on the state of the environment and to oversee the environmental statement process of the federal government. EPA consolidated what had been until then, many dispersed activities and established a single central focus for environmental concerns. Similarly, the Department of Energy was formed (1977) to coordinate the energy activities of the government. These two agencies, EPA and DOE, are at the center, therefore, of U.S. involvement with and concern over global energy development, global environmental changes and exploring the practicability of sustainable development.

Although I am not an expert on Russian history, it is tempting to speculate that a similar tension has existed here throughout the same time period. The modernizing spirit of Peter the Great seems to have embodied a view of nature not entirely dissimilar to his humbler contemporaries settling the American continent. Certainly, the giants of nineteenth century Russian literature contrasted the degradation of mind and body perpetrated by industrial urbanization to the ideal of the natural environment. The words are Tolstoy's but as well could have been Thoreau's: "Around lies the land with its grass, its woods, its pure water, pure air, sun birds, animals, but men with dreadful effort shut the sun from others and erect thirty-six storey houses, rocked by the wind, where there is neither grass nor trees, and where everything, both water and air is contaminated, all the food adulterated and spoilt, and life itself tedious and unhealthy." (Essays from Tula).

The great Russian scientist, V. I. Vernadsky, deserves his place alongside George Perkins Marsh among the founders of global environmental studies for his identification of both the biosphere (the name of his book on that topic in 1926) and the noosphere; the stage of biosphere development that meets the material, spiritual, and aesthetic demands of humankind. It seems that the concept of sustainable development may have been invented in the Soviet Union in the 1930's!

However, the USSR also has had its tensions between preservation and utilization. The twentieth century drive for economic growth without regard for the environment was not the exclusive prerogative of American capitalism, as is well illustrated by Lenin's famous dictum "Communism is Soviet power plus electrification of the whole country." However, just as U.S. environmental opposition killed projects such as Echo Dam in Dinosaur National Monument, it seems Soviet environmental opposition has finally laid to rest the Great Plan for the Transformation of Nature, initiated in the 1940's with the intent of diverting Siberian rivers to southern Russia and Central Asia.

The pace of development of environmental consciousness in the United States and the Soviet Union may have been uneven over the past three hundred years, but the new environmental Glasnost that is occurring here in the Soviet Union promises to bring the environmental agendas of both our countries into synchronous alignment. Thus, for both countries, concern about the environment has become a major boundary condition in future energy development.

3. The U.S. National Energy Strategy

Early in his administration, President George Bush recognized the need to develop a National Energy Strategy (NES) more comprehensive than previous efforts. As announced by Secretary of Energy, Admiral James Watkins in July, 1989, the NES will be developed over a period of some 18 months with the three-phase process culminating in December of 1990. The NES process will seek input from all interested organizations and individuals through a series of public meetings across the country which have begun already.

Phase I will produce a report to Congress in April, 1990 which describes the current status of the U.S. energy system, projects the future under present policies, characterizes public concerns and issues and analyzes major economic, technical and environmental constraints.

Phase II will end in September, 1990 with a report to Congress defining and analyzing various alternative strategies for achieving national energy goals. Phase III will be the NES itself, which will constitute the Administration's energy policy including budgets, legislative initiatives and regulatory changes.

The NES will be developed with the explicit understanding that environmental protection is an essential ingredient in energy policy. This is true for all parts of various fuel cycles from extraction or collection to conversion, to eventual end use and to the management of all residuals from these processes.

More and more, environmental protection is concerned with the cumulative effects of the energy enterprise as it grows. Such effects are demonstrated most vividly by atmospheric transfers such as acid rain falling on Canada because of discharges from hundreds of coal fired U.S. power plants and other sources. At a small scale, these emissions are unimportant and dilution is the solution to pollution. As the energy enterprise grows, cumulative effects become intolerable. In the U.S., acid rain has caused a multibillion dollar effort and developed so called "clean coal" technologies. Requiring the widespread application of these technologies through revision of the Clean Air Act seems imminent.[1] Also, part of the Bush Administration proposals to revisions of the Clean Air Act are stronger requirements for reducing urban pollution, notably smog and CO. These are likely to have a major impact on automobile emission control technology and on fuels. These proposals and actions by various States, most notably California could cause much more active use of alcohol fuels, especially methanol. The potential implications of these possible changes are being debated. If implemented, they will be expensive,[2] and they could impact fuel markets dramatically, most notably natural gas which would be the near term source of methanol.

Acid rain, smog, global climate, and the ozone layer will all be important issues shaping the NES as it evolves. They are as important as the issue of energy security which has been the major factor in U.S. energy policy since the Arab Oil Embargo of 1973-1974.

From what we can observe, Glasnost is causing a considerable increase in the intensity of debates about environmental issues in the Soviet Union. For one thing, the State Committee for the Protection of Nature was formed in January, 1988. Presumably this committee will serve a function not unlike our EPA.

All across the Soviet Union, people are talking about the environment as evidenced by a remarkable set of reports which appeared in the journal, Environment in December, 1988.[3]

As far as I am aware, Peristroika has not extended yet to the reorganization of the Soviet energy system as it has to the formulation of the Committee for the Protection of Nature. I understand, however, that policies are being put in place or are being debated which would cause energy prices to be set by actual costs. That was one of the important steps the U.S. took to encourage more rational energy decisions. It was a difficult thing for us to do and it took more than a decade to accomplish. Of course, many environmental costs can not be easily put into energy prices and that problem of "externalities" continues to plague decision making.

We will be most interested in hearing about the ways in which environmental concerns are factored into Soviet energy technology and energy policy. In fact, the academies could not have picked a better time to begin their joint discussion than now. Hopefully, the results will be important.

4. U.S. Contributions to the Four Seminar Topics

The four topics of this seminar came from the initial suggestions of Academician Yuriy Rudenko. They provide an agenda broad enough to span the energy-environment interface (or at least a good part of it) but also focused enough to provide a basis for more in-depth exchanges of ideas and discussion of specific suggestions. The four topics are:

- Energy technologies appropriate to industrialized and developing nations especially as they may relate to global climate changes;
- Data, data standards and modeling methods for measuring and forecasting energy system changes;
- Analyzing, measuring and comparing risks and impacts of various technologies and energy cycles; and
- Development of better technologies for the reduction of risks and impacts.

Energy Technology Choices of Industrialized and Developing Nations will, of course, determine the rate of change of greenhouse gases in the atmosphere. They are also important with respect to stratospheric ozone depletion since some refrigerants used in refrigerators, air conditioners and heat pumps and blowing agents for plastic insulation are among the worst of the troublesome clorofluorocarbons (CFC's). CFC's are also powerful infrared absorbers.

Energy technologies, however, also have important effects on local and regional environments, and it is certainly true that these more geographically constrained effects are the predominant ones influencing energy technology and fuel choices today.

It is a reasonable assumption that developing countries are much less concerned about protecting the environment than industrialized nations. For developing nations, the peril is poverty, not pollution. Table 1 contrasts (or stereotypes) the perspectives of developing and industrialized nations with respect to decisions about energy technology choices. Global climate change is but one of several reasons the industrialized world is concerned about the energy choices of the developing nations. Others include the pressures on oil markets (a point enlarged upon by William Martin in his paper), the fact that economic development is important to world stability and human welfare, and because developing nations are growing markets for technologies manufactured in industrialized countries.

The greenhouse problem is complicated not only because less polluting technologies are more expensive in general, but also by the fact that all non-fossil energy sources have significant limitations of different sorts. In fact, it seems a bit hypocritical for industrialized countries to preach to the developing nations something they themselves are unwilling to undertake. The problem with the deficiencies of the technical choices available to moderate the changing greenhouse effect are discussed in the paper by William Fulkerson. He points out that the one area where economical technology is available is in the area of more thermodynamically efficient conversion. The use of much more efficient technologies should be attractive to both industrialized and developing nations as Rob Socolow elaborates in his paper. Of course, greater efficiency may also reduce local and regional pollution, but not always. The cost of emissions control may be less thermodynamically efficient.

Environmental issues of energy development may be international from several other points of view. Pollution can be transported across borders which is certainly a major concern with respect to acid rain. It is also a significant

Table 1. Contrasts in Technology Choice Perspectives Between Industrialized and Developing Nations

Industrialized	Developing
• Insensitive To Capital Intensiveness With Protection Of Environment, Health And Safety A Growing Priority	• First Cost Sensitive
• Many Stringent Standards And Regulations Imposed On Technology	• Willing To Sacrifice Environmental Protection For Productivity
• Sophisticated Maintenance Tolerated	• Equipment Maintenance Is A Major Problem
• Commercial Sources Dominate	• Traditional Fuels Are Still Very Important And A Cause Of Deforestation
• Energy Prices Are Indexed to Real Costs – At Least That Is The Growing Trend	• Energy Prices Are Often Heavily Subsidized Which Distorts Rational Decision Making

concern about the growth of nuclear power. An accident anywhere influences nuclear power everywhere as we have learned from Three Mile Island and Chernobyl. The transport of radioactive materials frightens people much more than the actual consequences might suggest.

In addition, the international trade in fuel and energy technologies is important. (Again, the paper by William Martin reflects this consideration.) For example, natural gas from the Soviet Union (and the North Sea) may be a means to displace or constrain the use of coal and oil throughout Europe for several decades. Such substitutions can significantly reduce CO_2 emissions but may increase methane releases to the atmosphere. The United States is busy marketing its clean coal technologies around the world, in addition to the coal itself. Clean coal technologies represent an environmental decision making dilemma. They may greatly improve the local environment at the expense of the global environment. Since coal is already used, it is better to use it cleanly. Similar environmental considerations may arise as international electrical grids evolve.

Finally, the prospects for more collaborative efforts between nations and development of better energy technologies may yield important environmental benefits. One can site examples of cooperation such as the International Atomic Energy Agency (IAEA) and initiatives among the Soviet Union, the United States, Japan and the European Community on fusion research. Similar efforts are ongoing on nuclear fission technology and an active exchange is happening on technologies to improve efficiency of energy conversion and end use. In addition, efforts to establish international emission standards and agreements such as the Nuclear Nonproliferation Treaty profoundly influence energy technology development and evolution.

Our discussion of the first topic of energy technology choices and the international character of future energy development leads naturally to the second topic, "monitoring and projecting energy development across the world." Improving these capabilities will be crucial to better decision making by individual nations and the community of nations collectively.

The quality of data on energy systems has improved enormously over the past decade and one-half, but many difficulties persist. These include: 1) agreement between nations about the important variables to be measured; 2) consistency in the use of common definitions, units of measure and accounting conventions; 3) assuring necessary quality; and 4) finding appropriate methods to collect or to elicit data. The data for many developing nations is sparse and of dubious quality. Given the importance of developing nations on global environmental issues, this deficiency needs to be corrected. In addition, collecting compatible energy system and environmental data is particularly challenging for any country. These and other concerns are the subject of the paper by Linda Carlson.

The right data is essential to analyzing both how the energy system and the environment have changed over time and to project future trends. The importance of models is to provide a means for revealing how social forces and improved technologies may influence the quality of the environment. This sort of modeling is very difficult, and it is in the infancy of its development. Nevertheless, a great deal has been learned about the dynamics of energy systems and their residuals as is discussed in the paper by Jae Edmonds. Particularly challenging is the prediction of technology choice. Adoption of a given technology may be influenced by many factors including economic growth, resource availability and price and various government policies such as R&D, regulation and incentives.

In addition, many attributes determine competitive advantage of a given technology in addition to costs. These include productivity, quality, market availability, compatibility with existing conditions, and environmental, health, and safety characteristics.

This presents a bewildering array of variables, all of which differ from one country to another. Despite the complexity, some progress is being made and one can site heroic efforts such as the recent analysis by EPA of policy alternatives for controlling the greenhouse effect,[4] but much more research needs to be done, both on the data collection and the modeling fronts.

But how do we "compare the relative risks of energy technology and fuel cycle choices?" This third topic of the seminar confronts us directly with the tough problem of multi-objective comparative analyses. The impacts of energy systems can be viewed from numerous perspectives; for example, the geographical extent of the concern as indicated in Table 2; the time scale; the resource commitment and severity of possible consequences.

In the United States, a very interesting technique has been developed and is used by the federal government in making decisions about actions which may have major environmental consequences. This is the environmental impact statement process. It requires the careful analysis of the full consequences of the proposed action in comparison to alternatives. The process involves public hearings in which opinions from interested or effected people are solicited. Often the process results in substantial changes being made to the originally proposed action. The process is used in connection with many energy decisions as, for example, the licensing of nuclear power plants.

As Steven Peck points out in his paper, however, decision making on energy technology in the United States is decentralized. Individuals, companies, and electric utilities make their own decisions about technologies they will adopt. Thus, for example, the decision by a utility to build a coal fired rather than a nuclear plant is made by the utility without any interference by the federal government except that all environmental regulations must be complied with. It is through environmental regulations that concerns about risks are made explicit parts of the decision making calculus. Some environmental concerns have not yet become part of the regulatory equation, e.g., CO_2 emissions. The paper by Shelly Evans describes some of the processes and techniques used by EPA in setting environmental regulations.

Some would find it desirable to develop a universal measure of risk (where risk = consequences x probability) such that all environmental damage and health and safety risks are put on the same scale. Then estimates of the total risks of each energy technology and fuel cycle could be compared and balanced against differences in relative costs and performances. One way to do this might be to compare the gross characteristics of technologies such as normalized emissions of various pollutants, weigh each measure according to its importance and then add the scores. Also, maximum acceptable levels of each measure of impact could be established. A technology exceeding such a level would be deemed unacceptable.

Table 2. Current and Imminent Environment, Safety, and Health Problems and Issues Related to the Energy System

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Global consequences of energy use

- The greenhouse effect: a potential show stopper for fossil fuels
- Stratospheric ozone depletion: chlorofluorocarbon substitutes are needed
- Nuclear accidents and proliferation of nuclear fissionable material: what happens anywhere in the world impacts nuclear power everywhere

Multinational consequences

- Acid rain: will drive the development of cleaner coal technologies

National consequences

- Environmental, health, and safety risks of fuel cycles: all primary sources have undesirable impacts of one kind or another which may be the objects of national concern and regulation

Local and regional consequences

- Smog (ozone) and carbon monoxide: could promote the development of alternate fuels and vehicles
- Land and water resources: important factors in the choice of energy sources (e.g., solar, biomass, near-surface coal, and oil shale)
- NIMBY ("Not in my back yard"): this syndrome epitomizes the decision making problem for many new energy facilities

Individual (or family) level consequences

- Indoor air pollution: an important design constraint in new high-efficiency buildings and in retrofitting older ones
- Automobile safety: a potential barrier to improving vehicle efficiency through weight reduction

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Figures 2 through 4 and Tables 3 and 4 give some comparative characteristics of a number of electric technologies. Unfortunately no one has come up with a good weighting scheme to use to put such measures on a basis which can be added. Also not shown is the relative costs of alternatives. Although these sorts of gross comparisons may be interesting, they are unlikely to be very useful except perhaps to focus attention on R&D needs or to focus on a particular impact such as acid rain or CO_2.

Assessments of risks of alternative technologies for a specific application at a particular site may be very useful. The comparisons are typically between alternative 1) technologies; 2) plant designs; 3) effluent streams or components, and 4) careful options. For these decisions, the art of comparative risk assessments have progressed to an advanced state.

Another problem with comparative risk assessment of energy technologies is that some risks are perceived by the public to be much more important than others, regardless of their actual values computed by "experts." This may sometimes occur in the case where the probability of an event is very small but the consequence is very large; as in the case of a nuclear power plant catastrophic accident. In this case, the acceptance of risk may depend on TLC. That is <u>trust</u> by the public in the institutions or people responsible for the technology, understanding of who bears the <u>liability</u> if something goes wrong i.e. who pays, and whether or not people effected have <u>consented</u> to the risk.[6] The latter brings up the point of the differences between acceptance of vicarious (or voluntary) risk (e.g. skiing in Colorado) and involuntary risk to which a person is subjected without consent. Shelly Evans considers this aspect of risk assessment in her paper.

Finally, the public may be willing to spend much more to avoid risk from one technology than it is to avoid the same risk from another. For example, the U.S. public is willing to spend much more to avoid a cancer caused by radiation than to avoid one caused by some chemicals. So, when it comes to comparing risks, the public view may not correspond at all to that of the expert.

The fourth theme follows logically from the third. "<u>What can better technologies do to reduce important risks and impacts</u>?" Over the past decade, U.S. energy technology R&D has been preoccupied with this question. Improving

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CARBON DIOXIDE EMISSIONS: ELECTRIC TECHNOLOGIES

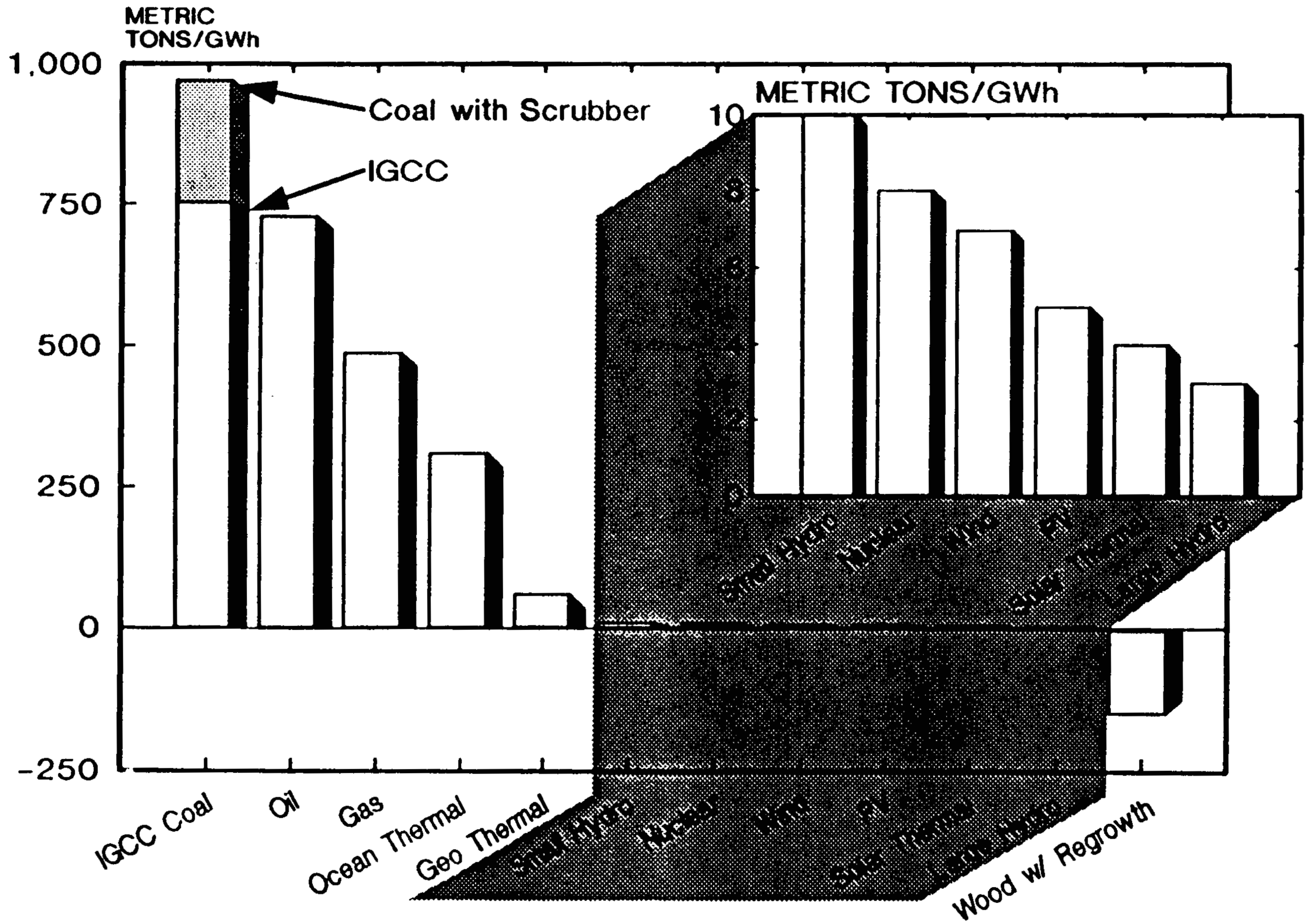
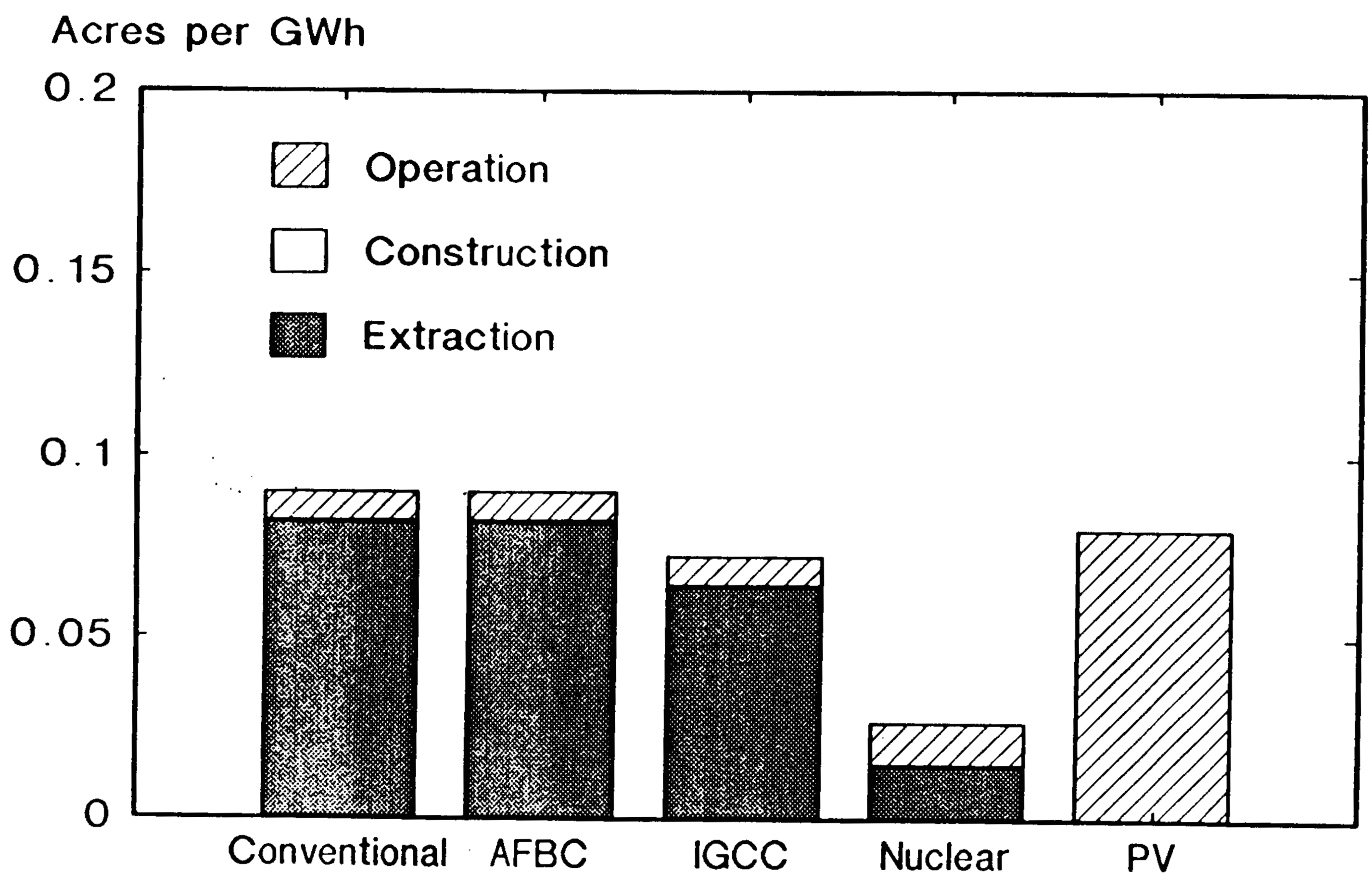


Fig. 2. Carbon dioxide emissions: Electric Technologies. Source: Robert L. San Martin, "Environmental Emissions from Energy Technology Systems: The Total Fuel Cycle," U.S. Department of Energy, Spring 1989.

LAND UTILIZATION



SOURCE: Meridan Corp. Report for the U.S. DOE, Energy Systems Emissions and Materiel Requirements, February, 1989

Fig. 3. Land utilization.

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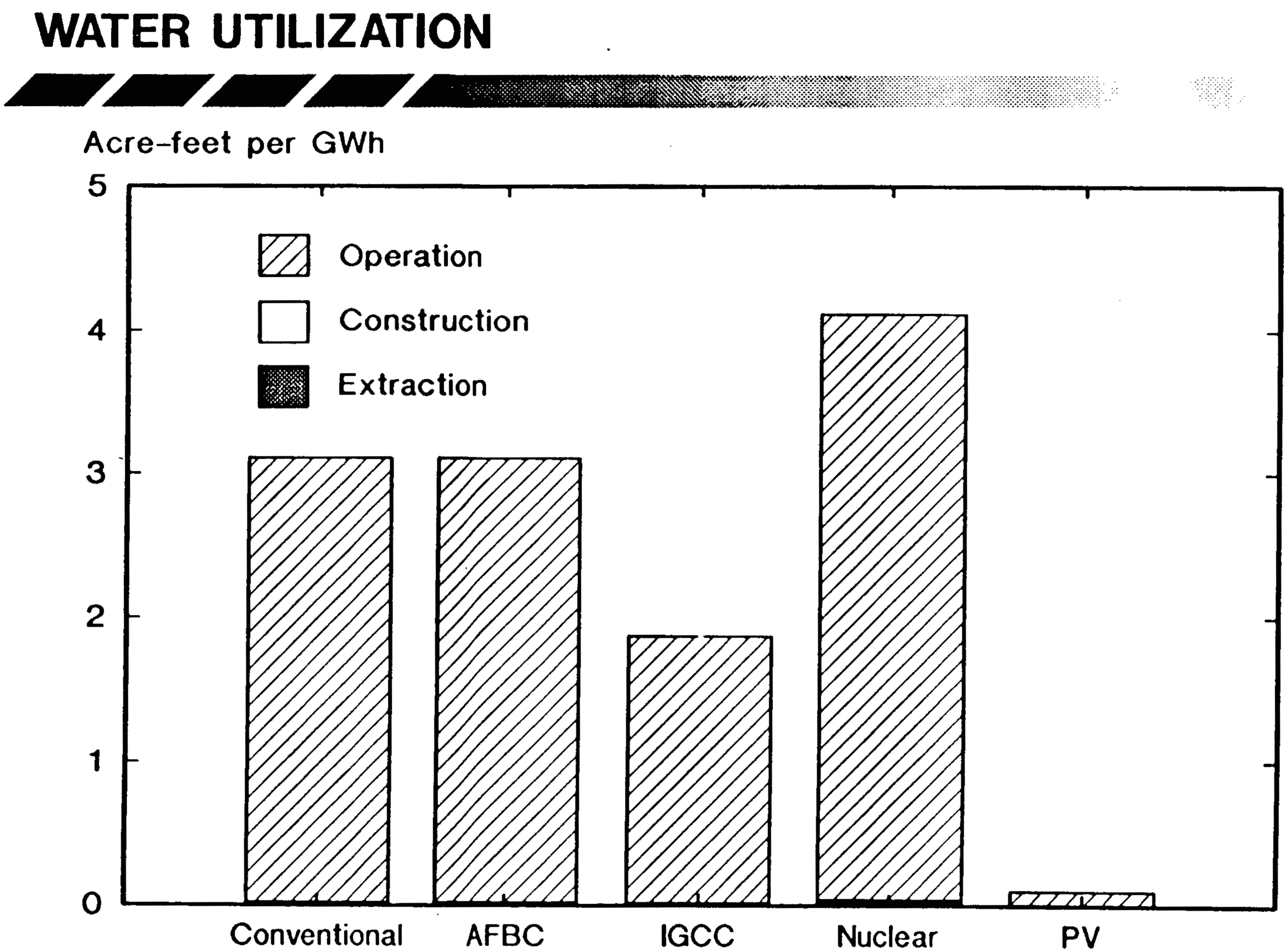


SOURCE: Meridan Corp. Report for the U.S. DOE, Energy Systems Emissions and Materiel Requirements, February, 1989

Fig. 4. Water utilization.

Table 3. Air Emissions: Electric Generation Systems (Tons per GWh)

	Conventional Plant	AFBC Plant	IGCC Electric Plant	Boiling Water Reactor	PV Central Station
CO_2					
Fuel Extraction	—	—	—*	1.642	NA†
Construction	1.048	1.048	1.048	1.088	5.890
Operation	1057.143	1055.942	822.945	5.861	NA
Total	1058.191	1057.090	823.993	8.590	5.890
NO_x					
Fuel Extraction	0.066	0.066	0.052	0.022	NA
Construction	0.001	0.001	0.001	0.001	0.008
Operation	2.914	1.484	0.198	0.011	NA
Total	2.986	1.551	0.251	0.034	0.008
SO_x					
Fuel Extraction	0.055	0.055	0.043	0.024	NA
Construction	0.002	0.002	0.002	0.001	0.023
Operation	2.914	2.911	0.291	0.003	NA
Total	2.971	2.968	0.336	0.029	0.023
Particulates					
Fuel Extraction	1.482	1.480	1.173	0.002	NA
Construction	0.001	0.001	0.002	0.001	0.017
Operation	0.143	0.143	0.001	neg	NA
Total	1.626	1.624	1.176	0.003	0.017
CO					
Fuel Extraction	0.061	0.061	0.048	0.002	NA
Construction	0.001	0.001	0.001	0.001	0.003
Operation	0.206	0.205	—	0.016	NA
Total	0.267	0.267	—	0.018	0.003
HC					
Fuel Extraction	0.039	0.039	0.030	0.001	NA
Construction	—	—	—	—	0.002
Operation	0.063	0.063	—	—	NA
Total	0.102	0.102	—	0.001	0.002
Aldehydes					
Fuel Extraction	0.008	0.008	0.006	—	NA
Construction	—	—	—	—	—
Operation	neg‡	neg	neg	neg	NA
Total	0.008	0.008	0.006	neg	—
Trace Metals					
Arsenic					
Fuel Extraction	NA	NA	NA	NA	NA
Construction	NA	NA	NA	NA	NA
Operation	0.064	—	—	NA	NA
Total	0.064	—	—	NA	NA

* (-) symbolizes unavailable or incomplete data in an area where this impact would be expected to occur.
† (NA) stands for not applicable for this technology or stage of production.
‡ (neg) stands for negligible.

Source: Meridan Corporation Report for U.S. Department of Energy, *Energy Systems Emissions & Material Requirements,* February, 1989.

Table 4. Water Emissions: Electric Generation Systems (Tons per GWh)

	Conventional Plant	AFBC Plant	IGCC Electric Plant	Boiling Water Reactor	PV Central Station
Dissolved Solids					
Fuel Extraction	0.278	0.277	0.216	—	NA
Construction	—	—	—	—	—
Operation	—	—	—	—	—
Total	0.278	0.277	0.216	—	—
Suspended Solids					
Fuel Extraction	0.005	0.005	0.004	—	NA
Construction	—	—	—	—	—
Operation	—	—	—	—	—
Total	0.005	0.005	0.004	—	—
Oil/Grease					
Fuel Extraction	neg	neg	neg	neg	NA
Construction	neg	neg	neg	neg	0.002
Operation	neg	neg	neg	neg	neg
Total	neg	neg	neg	neg	0.002
Ammonia					
Fuel Extraction	neg	neg	neg	0.002	NA
Construction	NA	NA	NA	NA	NA
Operation	NA	NA	NA	NA	NA
Total	neg	neg	neg	0.002	NA
Sulfate					
Fuel Extraction	0.192	0.191	0.149	0.001	NA
Construction	neg	neg	neg	neg	neg
Operation	neg	neg	neg	0.004	neg
Total	0.192	0.191	0.149	0.005	neg
Fluorine					
Fuel Extraction	NA	NA	NA	0.005	NA
Construction	NA	NA	NA	NA	NA
Operation	NA	NA	NA	NA	NA
Total	NA	NA	NA	0.005	NA
Nitrate					
Fuel Extraction	NA	NA	NA	0.004	NA
Construction	NA	NA	NA	NA	NA
Operation	NA	NA	NA	NA	NA
Total	NA	NA	NA	0.004	NA
Sodium					
Fuel Extraction	NA	NA	NA	0.001	NA
Construction	NA	NA	NA	NA	NA
Operation	NA	NA	NA	0.002	NA
Total	NA	NA	NA	0.003	NA
Tritium					
Fuel Extraction	NA	NA	NA	NA	NA
Construction	NA	NA	NA	NA	NA
Operation	NA	NA	NA	0.002	NA
Total	NA	NA	NA	0.002	NA

Source: Meridan Corporation Report for U.S. Department of Energy, *Energy Systems Emissions & Material Requirements,* February, 1989.

technology is, after all, one way to reduce the costs of protecting human health and safety and the environment.

U.S. efforts have focused on 1) clean coal technologies to reduce acid rain; 2) nuclear power plant safety, radioactive waste management and fixing legacy problems; 3) ways to reduce automobile emissions; and 4) substitutes for CFC. Also, as a result of concerns about global warming, interest is growing in technologies which can more efficiently convert and use fossil fuels, in natural gas as a substitute for coal and in renewable energy sources.

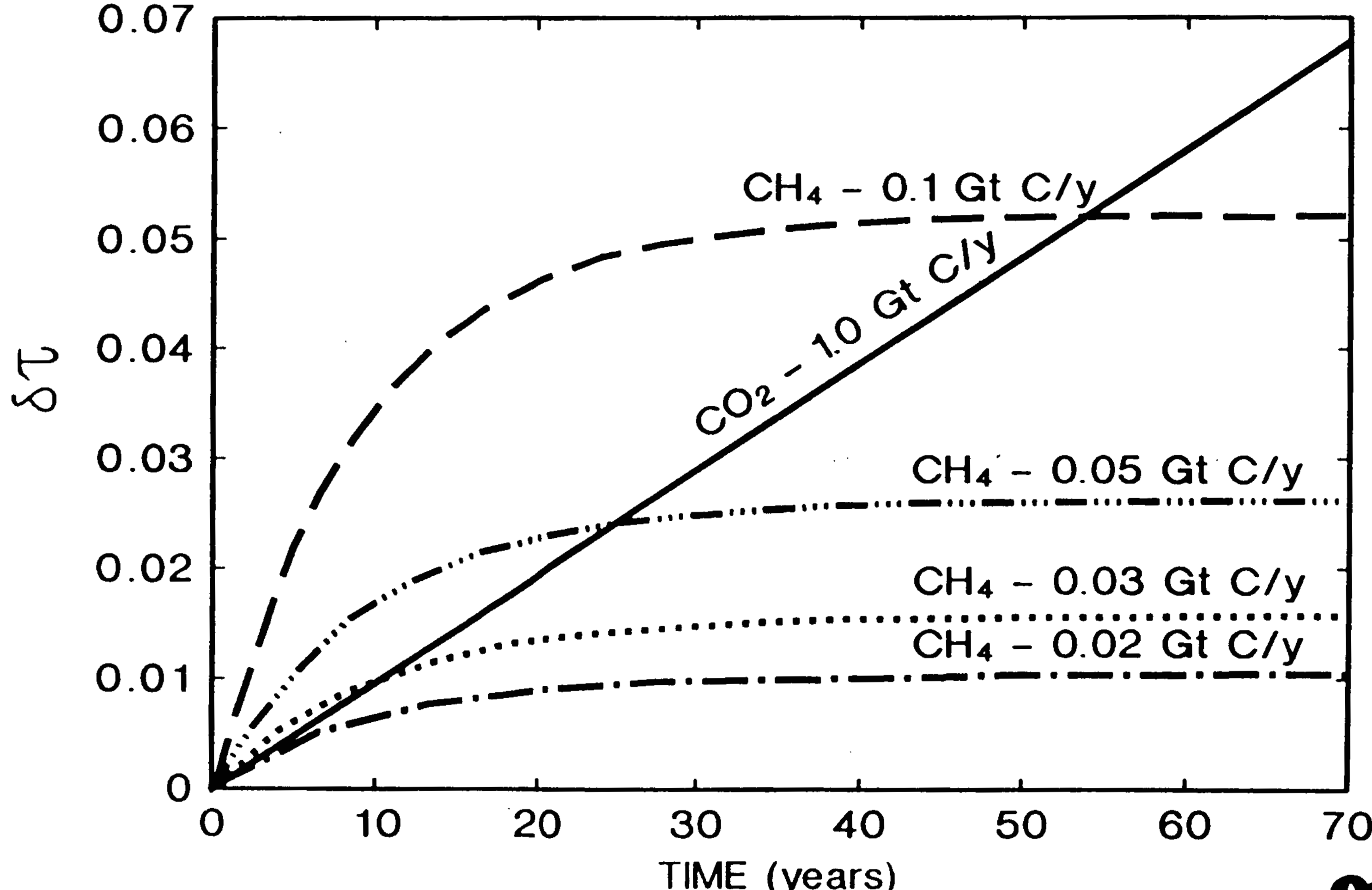
The paper by Myron Gotlieb considers the various important technologies for natural gas which can contribute to solving environmental problems. These range from cofiring with coal in power plants to reduce NO_x emissions to the use of compressed natural gas in vehicles. As Gotlieb points out advanced technologies such as steam injected turbines, the combined cycles of combustion turbine and steam Rankine cycle turbine, and fuel cells provide opportunities for producing electricity from gas at efficiencies greater than 50%. Thus, the advantage of gas over coal for reducing CO_2 emission is two-fold. First the hydrogen to carbon ratio is four times as great so carbon emissions per unit of combustion energy is only about 3/5 that of coal, and secondly, the combustion heat can be used more efficiently.

A very large question is posed by natural gas use, however. Methane is a strong greenhouse gas, much more optically active on a molecule by molecule basis than CO_2. Furthermore, it is increasing in the atmosphere at about 1%/year. The sources are not well understood but they include both biological sources and fossil fuel sources. The later is estimated to be about 20% of the total and comes from coal seams and from the natural gas and petroleum systems.[7] We need to know much more about these sources. As shown in Figure 5, if leakage from the natural gas system is proportional to the use rate, and it is of the order of 2% or more than the advantages of using natural gas compared to coal may be lost; at least until the methane begins to saturate (at about 30 years).

It should be noted, however, that new clean coal technologies applied to refurbish existing coal fired plants in the United States can also reduce emissions substantially. The potential of this so called "repowering" is shown in

Fig. 5.

THE GREENHOUSE EFFECT OF NATURAL GAS IS THE SUM OF CO_2 AND METHANE LEAKAGE



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Combined greenhouse effect of burning natural gas for various gas system leakage rates. The gas use rate is assumed to be constant at 1.0 GtC/yr., about what the world rate is today. The atmospheric fraction for CO_2 release is assumed to be 0.5 and to be constant over time. Hence, the greenhouse effect of CO_2 emissions vary linearly. The methane leakage rates are assumed to range from 0.02 to 0.1 GtC/yr. The greenhouse effect of the methane emissions reaches a plateau because the rate of destruction of the molecule is assumed to be proportional to the atmospheric concentration. The greenhouse effect is represented by τ which is defined as $\Delta T(t)/\Delta T_{CO_2\ doubling}$ where $\Delta T_{CO_2\ doubling}$ is the temperature rise from doubling the concentration of CO_2 in the atmosphere.

Table 5. Full adoption of these advanced technologies could reduce SO_2 emissions in the United States by 29 to 44%, NO_x by 14 to 17% and CO_2 by 5 to 12%. Solid residues would range from 8% larger to 16% smaller.

The paper by Jack White puts many of the energy technology alternatives in perspective. In particular, the role of government in stimulating the development and adoption of new technologies is discussed. Success requires a creative partnership between government and the private sector. Examples are given of innovative projects sponsored by the New York State Energy Research and Development Administration and carried out by private sector firms capable of commercializing successful technology developed.

One conclusion from all this seems obvious. There are no perfect energy technologies. All are flawed to one degree or another with respect to their impacts on the environment and human health and safety. The so called inexhaustible sources, solar, nuclear fission and fusion are not ready yet to compete economically with fossil fuels on a large scale. Ultimately, we will need at least one of these inexhaustible sources as inexpensive fossil resources diminish. They may be needed much sooner if global climate change becomes as serious a problem as many believe it will. Thus, a broad R&D effort is required to advance the state of energy technologies, both fossil and non-fossil, and to better understand the consequences of each as the energy systems of the world expand.

In some areas, R&D might best be pursued through international or bilateral collaboration whereas the natural competition between nations may produce more rapid advances in others. Nevertheless, since the energy systems of nations are coupled environmentally, sharing of information is essential and cooperation to obtain a better understanding of environmental impacts is a good idea regardless. That is why this joint activity between the two academics can lead to productive and important outcomes.

Table 5. Environmental Characteristics for the Repowering Technologies

	Applicable Market	Change in national emissions (%)			
	(quads)	SO_2	NO_x	CO_2	Solid Waste
CAFB	27.4	-44	-17	-5	+8
PFB	27.4	-48	-17	-8	-4
IGCC	27.4	-37	-17	-6	-5
Fuel Cell	27.4	-29	-14	-12	-16

Source: *Programmatic Environmental Impact Statement on the Clean Coal Technology Demonstration Program*, U.S. Department of Energy Report DOE/EIS-0146D, June, 1989.

CAFB - Circulating Atmospheric Fluidized Bed

PFB - Pressurized Fluidized Bed

IGCC - Intergrating Gasification Confined Cycle

REFERENCES

[1] Bush Administration proposed revision of Clean Air Act. (to be obtained)

[2] Russell, Milton. September 9, 1988, "Ozone Pollutions: The Hard Choices" *Science* 241.

[3] "Three Reports from the Soviet Union", *Environment*, 30, #10, p. 4-15, 1988.

[4] U.S. Environmental Protection Agency. Lashof, Daniel A. and Tirpak, Dennis, A. February 1989. *Policy Options for Stabilizing Global Climate*, Draft Report to Congress.

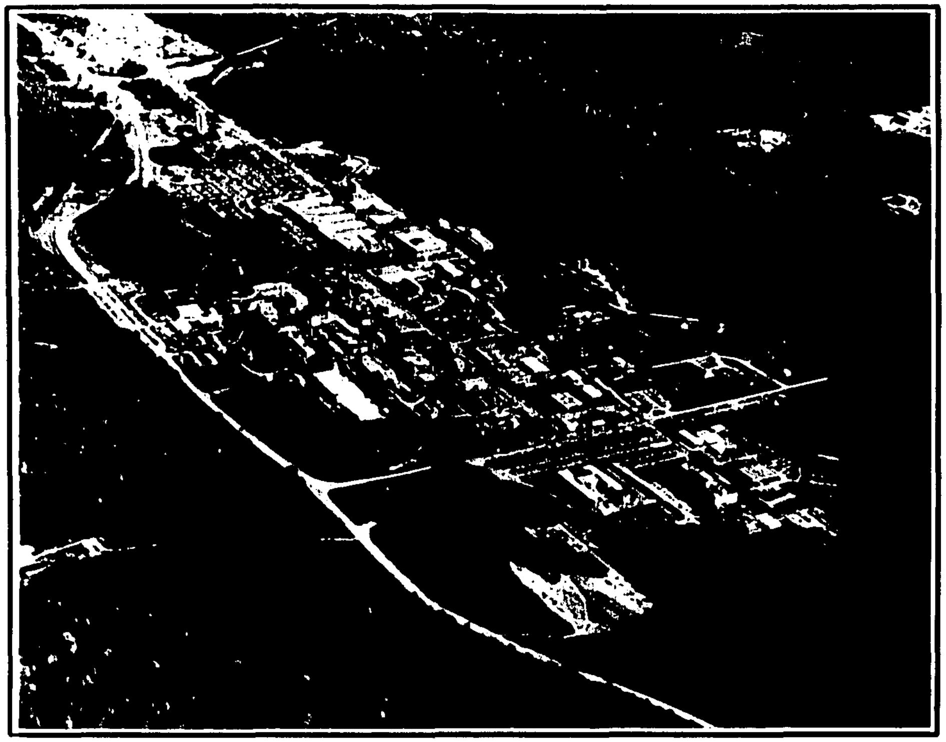
[5] Fulkerson W. et al., 1989. *Energy Technology R&D: What Could Make A Difference?*. ORNL 6541/V1. Oak Ridge National Laboratory, Oak Ridge, Tenn. vol 1: vol 2 ORNL 6541/V2, in press.

[6] Rayner, S. and Cantor, R. 1987. "How Fair Is Safe Enough? The Cultural Approach to Societal Technologty Choice.[1] *Risk Analysis,* Vol 7, No. 1. 1987 p. 1-9.

[7] Wahlen, M., Tanaka, N., Henry, R., Deck, B., Zeglen, J., Vogel, J. S., Southon, J., Shemesh, A., Fairbanks, R., and Broecker, W. "Carbon -14 in Methane Sources and in Atmospheric Methane: The Contribution from Fossil Carbon.*Science* 254. p. 286-290.

ORNL-DWG 89Z-16857

Environmental Boundaries To Energy Development



Alvin W. Trivelpiece
Director,
Oak Ridge National Laboratory

- Public attitudes toward the environment
- The U.S. National Energy Strategy
- Four seminar topics
  — U.S. contributions

The Joint U.S. National Academy of Sciences and Academy of Sciences of the USSR Seminar on Global Energy Development and Associated Ecological (Environmental) Impacts
Moscow, USSR
October 17 - 20, 1989

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Decline In High-Elevation U.S. Forests Is Estimated To Be 1.5 Million ha

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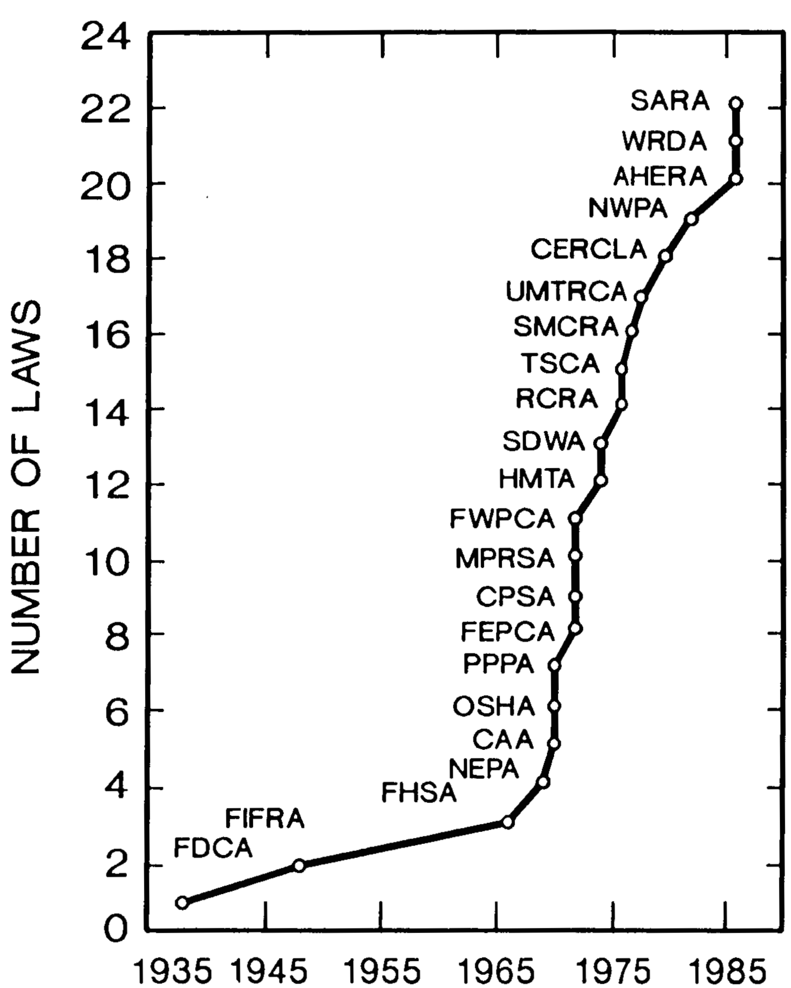
GROWTH OF HEALTH AND ENVIRONMENTAL PROTECTION LAWS



FDCA	- FEDERAL DRUG AND COSMETICS (1938)
FIFRA	- FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE (1948, 1972, 1975, 1983)
FHSA	- FEDERAL HAZARDOUS SUBSTANCES (1966)
NEPA	- NATIONAL ENVIRONMENT POLICY (1969)
PPPA	- POISONOUS PACKAGING PREVENTION (1970)
OSHA	- OCCUPATIONAL SAFETY AND HEALTH (1970)
CAA	- CLEAR AIR (1970, 1977)
FWPCA	- FEDERAL WATER POLLUTION CONTROL (CLEAN WATER) (NOW WATER QUALITY) (1972, 1977, 1987)
MPRSA	- MARINE PROTECTION, RESEARCH, AND SANCTUARIES (1972)
CPSA	- CONSUMER PRODUCT SAFETY (1972)
FWPCA	- FEDERAL ENVIRONMENTAL POLLUTION CONTROL (1972)
SDWA	- SAFE DRINKING WATER (1974, 1977, 1986)
HMTA	- HAZARDOUS MATERIALS TRANSPORTATION (1974, 1984)
RCRA	- RESOURCE CONSERVATION AND RECOVERY (1976, 1979)
TSCA	- TOXIC SUBSTANCE CONTROL (1976)
SMCRA	- SURFACE MINE CONTROL AND RECLAMATION (1977)
UMTRCA	- URANIUM MILL TAILINGS RADIATION CONTROL (1978)
CERCLA	- COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (1980)
NWPA	- NUCLEAR WASTE POLICY ACT (1982)
AHERA	- ASBESTOS HAZARD EMERGENCY RESPONSE ACT (1986)
WRDA	- WATER RESOURCES DEVELOPMENT ACT (1986)
SARA	- SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT (EXTENSION OF CERCLA) (1986)

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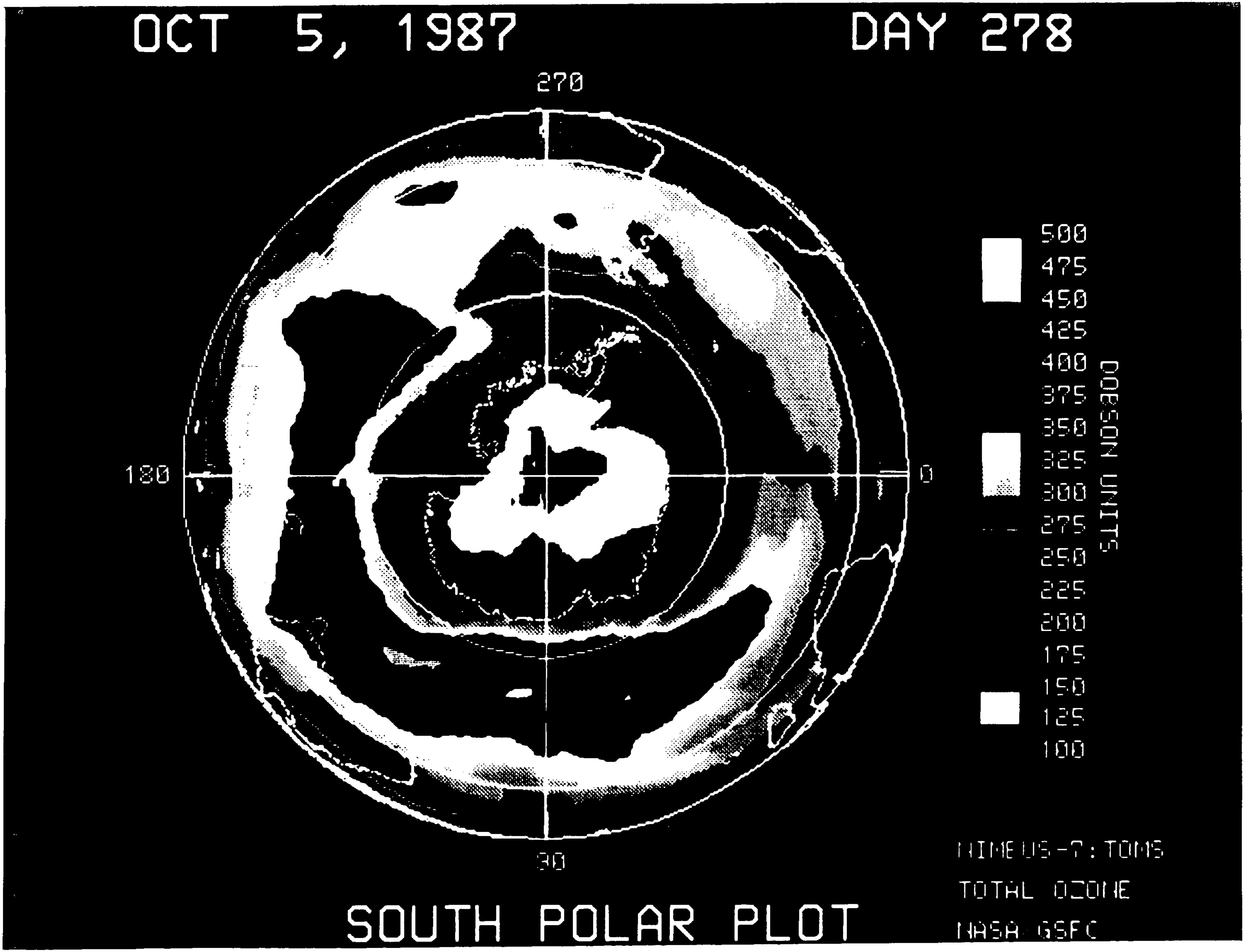

OCT 5, 1987
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150
125
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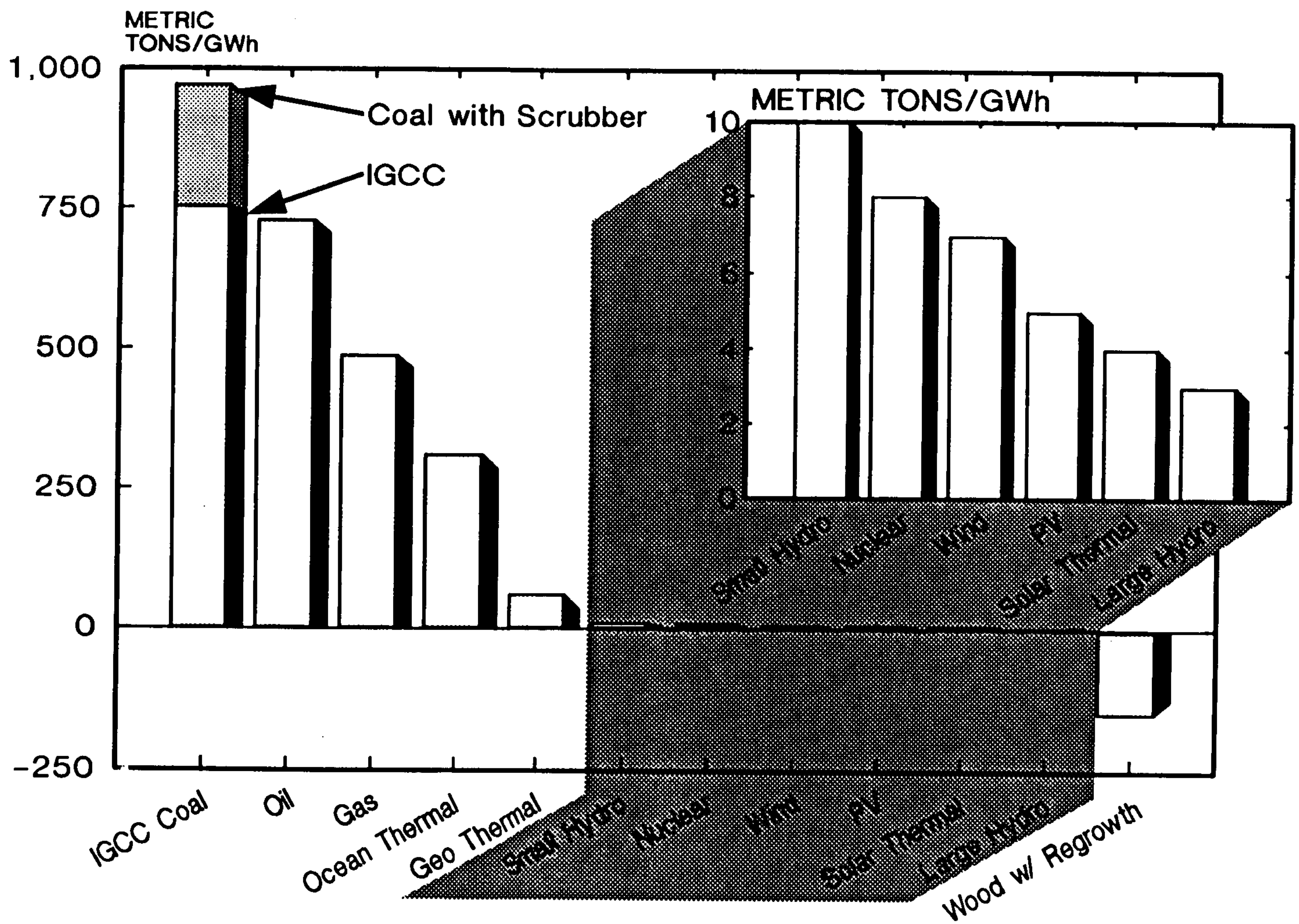
DOBSON UNITS
NIMBUS-7: TOMS
TOTAL OZONE
NASA GSFC
SOUTH POLAR PLOT

ORNL-DWG 89Z-16630

CARBON DIOXIDE EMISSIONS: ELECTRIC TECHNOLOGIES



SOURCE: Robert L. SanMartin, "Environmental Emissions from Energy Technology Systems: The Total Fuel Cycle," U.S. DOE, Spring 1989

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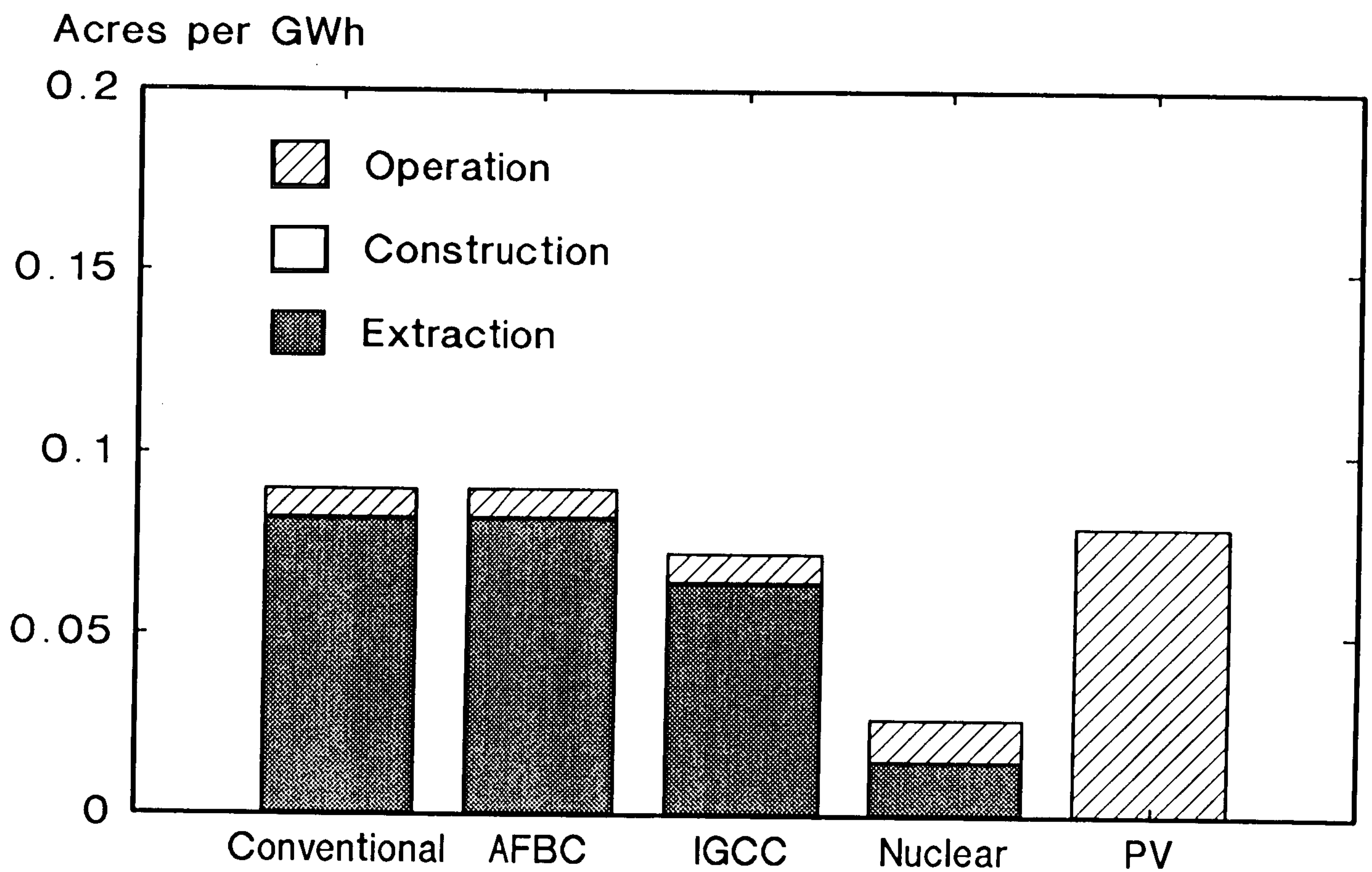
ORNL-DWG 89Z-16631

LAND UTILIZATION



SOURCE: Meridan Corp. Report for the U.S. DOE, Energy Systems Emissions and Materiel Requirements, February, 1989

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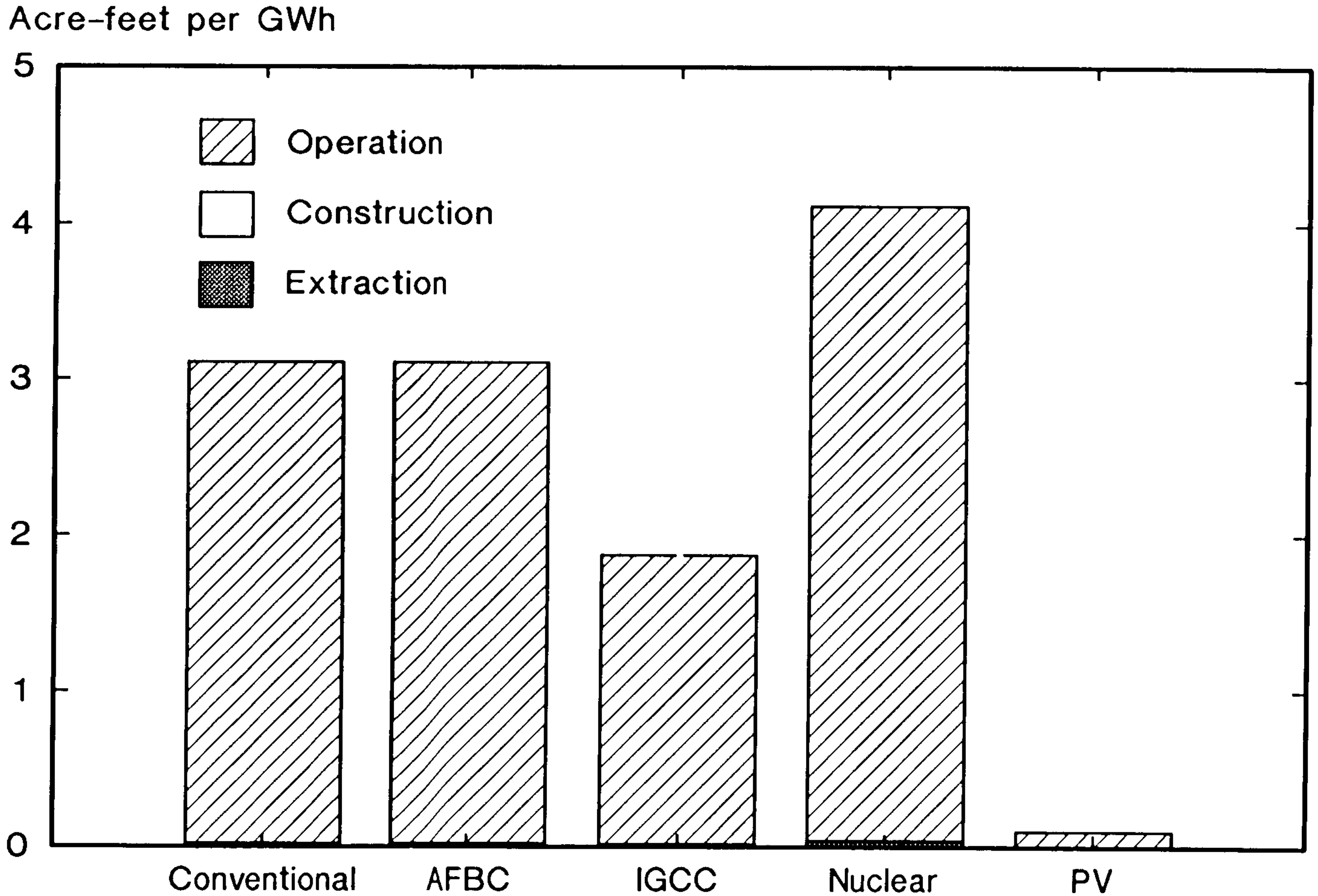
ORNL-DWG 89Z-16632

WATER UTILIZATION



SOURCE: Meridan Co~p. Report for the U.S. DOE, Energy Systems Emissions and Materiel Requirements, February, 1989

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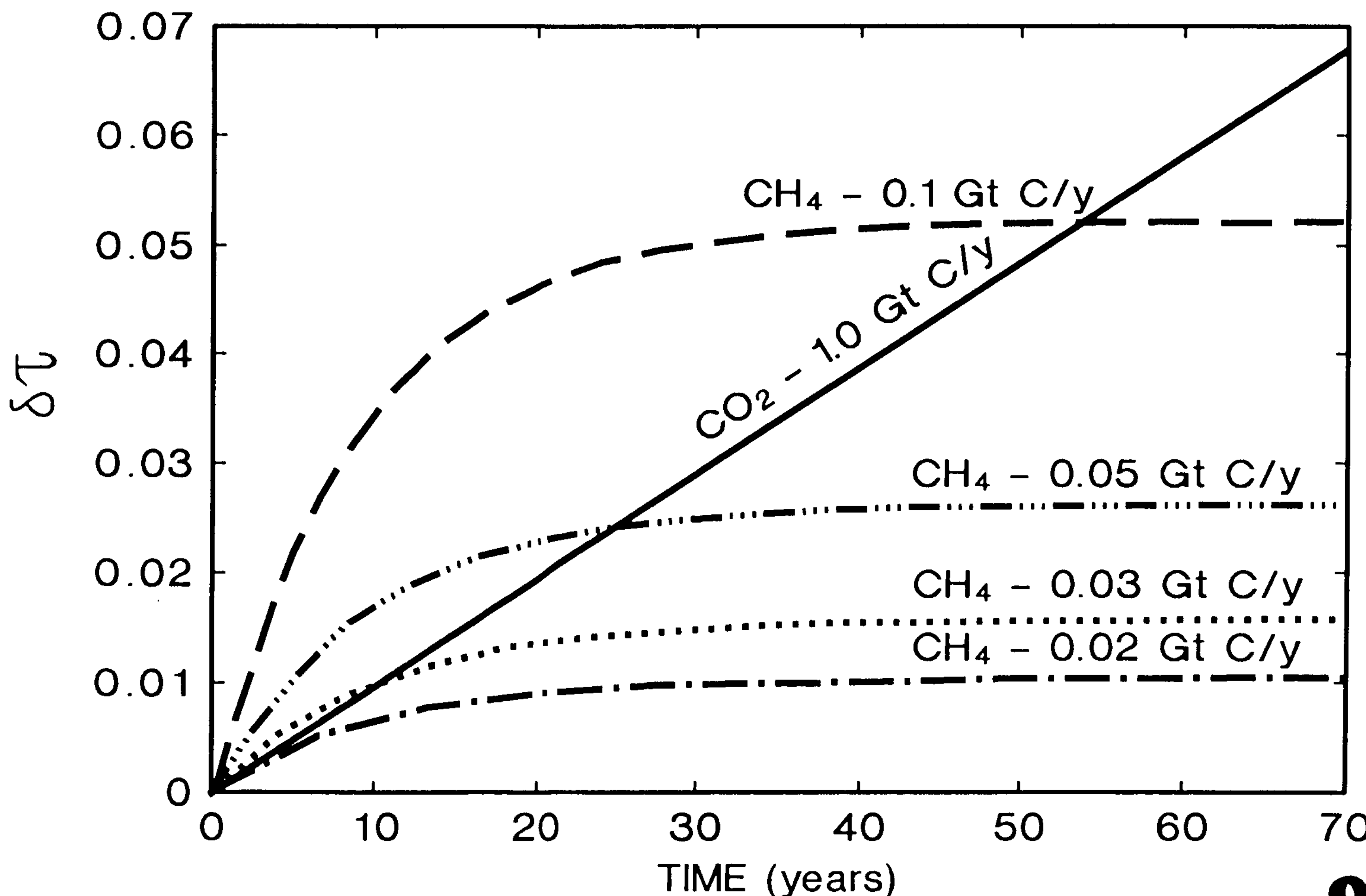
THE GREENHOUSE EFFECT OF NATURAL GAS IS THE SUM OF CO_2 AND METHANE LEAKAGE



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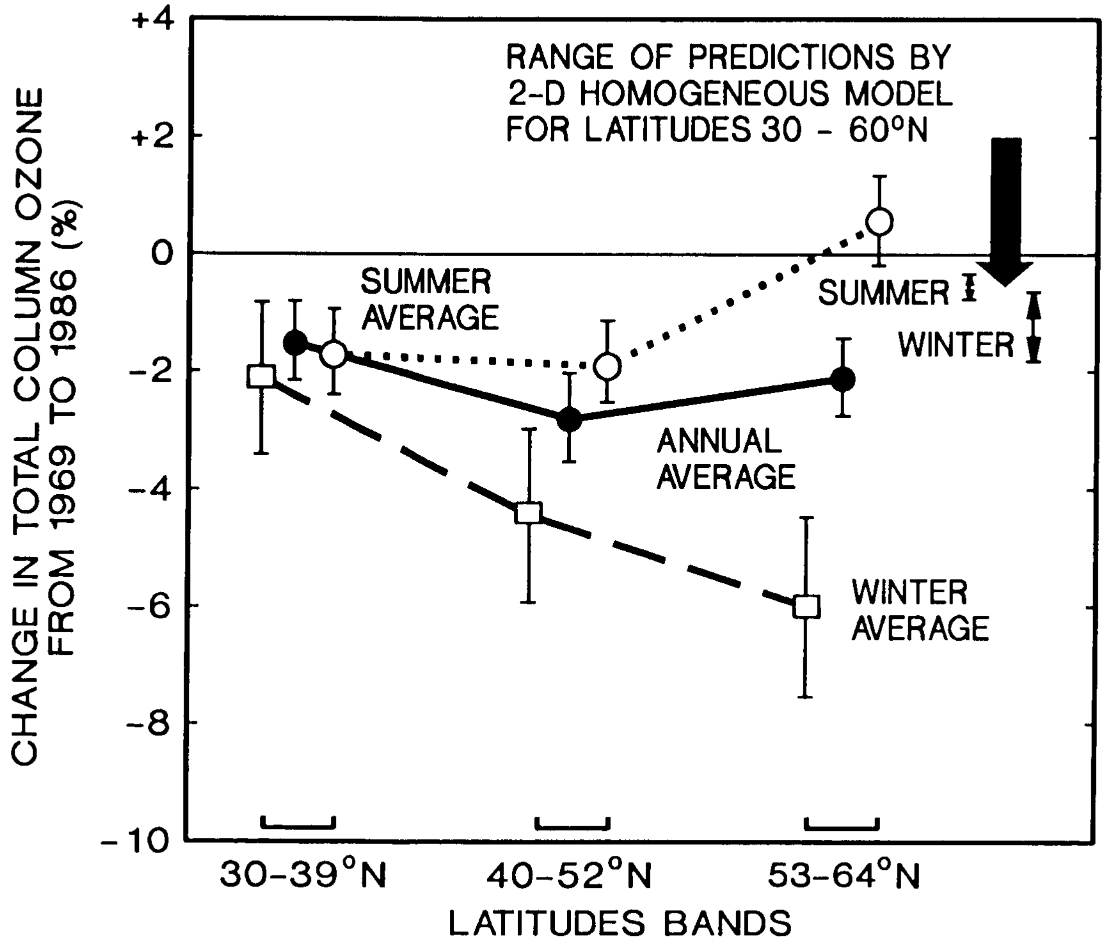
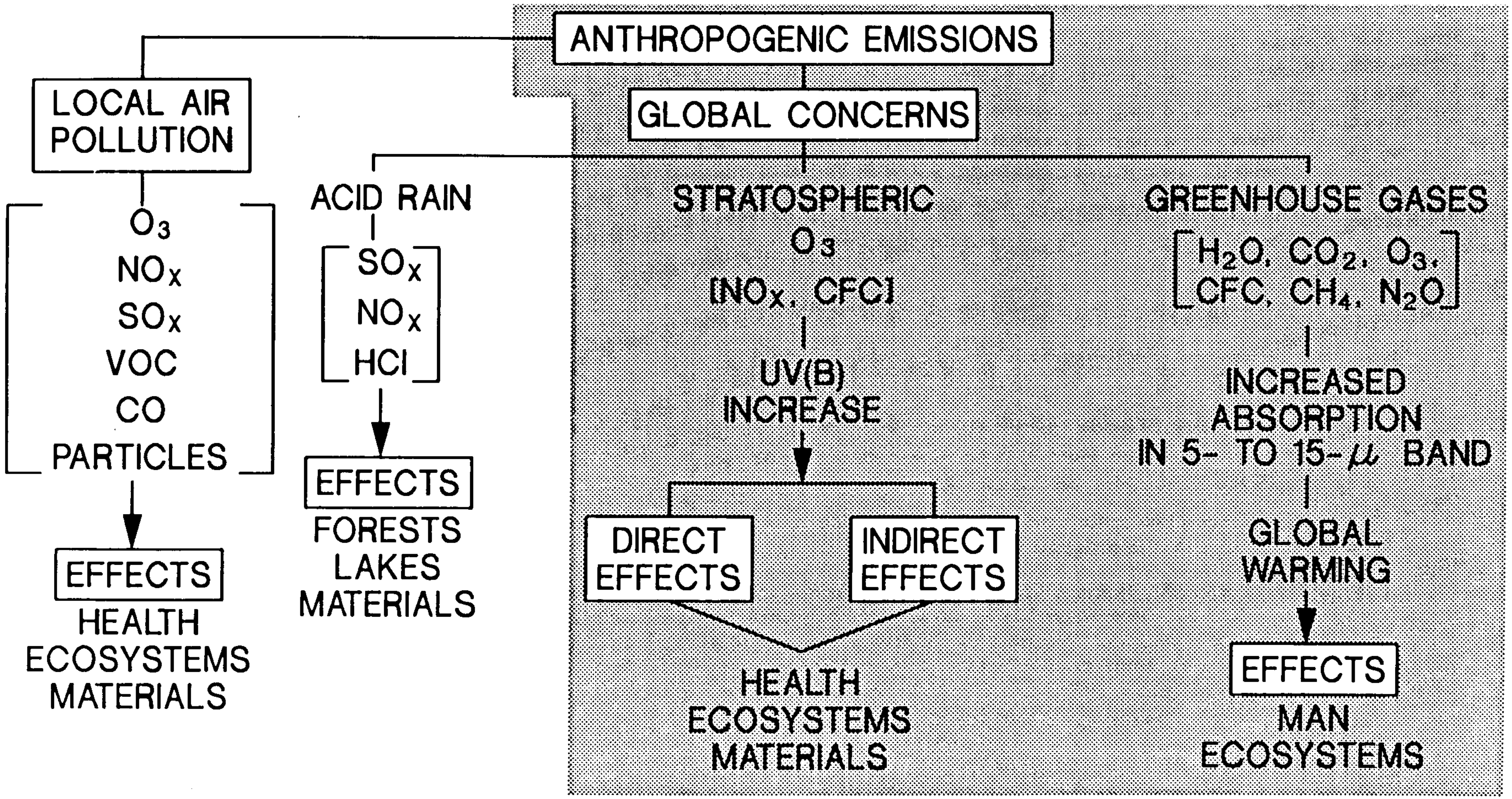
SEASONAL DISTRIBUTION OF GLOBAL OZONE (DOBSON MEASUREMENTS)



ORNL-DWG 89Z-16864

Ozone Issue Includes Linkages and Feedbacks With Tropospheric Pollution And The Greenhouse Effect



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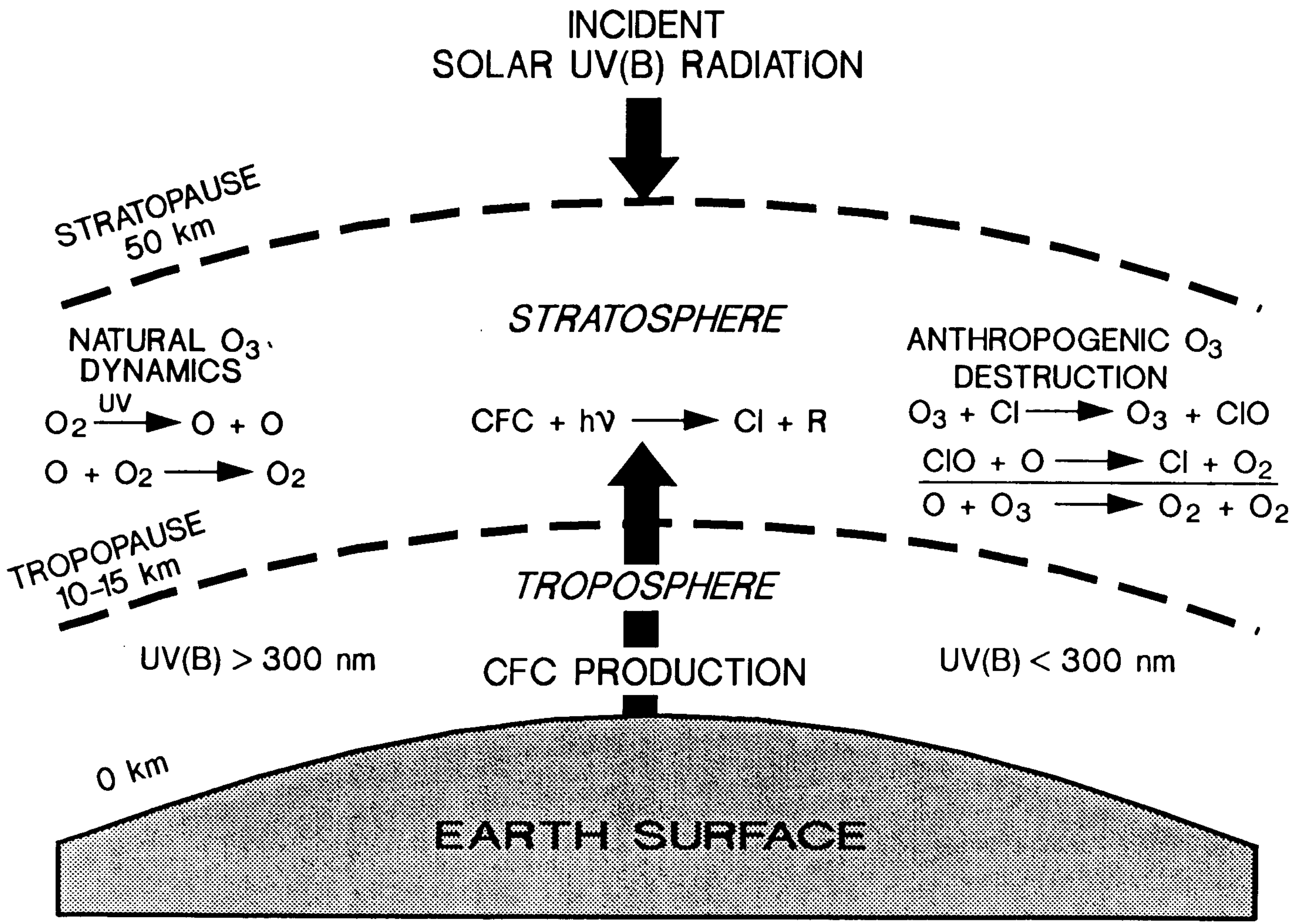
ORNL-DWG 89Z-16859

NATURAL AND ANTHROPOGENIC OZONE DYNAMICS



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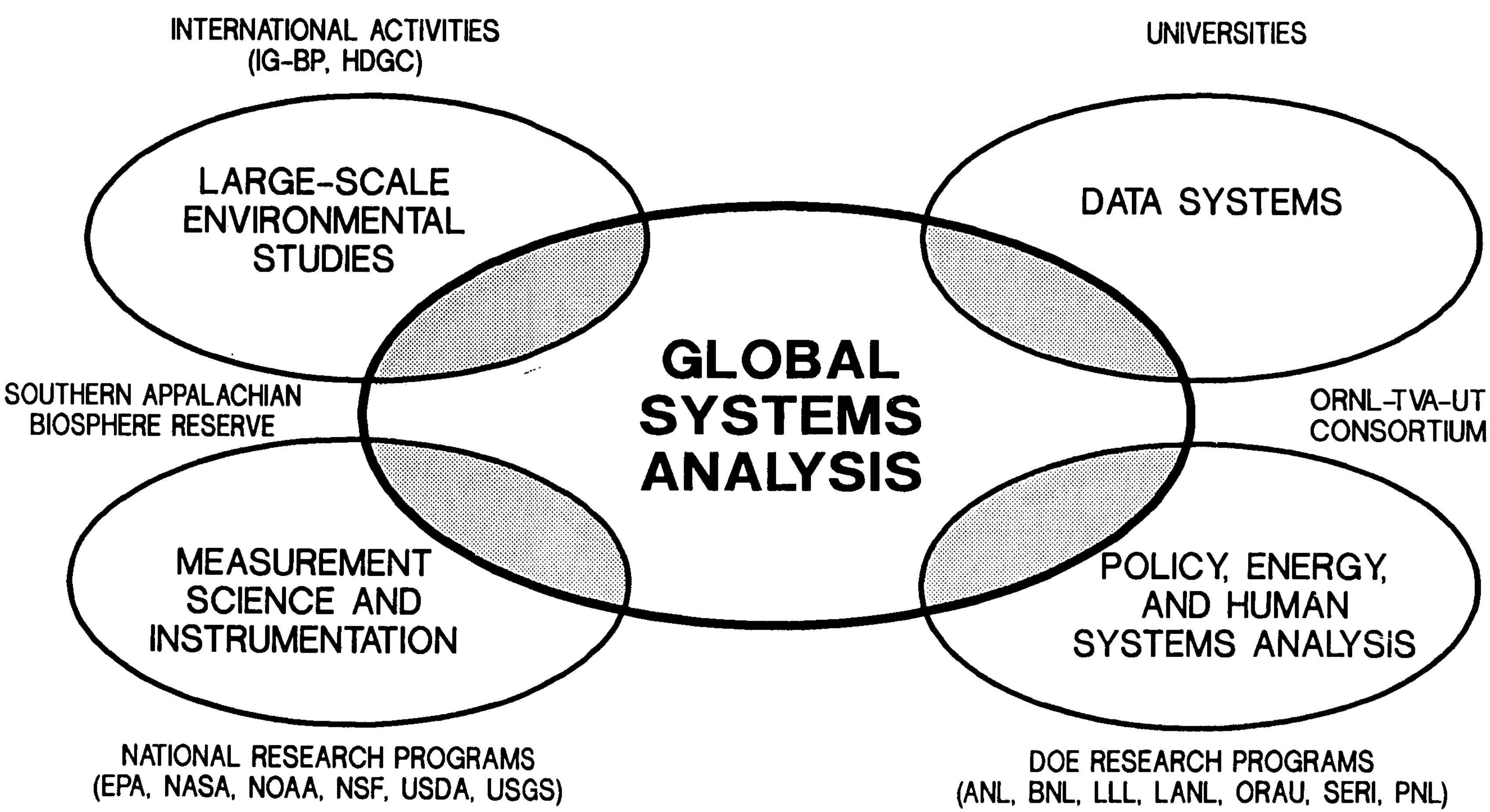
ORNL DWG 89Z-13888

ORNL Center For Global Environmental Studies



ORNL-DWG 89Z-16860

Contrasts In Technology Choice Perspectives

Industrialized Countries	Developing Countries
• Capital insensitive with environment a growing priority	• First cost sensitive
• Many standards and regulations	• Productivity first; pollution control second
• Sophisticated maintenance tolerated	• Equipment maintenance a major problem
• Commercial sources dominate	• Traditional fuels important - a cause of deforestation
• Prices reflect costs - a growing trend	• Prices heavily subsidized

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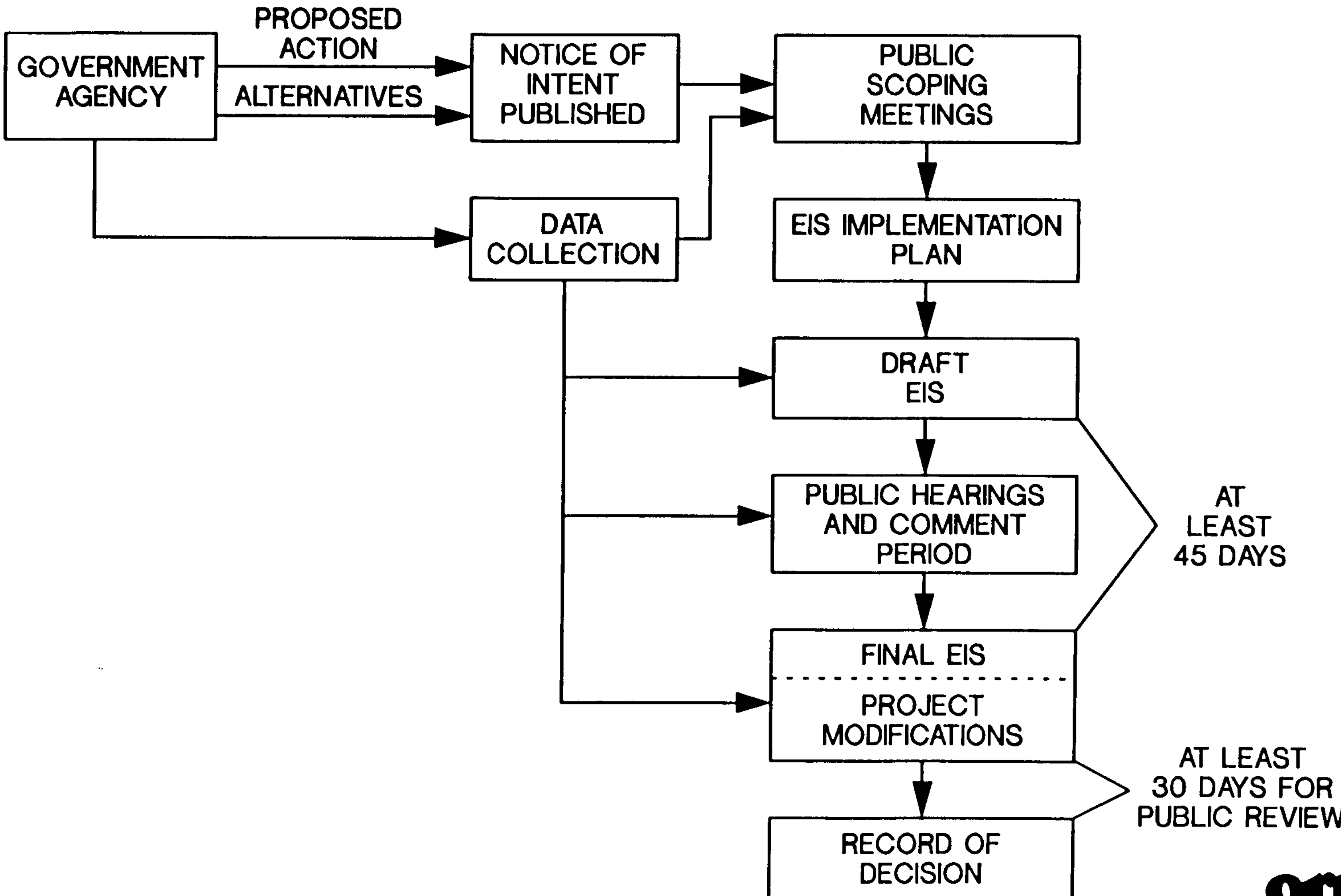
The Data Problems In Developing Countries Make Analysis Difficult

- Even at the most aggregate levels, data are inconsistent or unavailable

- Comparative analysis of national income accounts done by University of Pennsylvania and the Wharton School firnds the poorest data in the poorest countries of Africa and South America

ORNL-DWG 89Z-16924

U.S. ENVIRONMENTAL IMPACT STATEMENT PROCESS INVOLVES THE PUBLIC IN DECISION MAKING



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Environment, Safety And Health Issues Related To The Energy System

- Global concerns
  - Changing greenhouse effect
  - Stratospheric ozone depletion
  - Nuclear accidents and deversion of fissionable material
- Multinational consequences
  - Acid rain
- National consequences
  - Relative risks of fuel cycles
- Local and regional consequences
  - Smog and rising CO levels
  - Land and water resource committment
- Individual or family level consequences
  - indoor air pollution
  - Automobile safety
  - Energy service safety

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Costs Per Life Saved By Reducing Cancer Risks

• Ionizing Radiation	$3.6 million (NRC)
• Chemical Carcinogens	$2 million (EPA) $3.8 million (44 Federal Agencies)

Sources:

NRC; Safety Goals for Nuclear Power Plant Operations, NUREG-0880, Rev 1, 1983.

Travis, C.C., Richter-Pack, S. and Fisher, A., "Cost Effectiveness as a Factor in Cancer Risk Management", Environ. Intern., 13, 469-74, 1987.

ORNL-DWG 89Z-16863

Environmental Characteristics For The Repowering Technologies

	Applicable Market	Change in national emissions (%)			
	(quads)	SO_2	NO_X	CO_2	Solid Waste
CAFB	27	-44	-17	-5	8
PFB	27	-48	-17	-8	-4
IGCC	27	-37	-17	-6	-5
Fuel Cell	27	-29	-14	-12	-16

CAFB - Circulating Atmospheric Fluidized Bed

PFB - Pressurized Fludized Bed

IGCC - Intergrating Gasification Confined Cycle

SOURCE: Programmatic Environmental Impact Statement on the Clean Coal Technology Demonstration Program, U.S. DOE Report DOE/EIS-0146D, June, 1989.

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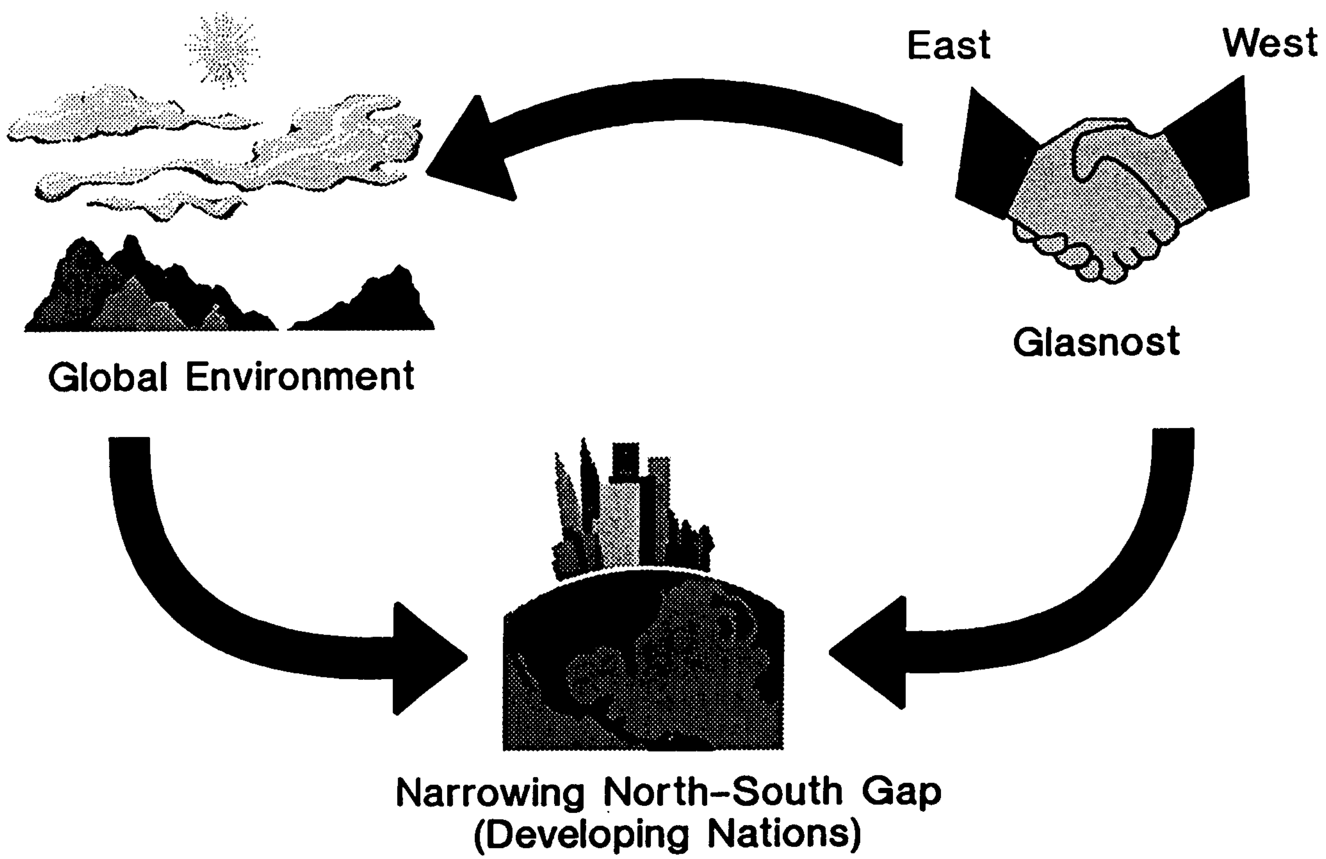
FUNDAMENTAL CHANGES ARE SHAPING ENERGY TECHNOLOGY R&D NEEDS



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ORNL-DWG 88Z-18228R

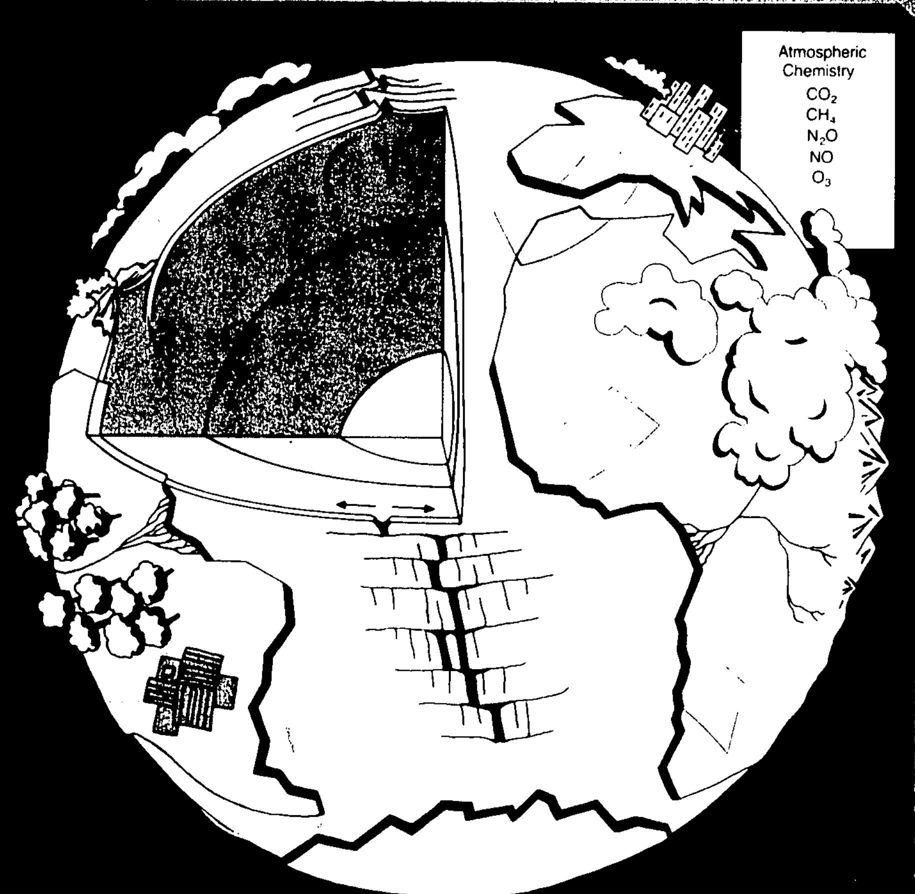
Examples Of Critical Global Issues

Climate Change

Ozone Depletion

Globally Distributed Contaminants

Erosion, Desertification, and Urbanization

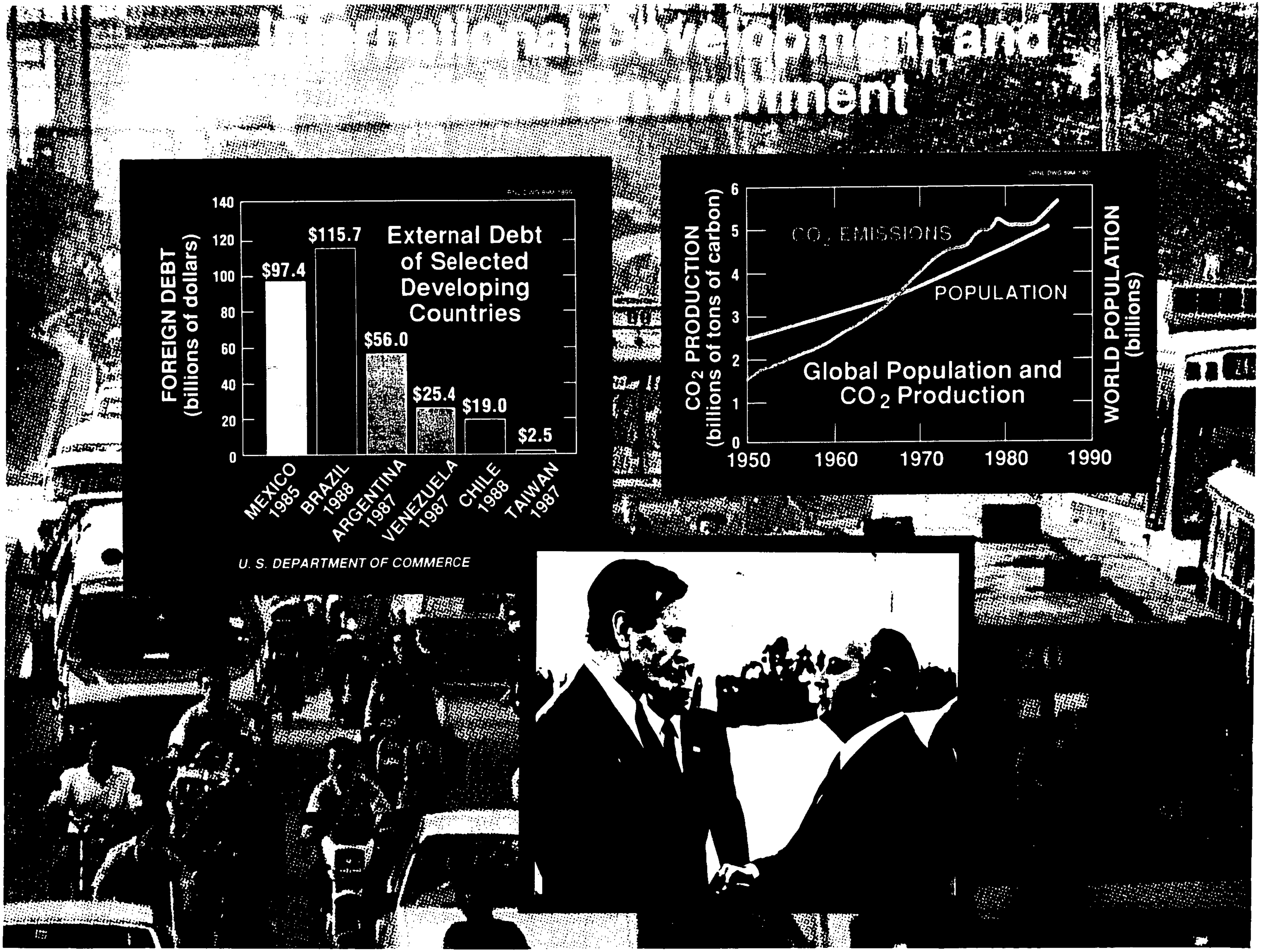


Ocean Pollution

Biodiversity

Deforestation

Resource Depletion


External Debt of Selected Developing Countries
FOREIGN DEBT (billions of dollars)
0
20
40
60
80
100
120
140
$97.4
$115.7
$56.0
$25.4
$19.0
$2.5
MEXICO 1985
BRAZIL 1988
ARGENTINA 1987
VENEZUELA 1987
CHILE 1988
TAIWAN 1987
U. S. DEPARTMENT OF COMMERCE
Global Population and CO_2 Production
CO_2 PRODUCTION (billions of tons of carbon)
WORLD POPULATION (billions)
CO_2 EMISSIONS
POPULATION
0
1
2
3
4
5
6
1950
1960
1970
1980
1990