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Climate Change and Transnational Corporations

Analysis and Trends

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Preface

In Economic and Social Council resolution 1989/25, the Council requested an analytic study of the main sectors of activity that have adverse effects on environmental preservation and the factors that determine the allocation of activities between developed and developing countries. The present report, entitled *Climate Change and Transnational Corporations: Analysis and Trends*, is in response to that request.

The problem of global warming and the dangers it presents to global survival are being given high priority by the United Nations. Discussions are under way leading to a convention on global climate change under the auspices of United Nations intergovernmental bodies. The study was designed as a contribution to that process. It focuses on six transnational energy-producing and energy-consuming industrial sectors, in which corporate practices have a direct and major impact on the problems associated with global climate change. The sectors are fossil fuel production, transportation, electricity-generation, energy-intensive metals production, chlorofluorocarbons and other ozone-depleting chemicals, and inorganic nitrogen fertilizers.

The study explores the relative differential impacts between industrialized and developing countries of each sector, and asks how each sector would have to be restructured in order to limit global climate change and ozone depletion. It concludes that major changes in the technical processes and investment patterns of the transnational corporations in those sectors would be necessary if catastrophic environmental changes are to be avoided.

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New York, December 1991

Contents

Page

Page

Page

List of tables

List of figures

EXECUTIVE SUMMARY

Human activities which result in the release of carbon dioxide, chlorofluorocarbons and other chemicals to the atmosphere threaten to change dramatically the earth's climate and damage its protective stratospheric ozone shield. Many national Governments and international institutions have recognized that addressing the problem of human-generated emissions of greenhouse and ozone depleting gases is one of the most important challenges the world now faces.

The present study concentrates on the ways in which the activities of transnational corporations contribute to this global environmental threat. It identifies concrete steps that transnational corporations (TNCs) can adopt to mitigate the damage and prevent future destruction. The overall purpose of the study is to contribute to the analysis of environmental restructuring and the requirements for a sustainable economy. Environmental restructuring will require the redesigning of economic activities, such as investment patterns and technological choices, in ways that inflict the least possible damage to the environment and achieve sustainability. The policies and principles recommended in this study complement actions that need to be taken by other institutions, such as national Governments, non-governmental organizations, the United Nations system, and other interested parties.

The threat of global climate change caused by anthropogenic emissions is expected to be a far more difficult problem to address than stratospheric ozone depletion, which has been addressed through the intergovernmental agreement, the Montreal Protocol on Substances that Deplete the Ozone Layer, of 16 September 1987. The decisions made by Governments, corporations and citizens over the next several years will be pivotal as international negotiations on limiting those gases are as yet in an early stage.

Most of the chemicals involved in ozone depletion and global warming are closely associated with industrial activities. The combustion of fossil fuels as a source of energy is the most important cause of the growing accumulation of carbon dioxide in the atmosphere, the source of roughly half of the global warming problem. Emissions of the greenhouse gases methane and nitrous oxide also result from the production and use of fossil fuels. Additional nitrous oxide emissions are tied to energy-intensive practices in agriculture, such as the use of nitrogen fertilizers. Chlorofluorocarbons and their chemical relatives would not be present in the atmosphere at all were it not for their development and use by humans in the twentieth century.

In June 1990, the Intergovernmental Panel on Climate Change (IPCC), made the following calculations: *

- "Atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to change in emissions. Continued emissions of these gases at present rates would commit us to increase concentrations for centuries ahead. The longer emissions continue to increase at present-day rates, the greater reductions would have to be for concentrations to stabilise at a given level.
- "The long-lived gases would require immediate reductions in emissions from human activities of over 60% to stabilise their concentrations at today's levels; methane would require a 15-20% reduction."

Governments, citizens, international organizations and private industry will all have to participate if such reductions are to be realized. The actions which will have to be taken will touch most aspects of industrial society. Transnational corporations will play a particularly important role. The influence of TNCs extends over roughly 50 per cent of all emissions of greenhouse gases. This includes about half of the oil production business, virtually all of the production of road vehicles outside of the centralized economies, most chlorofluorocarbon production, and significant portions of electricity generation and use.

The transnational corporate role in the energy sector and in the release of damaging gases must be understood both in its present and historical context. The report uses the case study approach in order to provide insight into the complex issues of the global environment and the role of TNCs through concrete examples which illustrate the variety of problems faced. Each case study includes discussion of the problems and the possibilities of restructuring.

Case studies

The case studies look at transnational corporations which are involved in several different stages of the energy sector: producers of fossil fuel, vendors of equipment or materials which utilize fossil fuels and corporations which use energy-intensive manufacturing processes. The role of TNCs in the production and consumption of CFCs and in the production of nitrogenous fertilizers, which similarly result in greenhouse gas emissions, will also be analysed. These case studies are complementary to those which deal more directly with the energy sector. The case studies are the following:

(a) Fossil fuel production

Although control of the industry by the largest TNC oil producers has lessened significantly in recent decades, TNCs still produce or market roughly 50 per cent of fossil fuels. Direct release of damaging emissions from this industry include carbon dioxide from energy consumed in the production process approximately 8 per cent of all carbon dioxide emissions and releases of methane (the primary component in natural gas) from leaks during natural gas production, leaks from coal mines and from

* IPCC, "Policy-makers' summary of the scientific assessment of climate change", Report to IPCC from Working Group I, p. 1 (June 1990), prepared at the Meteorological Office, Bracknell, United Kingdom. The IPCC is an intergovernmental body under the joint auspices of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

venting at the oil well-head. This wasteful venting of natural gas released during the oil extraction process represents a loss to developing country economies and natural resource base. Transnational corporations focusing on producing oil for the industrialized American and European markets generally do not capture the natural gas, since it is not profitable for them to do so.

(b) Transportation

This sector is responsible for about 20 per cent of the projected global warming; most of this is in fossil-fuel-consuming road vehicles. Historically, automobile producers in the United States have discouraged both public transportation and non-fossil-fuel-based transportation. In addition, vehicle manufacturers continue to produce automobiles which are far less fuel efficient than available prototypes. Their unwillingness to change this pattern demonstrates the problems which can occur in the absence of effective and consistent regulation and taxation policies.

(c) Electricity generation

Approximately one third of all use of fossil fuels goes to the generation of electricity. Although most electric generation facilities are under national or regional control, TNCs play an important role in designing equipment and plants. Plant designs have inappropriately placed priority on size rather than efficiency. Cogeneration, the simultaneous generation of electricity and heat, has been vastly underutilized and the exploitation of renewable energy sources (which are non-carbon based) has been neglected.

(d) Production of energy-intensive metals

Worldwide, the production of aluminium, copper and iron consume over 7 per cent of total commercial energy use. Aluminium alone, whose production process is the most energy intensive, absorbs 7 per cent of all industrial electricity use. The Grande Carajas Programme in Brazil, which includes mining and metallurgical projects and a hydro dam, was intended to be a positive force in Brazil's economic development, but it is also causing severe environmental and social problems through increased deforestation and the ruining of the livelihoods of the indigenous population. In the case of the Askosombo dam in Ghana, a Kaiser Aluminum joint-venture contractually required much of Ghana's available hydroelectric power, leaving the rest of the country to rely for many years on more expensive and less reliable sources of power.

(e) CFCs and other ozone-depleting chemicals

These chemicals contribute at least 15 per cent of the global warming problem. TNCs are the primary producers and intermediate consumer of CFCs and related compounds, which are used in refrigeration and a variety of other applications. After initial resistance to reducing the use of those chemicals, both producers and users of CFCs have responded to the reality of international regulation (and the consequent global phase-out of the compounds) by working quickly to develop alternatives. The Montreal Protocol, which regulates the use of CFCs and has set up timetables for their elimination, serves as an excellent guide to the potential effectiveness of international regulation.

(f) Inorganic nitrogen fertilizers

These chemicals contribute to global warming both because of the use of energy in producing them and because of the nitrous oxide which is released through their use. Nitrous oxides contribute roughly 5 per cent of the global warming problem. Nitrogen fertilizer production is still largely in the hands of TNCs, which have historically promoted patterns of over-use, often in conjunction with government development schemes. Excessive use of fertilizers has also resulted in other forms of environmental degradation.

The comparative environmental practices of corporations in different parts of the world reveal disparities between TNC production processes in countries where there is an absence of regulations or conflicting kinds of regulation for a variety of reasons. For example, cars produced for the Brazilian market are produced to a lower efficiency and emissions standards than those in countries where regulations are in place. Similarly, in the late 1970s, a ban on the use of CFCs in aerosols in Canada, Sweden and the United States did not affect other countries, where there was no regulation.

Regulatory policies and environmental restructuring

Addressing the problems of greenhouse gas emissions will require cooperative efforts by corporations, Governments, intergovernmental organizations and non-governmental organizations. In most cases, transnational corporations cannot be expected to change their practices on their own. Even if individual corporations were to establish environmental protection as a goal, global competition generally would make it difficult for companies that operate internationally to take costly conservation measures when their competitors do not. Once a global regulatory trend has been established by Governments, however, TNCs can provide a strong base of technical information with which rapid transitions to safer practices can be made.

One of the most promising paths for reducing emissions of carbon dioxide and other damaging chemicals will be international guidelines on reductions, such as those established by the Montreal Protocol for CFCs and other ozone-depleting chemicals. Governments and local authorities will have to take responsibility for other specific steps. International bodies should also be involved because of the transboundary implications of climate change and the role of transnational corporations. These steps should include specific regulations on energy efficiency and supplementary taxation to discourage wasteful practices. Tax revenue should help fund the development of more environmentally sound technologies. Taxation and regulation are complementary methods for requiring corporations to internalize the costs of the environmental damage caused by their activities and the costs of switching to better systems.

An important step in developing regulations will be requiring corporate environmental impact statements. Corporations which are vendors of equipment, the use of which involves release of damaging emissions, corporations which produce fossil fuels and corporations which use significant amounts of energy from fossil fuels or electricity should provide analyses of the damage their products or processes may cause to the environment, and the potential alternatives which are available. Statements should be made available to Government, non-governmental organizations, workers and the public at large. Those impact statements will provide a bank of information from which international and national regulatory standards can be developed.

Restructuring the energy sector will also be a vital element in limiting global climate change and ozone depletion. In the long run, conversion from fossil fuel energy sources to the use of alternative, renewable safe energy sources is the key to preventing global warming and the global environmental degradation related to industrial pollution. Until that is achieved, transition measures can and should be taken by TNCs and other large energy producers. Far-sighted companies should be making new investments in alternative sources of energy, such as solar, geothermal, cogeneration, as well as environmentally safe exploitation of natural gas.

The wide range of choices available today have the potential to displace significant amounts of greenhouse gas emissions. Evaluations of the emissions and other environmental problems related to those methods of generation in comparison to others will be necessary, along with analysis of the energy conservation potential.

There is also significant room for improvement in recycling and reuse of toxic materials which would also reduce emissions. Restructuring will require determinations about energy-efficient and cost-effective alternatives.

Improvements in the way vehicles are used and in the vehicles themselves would alleviate the present levels of greenhouse gas emissions and other forms of environmental degradation related to the transportation sector, such as urban air pollution. For the short term, increased fuel efficiency, fewer vehicles and fewer miles driven would reduce carbon emissions. All three of these are possible if industry can restructure with those goals in mind.

The following are some suggestions for action by corporations and Governments that are discussed in the case studies. Some suggestions can be implemented fairly easily, while others will require significant revision of investment decisions.

Production of fossil fuels

(a) Venting from existing gas wells should be stopped immediately. A thorough analysis in areas where gas is still vented and flared would, in most cases, reveal the economic desirability, as well the environmental benefits, of trapping and utilizing the gas;

(b) Utilization of natural gas to displace oil and coal in efficient power plants and in cogeneration stations should be accelerated. Steps should be taken in advance to investigate and cure the leaks of natural gas so as not to aggravate atmospheric methane accumulations;

(c) Methods to minimize methane emissions from abandoned coal mines should be developed and implemented on an urgent basis;

(d) A tax on fossil fuel in the OECD countries on the basis of carbon content would internalize some of the costs and could be used to implement various conservation policies.

Transportation

(a) Corporations should urgently start developing high efficiency prototypes and put them into production;

(b) TNCs should observe minimum universal standards on emissions and fuel efficiency in their global production and marketing operations;

(c) TNCs should do systems analyses, which include economic and environmental costs of poor tires, roads, older vehicles etc. Those would provide a basis on which countries could make reasonable decisions about the structure of transportation systems;

(d) International and national standards need to be mandated for fuel-efficiency requirements.

Electricity-generation

Electricity utilities need to take steps to ensure the most efficient use possible of fuels. Producers of electric generation equipment must be required to produce generic and specific analyses which encourage the best use of energy resources. Those should include the following:

(a) Comparison of relative greenhouse gas emissions among the various methods of electricity generation. Options should include other fuels, cogeneration and the same fuel with more efficient generation;

(b) An analysis of energy conservation potential to supplement, complement or replace the proposed generation;

(c) When options are considered, a full array of other costs, such as nuclear waste disposal and known accident risks, should be presented;

(d) Specific attention should be paid to generator size and optimization for the particular grid in which the generator is being installed;

(e) Power planning models in use are not adequate, since many are biased towards supply rather than conservation. Models of the "least cost" variety should be used. Contingencies and costs in case of shortages and surpluses and the ability of the electricity system to deal with them should be presented;

(f) Renewable energy sources — such as biomass, hydropower, various solar options, wind energy and geothermal energy — should be used wherever possible;

(g) Analyses of the financial risk under various generation and conservation options are needed: the factors which must be considered are: (i) lead times of construction and realization of capacity; (ii) uncertainty due to national and international regulatory environment; (iii) variation in costs introduced by the size of equipment relative to grid size;

(h) Health risks from the various options, combining various types of generation and conservation measures, should be assessed.

Production of energy-intensive metals

(a) Comprehensive analysis of all energy conservation options and their costs and benefits, not only for the enterprise, but also for the country in which the operation is taking place. Energy conservation options which are economical internally should be implemented in co-operation with Governments of host countries;

(b) Analysis of the greenhouse gas emissions and other environmental implications of replacement materials which could fulfil similar functions;

(c) Analysis of the potential for using recycling to produce similar quantities of materials both in the country where operations are taking place or proposed, as well as in the countries where the product is to be marketed. This should include an analysis of the option of importing scrap metals;

(d) Comprehensive analysis of the environmental and health costs from production, use and disposal of the product, and the countries which would be incurring those costs under the prevailing marketing plan.

CFCs and other ozone-depleting chemicals

(a) Corporations should halt the use of CFCs as quickly as possible — before international deadlines if practicable. This is clearly feasible in almost all industries, with the possible exception of the manufacture of refrigerators;

(b) Corporations should halt the use of other chemicals also known to be highly damaging to the ozone layer, such as methyl chloroform or carbon tetrachloride, before international deadlines;

(c) Corporations which produce materials which store CFCs or even CFC alternatives, such as producers of polyurethane foam and refrigerators, should be expected to work on methods to recycle and recover those products and, if feasible, they should be held responsible recovering them;

(d) HFCs and HCFCs should be used to replace CFCs as little as possible. They should not be used in aerosol spray cans, since other alternatives are available. For other more vital uses, they should be viewed strictly as interim substitutes. In general, corporations should seek to replace CFCs with materials which are as benign as possible in all environmental, health and safety respects.

Inorganic nitrogen fertilizers

Since TNCs have been very active in promoting the use of the chemical nitrogen fertilizers, they should carry out assessments of the damage that such use has already done, and what might be done to repair it.

TNCs now involved in developing plant varieties which are genetically engineered and which will require even more dependence on TNC-manufactured inputs should perform comprehensive assessments of the energy, environmental, social and economic impacts of those new products before they are sold.

In the context of present chemical fertilizer plants and applications, TNCs should:

(a) Make estimates on a country-by-country basis of how much the use of chemical fertilizers could be reduced by more efficient application and subsitution by organic nitrogen, nitrogen-fixing crops etc.;

(b) Make investments to reduce energy consumption in the manufacture of chemical fertilizers. Potential savings are estimated by the World Bank to be as high as 10 to 25 per cent;

(c) Include information about alternative methods of fertilization and pest control in their literature, which is distributed to extension agencies and farmers;

(d) Conduct systems studies of the different options to determine the relative desirability of selective application of commercial fertilizers and substitution of natural sources. Users of inorganic nitrogen fertilizer should seek to reduce its consumption and find alternative plant nutrients.

Over the coming years, regulatory activities and international agreements are likely to alter considerably the framework within which those TNCs which affect greenhouse emissions function. The present study concludes that major changes, such as the ones discussed above, in the technical processes and investment patterns of TNCs will be necessary if potentially catastrophic environmental degradations are to be avoided.

PART ONE

Overview

CHAPTER I

INTRODUCTION

The present study is an outgrowth of one of the projects mandated by the Economic and Social Council in its resolution 1989/25 of 25 May 1989. The Council requested, among other things, analytic studies on the main sectors of activity that have adverse effects on environmental preservation, and the elaboration of operational principles for strengthening the participation of TNCs in efforts for environmental preservation and protection.

The overall purpose of the study is to contribute to the analysis of environmental restructuring and the requirements for a sustainable economy. Restructuring will require the redesigning of economic activities, such as investment patterns and choice of technological processes, in ways that inflict the least possible damage to the environment and that achieve sustainability. A complete and comprehensive blueprint for such environmental restructuring is far beyond the scope of the present study. Instead, the study concentrates on ways in which the activities of transnational corporations, and the current framework of incentives, which influences how TNCs decide to undertake those activities, contribute to the global environmental threat which confronts the world today. Using that analysis as a basis, the study discusses the impact of environmental restructuring on TNCs and identifies concrete steps that TNCs can adopt in order to help reduce their contribution to that threat. Those policies and principles complement actions that need to be taken by other institutions, such as national Governments, non-governmental organizations, the United Nations system and other interested parties.

A host of serious environmental problems face the world today, ranging from the threat of global warming owing to the emission of greenhouse gases, to the problems posed by acid rain, deforestation, hazardous and nuclear wastes, urban smog and even ordinary garbage disposal.

The actions which will have to be taken will touch most aspects of industrial society. Most of the chemicals involved in ozone depletion and global warming are closely associated with industrial activities. The combustion of fossil fuels as a source of energy is the most important cause of the growing accumulation of carbon dioxide in the atmosphere, the source of roughly half of the global warming problem. Considerable emissions of the greenhouse gases methane and nitrous oxide also result from the production and use of fossil fuels. Emissions of nitrous oxide, a damaging chemical, are tied to energy-intensive practices in agriculture, such as the use of nitrogen fertilizers. Chlorofluorocarbons and their chemical relatives, which are associated with ozone depletion and which are also strong greenhouse gases, are anthropogenic chemicals which would not be present in the atmosphere at all were it not for their development and use by humans in the twentieth century.

In June 1990, the Intergovernmental Panel on Climate Change (IPCC), made the following calculations: [1]

- "Atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to change in emissions. Continued emissions of these gases at present rates would commit us to increase concentrations for centuries ahead. The longer emissions continue to increase at present-day rates, the greater reduction would have to be for concentrations to stabilize at a given level.

- "The long-lived gases would require immediate reductions in emission from human activities of over 60 per cent to stabilize their concentrations at today's level; methane would require a 15 to 20 per cent reduction."

By addressing those problems, however, other serious problems will implicitly be addressed. For example, the primary greenhouse gas of concern is carbon dioxide, which is emitted as a result of energy-producing activities which rely on the combustion of carbon-based materials like coal, oil or gas. Burning those materials also releases various amounts of nitrogen and sulfur oxides, which contribute to smog and acid rain. Thus, reducing energy dependence on the combustion of carbon-based materials (primarily fossil fuels) will not only reduce greenhouse emissions, but will help alleviate problems such as acid rain and urban smog.

But global environmental problems are unique in that, in order to be fully addressed, solutions must ultimately be implemented on a global international scale. Local environmental problems like urban smog are theoretically addressable and largely solvable by the local community acting on its own (although action on the provincial, state or national level greatly facilitates local community action). This is not the case with global problems, which must also be addressed by international institutions and structures as an essential complement to local and national action.

The present state of very high emissions and inefficient use of energy, as well as the relatively undeveloped state of alternatives which are environmentally more sound, has complex roots. There are many actors in addition to Governments and TNCs which influence energy policy and practices and therefore influence the problems associated with global climate change. Within the industrial complex, other large-scale energy producers and consumers, institutions such as nationally-owned companies and the industrial operators within centrally planned economies, also have a major impact. The economic policies of the international and multilateral banks and institutions also influence energy policy and practices. Of course, the tastes, needs and desires of individual consumers and users, whether of cars, high-energy use manufactured goods, or through home consumption in cooking, heating and air-conditioning are clearly influential.

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1 IPCC, "Policy-makers' summary of the scientific assessment of climate change", Report to IPCC from Working Group I, p.1 (June 1990), prepared at the Meteorological Office, Bracknell, United Kingdom. The IPCC is an intergovernmental body under the joint auspices of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

A. The global environment and TNCs

Transnational corporations are key players in the international arena and they represent some of the most powerful economic forces in the modern world. Annual sales of the larger TNCs are on the order of $100 billion. Thus, they have a significant portion of the resources that will be needed to address environmental problems.

Given the size and scope of the industrial activities undertaken by TNCs, it is not surprising that they play a central role in the generation and accumulation of greenhouse and ozone-depleting gases through both the production and consumption of fossil fuels. Transnational corporations are involved as extractors, refiners and transporters of fossil fuels and as intermediate and final consumers of the energy.

Transnational corporations are also intimately involved with implementing and operating the technologies which cause the problems that confront us. Although government and private national corporations are often engaged in production activities similar to those of TNCs, it is the international corporations which manufacture and market on such a large scale that, through their decisions, establish industry standards for production technologies, which are then replicated and dominate the industry. Initial decisions by TNCs about which production technologies should be used are thus crucial in establishing what the environmental impacts of a given production process will be.

Transnational corporations produce the vast majority of fossil fuels in the developed, industrial world. They also participate in the production of oil and gas in other regions of the world either directly, through a share of the ownership of oil and gas fields or, indirectly, through marketing and export agreements and the sale of technology to nationally based corporations. In addition, nationally owned transnational corporations in some of the countries of the Organization of Petroleum Exporting Countries (OPEC) have moved to acquire downstream operations in refining and marketing of petroleum and its products in many countries of the world. Also, most of the oil production of OPEC is exported and marketed via TNCs. The portion of fossil fuel not produced by transnational corporations comes mainly from the economies of Eastern Europe (including the Soviet Union), China, Mexico and India. Finally, in 1985, roughly half of the total production of about 9.5 billion metric tons of coal equivalent of fuels was produced by TNCs.

The role of TNCs in fuel consumption is more complicated, but equally pervasive. Consumption of fossil fuels is integrally involved in the everyday life of industrial society. Transnational corporation consumers include corporations that utilize electricity or consume fossil fuels directly in manufacturing processes, as well as corporations that serve as a conduit for others' use of energy, such as those that manufacture electricity-generation equipment (which transforms fossil fuels into electricity) or automobiles (which produce vehicles that require fossil fuels to run). Even when the TNC role is not dominant, it is difficult to identify any area of manufacturing in which TNCs do not play a significant role at some stage in the production-to-consumption process.

The quantitative aspects of the role of TNCs in greenhouse gas emissions is a little-researched subject and, for that reason alone, the estimates presented here should be treated as tentative. However, besides the approximate nature of the calculations, there are inherent methodological questions and problems of fact and responsibility that make any single calculation in this area a matter of controversy and debate. It is important in this context to remember the reason for those calculations: it is to come up with policies, procedures and principles which will allow for large reductions in greenhouse gas emissions and also pave the way for a transition to safe energy sources and environmentally and economically sound energy-consumption practices. Thus, the order-of-magnitude calculations are useful, since they indicate broad priorities for the development of public policy.

Minimalist accounting of the involvement of TNCs in greenhouse gas emissions would ascribe to those corporations only the energy used directly in manufacturing processes and the extraction and refining of energy supplies, in direct proportion of TNC productive assets to total world productive assets. A maximalist accounting would add any greenhouse gases generated by non-TNCs which used the technologies or advice from service TNCs. An intermediate position would include emissions from activities of TNCs directly and from equipment such as cars and aerosol spray cans, which transnational corporations manufacture, but it would exclude emissions from those sources where TNCs have affected the design or selection of the technology, arranged financial credits or provided other service functions.

On the basis of this intermediate view, a rough idea of the amount of greenhouse gas emissions in which TNCs are involved can be derived. The items included in deriving the figures are mentioned in parentheses in each of the paragraphs below. Thus, TNCs are involved in the following:

(a) About half of the carbon dioxide emissions, including emissions from automobiles (OECD oil and gas use, plus half of OECD coal use, plus half of third world fossil fuel use);

(b) Roughly 10 to 20 per cent of the methane emissions, including leaks and vents from natural gas pipelines and from oil and coal production (half the venting from oil and gas production and use, half the emissions from coal mines);

(c) Roughly two thirds of CFCs, including aerosol sprays, car air-conditioners, and solvents and refrigeration applications in the OECD countries (OECD CFC use);

(d) Roughly half of the other gases, like nitrous oxides and ozone (greenhouse gas emissions due to tropospheric ozone and other pollutants correspond roughly to categories of fossil fuel use in item (a) above). This is a very rough assumption which understates the contribution of developing country sources, because of the higher emissions per unit of fossil fuel use in the developing countries.

A designation of transnational corporation involvement is not meant to exclude involvement by any others in the emissions of greenhouse gases, for instance, in the use of cars or other consumer goods. The estimates are designed to indicate an order of magnitude of emissions which could be affected by measures taken by TNCs, whether self-initiated or government-mandated. This admittedly approximate picture is shown visually in table 1.

B. Methodology: the case study approach

The purpose of the case study approach is to provide insight into the complex issues of the global environment and the role of TNCs through giving specific concrete examples which illustrate the variety of problems faced. Those case studies look at TNCs which are involved in several different stages of the energy sector: producers of fossil fuels, vendors of equipment or materials which utilize fossil fuels and corporations which use energy-intensive manufacturing processes. In addition, several other areas of TNC involvement, which similarly result in greenhouse gas emissions, will be analysed, including the TNC role in the production and consumption of CFCs and in the production of nitrogenous fertilizers. These case studies are complementary to those which deal more directly with the energy sector. The phase out of CFCs serves as a model for some of the steps which will be necessary for reducing other

Table 1. Estimated involvement of transnational corporations in the generation of man-made greenhouse gases

Gas	*Amount of gas generated by transnational corporations (approximate percentage of total amount generated)*	*Significant sources of greenhouse gases*
CO_2	50	Emissions from automobiles. Most of the oil and gas use in OECD countries. Half of coal use in OECD countries. Half of fossil fuel use in developing countries.
Methane	10-20	Half from oil and gas production and use. Half from emission from coal mines.
CFCs a/	60-70	Use of aerosol sprays, car airconditioners, solvents, foam products and refrigerators in OECD countries.
Other b/	50	Emissions from automobiles. Three quarters of oil and gas use in OECD countries. Half of coal use in OECD countries. Half of fossil fuel use in developing countries.

a/ Chlorofluorocarbons.

b/ Such as nitrogen oxides and tropospheric ozone.

greenhouse emissions and the use of nitrogen fertilizers exemplifies one of the many ways, beyond fossil fuel combustion, that TNCs directly influence greenhouse emissions. Each case study will include some discussion of the problems to be faced if restructuring is taken seriously (and it must be taken seriously to prevent the dire consequences that are being predicted as a result of global warming).

In all, the areas covered in the case studies effect roughly 80 per cent of the greenhouse gas problem: fossil fuel production and use accounts for about 60 per cent of the emissions problem, chlorofluorocarbons for about 15 per cent and nitrous oxide for about 5 per cent. TNCs are active in all of those areas to some degree. However, a considerable amount of production and use takes place within the centrally planned economies, where TNC participation in the energy sector is as yet relatively small.

Within each case-study sector, four basic steps are taken: an overview of that sector as a whole is given; the importance of TNCs in that sector is reviewed; key TNCs in that sector are identified; and the activities of those TNCs which have contributed to global environmental problems are examined. Each case study will conclude with recommendations and operational principles for changing policies and practices to mitigate the problems. The applicability of operational principles developed here is not limited to TNCs. Indeed, they may be equally applicable to non-TNCs, joint ventures and governmentally owned industries.

The following six major areas which contribute to global environmental problems are covered by case studies:

(a) *Fossil fuel production.* Fossil fuels, when burned for energy production, emit carbon dioxide, the single most important greenhouse gas. Production activities also contribute to the problem. First of all, energy is directly consumed in the production process, accounting for approximately 8 per cent of all carbon dioxide emissions. Secondly, methane, another important greenhouse gas, is released in the production process owing to the wasteful venting and flaring of natural gas at oil wells, and from leaks during coal mining and natural gas production and distribution. TNCs produce or market roughly 50 per cent of fossil fuels;

(b) *Transportation.* Transportation accounts for about 30 per cent of global energy use. The great majority of that energy use takes place in fossil-fuel-consuming road vehicles, which are produced largely by TNCs;

(c) *Electricity generation.* Approximately one third of all fossil fuels are consumed in the generation of electricity. Most electricity-generating plants are under the control of national or regional entities, but TNCs play an important role in the design of generating equipment and plants;

(d) *Production of energy-intensive metals.* The production of aluminium, copper and steel accounts for almost 7 per cent of total global commercial energy consumption, a vast amount for just one industrial sector. Metal-producing industries thus shape the energy-use patterns of large areas. Aluminium is the most energy-intensive of those metals, and is therefore examined in greater detail;

(e) *CFCs and other ozone-depleting chemicals.* CFCs are anthropogenic chemicals which are the primary cause of stratospheric ozone depletion. In addition, they constitute 15 per cent or more of greenhouse gas emissions. TNCs are the primary producers and intermediate consumers of CFCs and related compounds, which include halons (used primarily in fire suppression), methyl chloroform and carbon tetrachloride;

(f) *Inorganic nitrogen fertilizer production.* Nitrogen fertilizers contribute to greenhouse gas emissions in two primary ways. First, through energy consumption in producing them (which accounts for roughly 1 per cent of total commercial energy consumption) and, more importantly, through direct emissions of the greenhouse gas nitrous oxide during their use. Nitrogen fertilizer is produced largely by TNCs, which have promoted its use to the detriment of alternative farming methods, such as organic farming.

Those six areas were chosen for several reasons. First, those areas together account for the vast majority of the world's greenhouse gas emissions and stratospheric ozone depleting chemicals, as well as contribute significantly to the more regional and local problems of acid rain and urban smog.

Second, not only do those particular sectors account for the bulk of the world's global environmental problems, but TNCs have an inordinately large influence in those sectors — if not by direct control of the market, then by substantial indirect influence.

Third, despite many structural similarities among those sectors, they also represent an important diversity of detail that is necessary to keep in mind when developing encompassing and effective solutions to global environmental problems. Solutions that are relatively easily implemented in one sector may not be as easily applicable to another. A primary example of that is the contrast between the problems posed by the production of ozone-depleting chemicals and the much more complex and difficult problem of carbon dioxide emissions associated with fossil fuel production and use.

The issue of stratospheric ozone depletion was the subject of the Vienna Convention for the Protection of the Ozone Layer, of 22 March 1985, and the Montreal Protocol on Substances that Deplete the Ozone Layer, of 16 September 1987. While the example of this process, together with a history of the problem, provides a guide for intergovernmental negotiations on environmental problems, it must be remembered that this case involves a relatively narrow segment of the economy: a handful of producers, whose major business lies elsewhere, producing CFCs and halons worth no more than a few billion dollars per year.

On the other hand, fossil fuel use (the single largest source of greenhouse gas emissions) affects every aspect of the world economy and the lives of almost everyone on the planet from the poorest to the wealthiest. The energy and electricity production sectors alone involve annual sales on the order of $1.5 trillion. The difficulties inherent in addressing the global warming problems are thus much greater than the difficulties encountered in addressing the problem of stratospheric ozone depletion.

C. Developing policies and principles

An important pattern revealed by these case studies is the way in which past decisions by TNCs and policy-making bodies in general become intertwined with and influence social, technological and economic structures. Those structures, once established, then tend to limit and constrain current and future options for environmental policies. A particularly clear example of this can be seen in the transportation sector, in which corporate policies in the 1920s and 1930s in the United States were instrumental in undermining the domestic rail transportation option, while bringing about the present structural dependence on a road transportation system. The present system in the United States now systematically encourages road transport over rail transport and private vehicles over public ones. The consequent transportation requirements consume much more energy, cost billions of extra dollars, result in an unknown number of additional transportation fatalities, and cause billions of tons more of pollutants to be emitted to the atmosphere than would otherwise be the case. All of this is now built into the very structure of society in the United States and in other industrialized countries, and will require large investments to alter significantly.

Thus, an important goal of the present study is to suggest ways that TNC policy decisions can be made which will minimize the constriction of the range of choices available to both current and future decision makers. For example, one of the primary recommendations of this study is the preparation of environmental impact statements which would be available to the public, as a routine part of the TNC decision-making process. This is an expansion of the policies already required under limited circumstances for government action in a number of industrialized countries. Such a principle would expose the decision-making process to a broader range of alternatives than those that would be raised by the narrow considerations of the profit motive alone.

It is, of course, never possible to predict completely all of the ways in which current policy choices will affect future options for dealing with a multiplicity of problems, but the possibility of making intelligent choices is increased by knowing all the foreseeable options rather than only one or a few.

Overall, it should be kept in mind that this analysis and these recommendations are offered with one major aspiration: to help focus attention and debate on the connection between global economic and environmental issues and the role of transnational corporations within the global structure.

CHAPTER II

SETTING THE CONTEXT FOR CHANGE

World-wide efforts to address the issue of greenhouse gas emissions and other environmental issues will require concerted action at all levels from local to global. There are a number of actors involved in the issue of producing and controlling greenhouse emissions. They include transnational corporations and banks; other large-scale energy-producing and energy-using institutions, such as nationally-owned companies, and private corporations which are not TNCs; national Governments; the United Nations and its agencies; and other intergovernmental institutions, such as the General Agreement on Tariffs and Trade (GATT) and the European Economic Community; non-governmental organizations, communities and academia.

Despite the fact that TNCs are directly responsible for a large portion of emissions and affect the remainder substantially, TNCs alone cannot achieve or be expected to achieve environmental protection. This is the case even with local problems where issues of responsibility are less difficult. In global issues, where authority over resources and liability for damage are more diffuse, responsibility cannot be easily apportioned. Moreover, TNCs inherently lack a long-term environmental perspective and the corresponding appropriate structural goals, because the paramount institutional goal of profit limits institutional ability to respond.

For TNCs to act to protect the environment by making investments in pollution control, efficiency, alternative technologies and processes, and so on, it will be generally necessary to have a set of incentives, regulations and sanctions which not only target specific problems, but which create a social, economic and political environment in which mortgaging the future to provide profits and goods in the present is an unacceptable business practice.

Global atmospheric protection poses special problems. Even more than with emissions of pollutants which can be cleaned up, prevention is an utter necessity when it comes to global environmental issues. There is only one Earth, and individual, corporate, governmental and intergovernmental actions must reflect that fact. Undoing the damage from such emissions is a very difficult and costly affair and, under many circumstances, it may not be possible at all. Public and corporate policies have not yet been adequately adjusted to deal with that risk.

Moreover, standard legal techniques for holding corporations accountable for their actions are not as applicable to global environmental damage. The matters of proof and causation as they relate to the activities of a single corporation or even a set of corporations is much more problematic for issues of global damage.

It is clear that global agreements like the Montreal Protocol, combined with local and national regulations, are necessary. New mechanisms for global enforcement and recourse for adversely affected communities are also necessary. Finally, questions of liability in regard to local and national laws need to be addressed.

A. Cost of reducing greenhouse gas emissions

There has been considerable speculation on the costs of reducing greenhouse gas emissions to a level which will stabilize their concentrations and gradually begin the reduction process. Some preliminary calculations of the costs arising from global warming using various models have been made.[2] It is quite different, however, to estimate the costs of reducing greenhouse gas emissions compared to the costs of not doing it, which would be very useful.

The costs of inaction of letting greenhouse gas emissions build up are very difficult to calculate. Even the relatively simple aspect of the costs of sea level rises are very speculative. More importantly, model estimates and corresponding cost estimates do not take into account the possibilities of runaway processes which might lead to truly catastrophic levels of pollutant accumulations. Such a build-up risks jeopardizing the very composition of the atmosphere, so that any calculation of its costs is essentially meaningless. It is for this reason that prevention and action before there is firm evidence of irreversible damage are critical.

Despite the obvious difficulty in calculating the costs of inaction, there are some areas where initial estimates might be useful. For example, in the event of rises in sea levels as a result of global warming, some TNCs may lose significant investments. Offshore drilling platforms will be at risk. Land-based shipping facilities, which include pipelines and storage tanks, might be flooded or made inoperable by sea-water contamination. Other sectors with large industrial facilities in coastal areas are also at risk.

Other phenomena affecting energy companies might be, for example, a decrease in market demand for fuel in relation to changes in the relative role of key fossil-energy sources while the world population demands greater energy efficiency. Market demand will also affect the demand for fuel in the transportation sector, since significant savings to society include higher efficiency cars and expanded public transportation systems.

Global warming will effect the length of the seasons. Over time, the markets for home heating oil will shift towards the poles. There will also be significant costs associated with the weather extremes and storms that are predicted.

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2 United States Environmental Protection Agency, *Policy Options for Stabilizing Global Climate*, vols. I and II and *Executive Summary, Draft Report to Congress* (Washington, D.C.) United States Environmental Protection Agency, Office of Policy, Planning and Evaluation (February 1989), p. III-36. Hereafter referred to as EPA, *Global Climate* (1989).

Projection of the costs of prevention also has many speculative aspects, because those costs and even the nature of technology depend crucially on public policy and on national and international agreements. The history of regulations regarding CFCs is very instructive in that respect.

Only a few years ago, many industries were warning of immense costs and even the collapse of civilization if CFCs were to be phased out entirely. A front-page article in the Washington Post invited its readers to imagine life without refrigerators and personal computers. [3] It has now been decided that CFCs, halons and two other ozone-depleting chemicals, carbon tetrachloride and methyl chloroform, will be phased out by the year 2000. Instead of complaining and issuing dire predictions, corporations have become serious about reducing emissions, using presently available substitutes, searching for new substitutes and shifting to processes that do not involve any environmentally-damaging chemicals. Indeed, many companies are saving money by reducing emissions and by switching to processes which cost less and are cleaner. Others are facing moderately higher costs. Overall, complaints of unbearably high costs are now much rarer, and pronouncements about the end of civilization have practically disappeared from respectable circles.

The reduction of greenhouse gas emissions will be a much more complex process, involving more elaborate mixes of regulations, taxes, incentives and international agreements. Therefore, estimates of overall costs of reducing emissions of principal greenhouse gases are even more speculative than those of CFCs.

For starters, though, there are a wide variety of measures involving greenhouse gases whose emissions could be reduced by measures which are economical today, or whose reduction is desirable from the point of view of environmental and economic policy in other areas. There are many energy conservation measures which are not being implemented owing to institutional barriers, failures of market functioning, inadequate regulations and so on. For instance, the construction of buildings with less than optimum energy efficiency is often attributable to the problem that builders do not pay the energy bills. Another example is the crisis in municipal waste disposal in landfills, which are one of the big sources of methane emissions. Recovery of methane from existing landfills is not being practiced because of the institutional problem that landfills are generally municipally run, and are usually separate from energy utilities. Various existing means of managing municipal solid waste in more environmentally sound manners will conserve energy and reduce emissions of methane. In those areas, reduction of greenhouse gas emissions will not necessarily increase costs.

Achieving these substantial reductions requires better and more coordinated public policy and more responsibility on the part of local governments, as well as companies, so that environmental considerations are well integrated into all major aspects of resource management.

There are other areas where there will be some costs, but where ultimate costs are difficult to calculate because of mitigating circumstances. For instance, electric cars are considerably more expensive than conventional gasoline-powered vehicles today. Yet regulations requiring more efficient cars could stimulate inventiveness and could result in new cars or transportation mixes which may not be more expensive. Efficient electric cars may in a decade turn out to be less expensive to purchase and run, particularly once all the costs of cleaning up urban air pollutants via pollution controls on gasoline cars and the adverse health impacts of air pollution are taken into account.

3 Michael Weisskopf, "CFCs: rise and fall of chemical miracle", *Washington Post* (10 April 1988).

The use of inorganic fertilizers is a source of nitrous oxide emissions today. The cost of its replacement by organic fertilizers can at one level be calculated, if one restricts costs to additional labour requirements and somewhat reduced yields. Yet, the matter is more complex, because organic fertilizers build up soil fertility and enable more secure long-term production, while excessive use of chemical nitrogen is degrading large areas and reducing long-term fertility and polluting groundwater.

In some areas, it may be possible to put upper limits on cost. For instance, solar thermal technology and wind electric-power generation are commercial in some selected areas. Photovoltaic cells are commercially available for many applications, though they are not yet competitive for large-scale generation. Even for this, costs are within a factor of two or three of coal generation, even without any taxes on fossil fuel use. Appropriate cost internalization to include environmental costs would make the additional costs of solar energy far lower than they are today. Further, those costs are likely to come down substantially within the next decade, though it is difficult to predict the magnitude of such declines. Biomass energy, such as wood from plantations for electricity generation with high efficiency is also now feasible. It may be possible to impute upper limits on the costs of reductions of carbon dioxide emissions in the electricity sector (and through it, sectors where electricity can be used as a substitute for direct use of fossil fuels) by assuming that a certain proportion of fossil fuels would be replaced by solar, wind or biomass energy. Such additional costs should be imputed only after the presently economical measures, such as cogeneration and increased efficiency of energy use, are taken into account.

Those costs may not be as high as feared, since a great many of the possibilities for increasing efficiency are not even under discussion in the context of reduction of greenhouse gas emissions. One dramatic example is the common use of charcoal for cooking in many urban areas of the developing world. In Kenya, for instance, the amount of charcoal used for cooking per person per year is about 500 kilograms. With present methods of charcoal production in Kenya, it takes 2.5 tons of fuelwood to produce that amount of charcoal. The same amount of wood could be used to generate about 4,000 kilowatt hours of electricity, which could supply 10 people with cooking energy. Thus, energy efficiency would be increased 10-fold. Peri-urban forestry would get a boost. Not only would greenhouse gas emissions be reduced, but there could also be a net increase in forested areas, resulting in increased absorption of carbon dioxide from the atmosphere.

The central problem in those examples is not the availability of technology, but how the priorities of public policy are to be oriented so that economic needs and environmental protection are in harmony. Today, for example, public policy allows the subsidizing of aluminium production and other energy-intensive production of metals from ore by preferentially allowing companies to use lower-cost sources of electricity, thus forcing host developing countries to purchase higher-priced energy for their own needs. This discourages recycling and energy conservation, reduces employment and deprives other sectors of much needed electricity. Clearly energy production and consumption policies and practices need a basic reorientation. Until that is done, the use of human, physical and financial resources will continue to be wasteful and environmentally damaging at all levels from the local to the global.

Those economic problems go far beyond the level of what individual TNCs can do. They belong in the realm of general public policy within which TNCs, other economic and governmental institutions, individuals and communities must exist and work. Particularly in developing countries, the inefficient use of energy resources is resulting not only in high costs in terms of greenhouse gas emissions and other pollution, but also in high costs for the purchase of unnecessarily large quantities of fuel, often with limited foreign exchange reserves that could be spent on other necessities.

In addition to those considerations of direct costs of reducing greenhouse gas emissions, there also are many direct costs of continuing along the present course. The case studies which follow provide a rich source of examples:

(a) The cost to a country of venting or flaring natural gas versus installing the infrastructure necessary to use it to replace oil has generally not been calculated. While venting is a negligible cost to TNCs, it represents a great cost to the host country in the replacement of fuel and loss of gas revenue. The costs of replacement fuels and loss of potential income have both increased since 1973.

(b) The cost of obsolete or inefficient equipment, such as equipment which consumes higher energy for the production of aluminium, for example, needs to be calculated from the point of view of the host country. Extra investments are needed for domestic power production, which requires importing oil. Sometimes there can be immense opportunity costs, as in the case of Ghana described in the case study on the production of energy-intensive metals. (see chapter VII). There are also health and environmental costs which need to be taken into account.

(c) There are considerable costs for not using the best available technology. For instance, the costs of poor tires, poor roads and poor car efficiencies need to be calculated on a systems basis both in terms of domestic currency and foreign exchange. Motor vehicles which operate inefficiently not only emit larger quantities of greenhouse gases, but also increase oil requirements, and the import bill if oil is imported.

(d) Energy sector investments in production and many energy-intensive consumption areas require large investments in terms of infrastructure by Governments. Those include roads, ports, dams, schools, and often include building entire new communities, as well as relocating people displaced by projects. TNCs usually do not pay up front for these costs. Costs essential to the project are paid for through taxation, which seldom covers the total infrastructure costs. Thus, there is little incentive for corporations to minimize those front-end costs. At the same time, those energy-intensive sectors are also associated with a high rate of abandonment of their facilities when resources are exhausted or when more economical resources are discovered elsewhere. That leaves communities with the back-end costs associated with debt, unemployment, crime etc. — all the effects of a local depression.

In order for regulations, taxes and other instruments of economic policy to be used effectively, corporate information needs to be complemented by analyses on the national and local levels to reveal the costs and benefits to various actors of investments in the energy-producing and energy-consuming sectors.

To date, however, firms have avoided costing the greenhouse effect perhaps to avoid major changes until faced by regulation. It would be hard to argue for expansion of existing product growth if the cost is high in terms of global warming. This exposure might, in fact, accelerate a market decline. Alternatively, sometimes very high corporate estimates are made for either prevention or cure in order to argue against regulation or pave the way for a new government subsidy.

B. Regulation

Regulation, like taxation, is one way to create rules in which social and economic institutions operate. Regulations, like taxes, can translate into alternative products and different prices, channelling economic activity along directions which are not likely to be taken by companies acting on their own. In some instances, regulation is much more effective than taxation; in other cases, the reverse is true. Thus the two tools are complementary.

DuPont, the leading CFC-manufacturer, suspended research on CFC alternatives for several years in the early 1980s, despite the fact that the danger of ozone depletion had already been recognized. DuPont's explanation was that, in "the absence of regulation, there was nothing to drive the search for alternatives, because there was no market demand".[4] National and international regulations have now created a market for CFC alternatives, and are today driving the search for them.

Regulations will be a key element of any policy to deal with reducing greenhouse gas emissions. International agreements and national legislation which set targets for reductions in emissions of greenhouse gases will likely be needed to provide an overall context for global environmental protection. This is one of the most direct methods to meet goals for emissions reduction. In addition to a global control on greenhouse gas emissions, regulations are needed at the national and local levels in order to capture the optimum level of energy efficiency.

Energy efficiency

Energy efficiency is an area of controversy because of the vested interests of both energy producers and energy processors to sell more of their products. To manufacturers of appliances, as well as other manufactures of energy-consuming devices, energy efficiency is generally not a major consideration. Energy efficiency is usually not an item of glamour like the style of a car or appliance. Life-cycle costs, that is, the costs to the consumer over the life of the product, are not given their due economic value by many consumers for reasons that are still a matter of considerable debate. As a result, many of the efficiencies which are economically justifiable at a given price of energy go without being captured.

Considerable changes have occurred in industry and in institutional arrangements to favour energy efficiency in the past decade and a half, largely as a result of national regulation. Energy use per unit of production or gross national product has gone down to an extent not imagined by almost all analysts as recently as the mid-1970s. In the United States, utilities are routinely required to take conservation opportunities into account in their planning, in what has come to be known as the "least cost approach". That approach requires that energy services be delivered in the most efficient way and that investments in efficiency be considered as options either in whole or in part to investments in electricity-generation. That approach, with many refinements, needs to be extended to the entire energy-producing sector.

Energy-producing TNCs, as well as energy-consuming TNCs, which have the theoretical option of generating their own electricity or switching fuels, should be required to make such energy efficiency evaluations as part of the environmental impact assessment process. The process, which is now required

4 Kathleen H. Forte, DuPont Company, quoted in Arjun Makhijani, Anne Makhijani and Amanda Bickel, *Saving our Skins, Technical Potential and Policies for the Elimination of Ozone-Depleting Chlorine Compounds* (Washington, D.C., Environmental Policy Institute/Institute for Energy and Environmental Research, 1988), p. 131.

for major projects in many parts of the world, results in a government permit to proceed with the project as long as certain environmental factors are properly considered.

While many of those issues will have to be dealt with on a local and national level, it is reasonable to monitor some of those issues on the international level when dealing with TNCs operating with different standards in different countries. For example, TNC manufacturing processes in general should be held to certain standards of energy efficiency, for example, energy-efficient building design, use of energy-efficient equipment, use of cogeneration, use of energy-efficient lighting, motors and other equipment.

Given the seriousness of the problem of greenhouse gas emissions and the need to reduce them, providing TNCs with a "level playing field" is important. There should be guidelines, routinely updated, for minimum standards for energy efficiency of certain consumer products, commercial and industrial equipment, as well as for buildings.

International environment standards

An important benefit of international environmental regulation would be to help equalize environmental, health and safety conditions between the OECD countries and the developing countries, and even among OECD countries. The OECD countries' energy use and greenhouse releases are immense if compared with those of the developing countries on a per capita basis. Yet in the developing countries, although per capita use is low, the average efficiency of specific plants or appliances is generally worse than in OECD. Moreover, TNC activities in the developing countries have often involved working conditions and levels of environmental degradation which are seldom paralleled in OECD.

In developing countries, capital shortage has meant that large and small manufacturers who are energy consumers are unable to purchase new equipment when necessary. This has resulted in the extended use of older, less efficient equipment. Cars in developing countries tend to be fuel-inefficient, in part because they are kept on the road longer and are often poorly maintained. More is paid to purchase fuel, and with greater environmental costs, because of a shortage of capital for front-end investment. Similar financial constraints have resulted in a clear lag in the use of new technologies. That pattern has often been harmful both to economic development and to the environment.

While the role of TNCs in this situation is only part of a larger problem of economic inequities, TNCs have often done little to improve matters, despite the fact that they can usually enter a country with more modern equipment than can be purchased locally. Petroleum producers are a good example of this. Because of their focus on the export of oil to Europe and the United States, TNC oil producers traditionally made little effort to use or develop markets for the natural gas encountered when sinking oil wells. Instead, they vented or flared it, wasting valuable energy resources and damaging the environment. An enormous quantity of natural gas was flared and vented from Western Asian and other developing country oil fields in the several decades after the Second World War. It was only after the rise of OPEC as a relatively independent economic contender in the oil arena that many companies collaborated with OPEC Governments to make investments in petrochemical and other industries in order to use some of the gas that was available for industrial development in those areas.

Similarly, the transfer of unsuitable technology has been a problem. The electricity generation case study (chapter VI) demonstrates how TNCs which produce electricity-generation equipment helped to construct plants in developing countries which were on an inappropriate scale, often resulting in increases in cost and decreases in reliability.

In other areas, it is clear that TNCs have merely adjusted their own standards of production downwards, instead of helping to improve host country conditions. They have made use of more lax environmental laws to produce more cheaply, creating more pollution than they would otherwise. For example, German cars built in Brazil for Brazilian consumers have lower standards than those built in the Federal Republic of Germany for the United States. Similarly, TNCs respected the bans on use of ozone-depleting chlorofluorocarbons in aerosol spray cans in the United States, Canada and Sweden from 1978 onwards, while continuing to produce CFCs for use as aerosol propellants in other industrialized and developing countries in which they operated.

There is some limited evidence that TNCs have sought out areas with less stringent regulation for their operations, particularly for certain very hazardous industries.[5] Looser regulations can reduce costs and raise profits for TNCs which are producing for export to OECD. Yet it is important to note that environmental laws and requirements are likely to be only one of a group of factors which may attract a corporation to produce in a host developing country, such as available infrastructure and cost of labour.

The pressures which have lead TNCs to adjust their standards downward if local laws allow it, and to lobby local governments for still weaker regulation, are deeply embedded in the international economy. TNCs argue that they need to remain competitive in the international corporate world in which they operate. They often attribute the double standards in their operations to the differences between national laws. They note that it can be difficult, if not impossible, to produce materials through cleaner and more expensive methods if their competitors are not under the same constraints.

International regulation could potentially relieve some of those pressures. If environmental regulations were more equivalent from country-to-country by international law, corporations would feel less compelled to produce to low standards in order to be competitive. Likewise, host countries would be under less pressure to sacrifice their local environments or the safety of their populations in order to retain the TNC presence. Such regulations should include health and safety measures. In addition, regulations could encourage the transfer of technology by requiring, for example, that production installations be as efficient as similar plants in the industrialized countries.

Finally, regulations designed to reduce environmental damage create demand for new products and new markets for existing environmentally sound ones. Thus, well-conceived regulations themselves can have the beneficial effect of redirecting environmentally destructive or damaging economic activity into more environmentally sound avenues. For instance, coal mines can be designed to recover and use the methane which they otherwise would emit into the atmosphere.

International regulation of TNCs can take the form of minimum standards to which they must conform in all their operations, even if local laws do not require them to do so. The better access to, and control of, capital and technology by TNCs would generally even out any competitive problems with respect to corporations which are not TNCs. The specific problem of relocation or threats of relocation by TNCs can be reduced by requiring corporations to pay the costs of social and economic disruption caused by plant closures. When there are funds to cover costs of dislocations and environmental damage

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5 United Nations Centre on Transnational Corporations, *Environmental Aspects of the Activities of Transnational Corporations: A Survey* (United Nations publication, Sales No. E.85.II.A.11). Hereafter referred to as UNCTC Survey (1985).

in case of project abandonment, communities and workers will be less fearful of demanding high environmental standards of corporations which are economically important to them.

Getting corporations to internalize the environmental costs of their operations is vital. Yet, in the case of greenhouse gas emissions, quantifying those costs is extremely difficult. This is particularly true since small increases in greenhouse gas levels could at some point result in dramatic non-linear changes in climate, along the lines of "the straw that broke the camel's back". Because of that problem, it is critical to act on the basis of risk rather than demonstration of actual damage. This means that taxation should serve as a method to promote safe alternatives, rather than the narrower economic definition of cost internalization.

For that purpose, taxation is particularly complementary to regulation. For instance, taxation of fossil fuels would generally encourage energy conservation, as well as use of alternative energy sources. But, in addition to being regressive, fuel taxes do not enable efficient capture of the possibilities for reducing environmental damage and risk of catastrophic greenhouse gas accumulations.

Environmentally motivated taxes can be used to make corporations more sensitive to the environmental costs of their activities and to ease the burden to society of the damage they cause. They provide similar incentives to non-corporate users of energy. Taxes also provide the economic resources to assist those in need and those who would be unjustly penalized by the process; they help to channel windfall profits that may arise from regulatory measures into public revenues, which can be used for reducing emissions and technological change to new energy sources.

Deciding upon levels of taxation, like deciding upon specific national regulatory measures, is a complex matter. One way to partially internalize in corporations the costs of greenhouse damage is to calculate what it will take to phase out fossil fuels in favour of technologies which are environmentally sound, like solar energy and wind energy. Those cost estimates can be used as guides to set levels of taxation on fossil fuels. One possibility is a "carbon tax", in which every fossil fuel would be weighted by its relative contribution to carbon dioxide emissions, that is, natural gas would be less heavily taxed than coal or oil. That would encourage a general transition away from fossil fuels, as well as favouring the use of those fuels which are less damaging in terms of greenhouse emissions. An international CO_2 tax would require innovative collection mechanisms and methods to deal with non-compliance. Revenues, however, could be used to help improve efficiency, finance alternative energy sources all over the world, finance the transfer of environmentally sound technology to the developing countries and finance R&D. As the costs of alternatives vary, the level of taxes could be adjusted downward. Eventually, they could be reduced or even eliminated when the transition is complete.

C. Liability and compensation

Today, legal liability and compensation in payments are not effective deterrents in the case of global warming and ozone depletion. Indeed, there is as yet no clear way in which this liability can be established. Small contributions made by individual corporations to potentially catastrophic global environmental damage do not lend themselves to established legal liability codes.

There are considerable difficulties in using liability for deterrence, even in more routine cases of fines for environmental damage: [6]

- "If the unsuccessful defendant [corporation] can internalize its damages as part of the cost of doing business, there will be no specific deterrence. Also, if insurance is generally available at moderate rates or risks can be spread through reciprocal arrangements there will be little or no financial incentive to reducing or eliminating the problem, and general deterrence will not result."

The situation is further complicated by the many jurisdictions in which TNCs operate. By 1982, 144 countries had agencies to oversee environmental issues, compared to only 26 countries having such agencies in 1972, the year of the United Nations Conference on the Human Environment held in Stockholm. [7] The 1985 UNCTC study entitled Environmental *Aspects of the Activities of Transnational Corporations: A Survey* noted the following regarding purely national policies: [8]

- "A number of factors...conspire to make purely national control systems variously evadable, inefficient, incomplete, unenforceable, exploitable, or negotiable (at the expense of desired environmental quality or occupational safety) with respect to transnational corporations".

Given the general problems in apportioning responsibility with regard to global greenhouse gas emissions, it would be more effective to have some overarching global rules and regulations which cover all TNC operations and allow national and sub-national Governments the option of imposing more stringent environmental protection rules. Once these national and sub-national laws and regulations are in place, the Governments at those levels can hold the TNCs accountable for adherence to these regulations, which have the effect of law.

With regard to direct liability, deterrence can be achieved only if damages are high enough to affect competitiveness, in cases where there is effective competition. Deterrence might also be enhanced by the prospect of holding individual corporate decision-makers personally and, when appropriate, criminally liable for their actions, if these happen to be in contravention of existing law. Such sanctions are being used with some effectiveness in Canada. [9]

Another way to enhance the incentives to corporations to fulfil environmental commitments is to require that fines be paid out of profits. This means that fines should not be allowed to be incorporated into a corporations' cost structure, passed onto consumers or be tax deductible. Similarly, fines against individuals in the top management should be non-reimbursable, directly or indirectly by the corporations.

6 Harry Poch, "Deterring corporate polluters", paper presented at a conference entitled "The Company Polluted So Why Did I Get Charged?" (Toronto, Canadian Environmental Law Research Foundation, 1988), p. 10.

7 *UNCTC Survey* (1985), op. cit., p. 26.

8 Ibid., para. 51.

9 See Poch, op. cit.

D. Policies and principles for TNCs

No one method, regulation, taxation or liability, will be adequate to respond to a problem as complex as that of greenhouse emissions. Governments will have to use all the tools currently at their disposal and many more which have yet to be developed and implemented. A new mechanism to regulate pollution at the global level is necessary to ensure that global economic activities are compatible with survival.

The role that the United Nations and its agencies have played in the Montreal Protocol provides an example for other intergovernmental agreements, such as the convention on global climate change, which is under discussion. The role and legitimacy of NGOs needs to be strengthened and expanded since NGOs are particularly crucial in making any new regulatory mechanisms effective. It should be noted that, in a number of countries, notably the United States, the ability of Non-Governmental Organizations to sue both corporations and the Government to require adherence to the law has been an effective tool for environmental protection.

Certain institutional changes regarding the acquisition and availability of information are also essential both from an environmental and economic point of view. TNCs as private profit-making entities, and private corporations generally, are not under a general obligation to assess the environmental impact of their activities or, indeed, the impact of their activities and decisions upon the communities in which they operate. Corporate study and disclosure today is narrow and responsive only to some national laws and regulations. There are no laws and regulations which require TNCs to consider the environmental impact of their activities on a global level, to take alternatives into account, or to act in a prudent manner. Indeed, acting upon the environmentally best approach on an individual basis may in some cases put corporations at a disadvantage with respect to their competitors. However, in many cases such evaluations might well point to better performance and increased profitability.

Yet systematic consideration of environmental impact of alternatives before investments are made is essential to environmental protection and to economic efficiency within that context. It is generally more expensive and less efficient to try and fix a problem once a poor choice of investment has led to environmental problems than to try and avoid it in the first place.

Avoiding further atmospheric damage will require major changes in the current operations of TNCs as well as in their long-term investment strategies.

The UNCTC has developed *Criteria for Sustainable Development Management,* which suggest some of the ways in which corporate decision-making that affect the environment need to change. The Criteria are "aimed at shifting management perspectives from a traditional business-as-usual view towards one that stimulates thinking on sustainable development". [10] Corporations are asked to evaluate actively their current production patterns and future development plans for their impact on the environment and on human health and safety. Initial steps include the adoption of a sustainable development policy, a review of planning, resource acquisition and operating procedures to make them consistent with the policy, as well as modification of corporate structure, lines of responsibility and internal reporting mechanisms for the same purpose. The long-term goal of the *Criteria* is the restructuring of corporations along environmentally sound lines.

10 UNCTC, *Criteria for Sustainable Development Management* (1990), p. 2. Prepared for the Commission on Transnational Corporations in response to a request by the Economic and Social Council in resolution 1989/25.

Certain common policies and principles specific to energy-producing and energy-consuming TNCs can be adopted in order to systematically incorporate environmental considerations into their planning, investments and operations. Moreover, there are no inherent reasons why non-TNC corporations, as well as joint-sector and governmental enterprises, cannot also adopt similar policies and operational principles.

There is some evidence that a portion of the corporate sector has decided that the time has come to make environmental considerations integral to their operations. At a conference on the sustainable use of energy, sponsored by the Federal Republic of Germany, at which most Governments of OECD member States, as well the International Chambers of Commerce, were represented, the following resolution was adopted by consensus: [11]

"Companies are invited...

"To prepare generic environmental impact assessments for public information of their products, manufacturing processes and activities, which should include assessments of impacts under anticipated conditions of use;

"To consider significant environmental protection actions in areas where there is potential for serious ecological harm based on risk, even if conclusive physical evidence of that damage is not yet available.

To provide voluntarily to Governments and Non-Governmental Organisations sufficient information to enable independent analyses of environmental impacts of their activities."

TNCs should begin comprehensive reviews of their operations and products to understand all aspects of their effects on the environment. Many have already begun this process. It is the first step in the goal of rearranging production away from the energy-intensive, non-recyclable, environmentally damaging structure of production which exists today to one that is compatible with sustainable resource use. Those steps are of utmost importance for the TNCs engaged in energy-intensive production, particularly energy conversion, and for the TNCs engaged in the production of fossil fuels and CFCs, since those products are a threat to the very habitability of the Earth.

Corporations should set standards for themselves on environmental and energy conservation issues through industry associations in the same way that they establish quality and production standards that are necessary for the functioning of the market. Everything from the size of screws and electrical outlets to the number and size of pins on electronic chips to basic equipment characteristics are standardized. Some of the standardization is done through national and international governmental groups, but a great deal of it is done by industry-sponsored standards associations. There is no reason that industry cannot set standards for itself on environmental and energy efficiency issues as well.

TNCs should develop strategies for limiting resource depletion and should introduce methods of production which conserve and enhance the productivity of natural resource systems, rather than deplete them.

For example, there are enormous opportunities for energy conservation in all sectors which have not been captured, even though they might be economical in relation to the price of energy. There is often a lack of institutional awareness as to the magnitude of the financial and energy savings which could be

11 Recommendations of the Workshop on Energy and Environment Sustainable Energy Use, held from 11 to 14 December 1989, in Velen, Westphalia, Federal Republic of Germany.

achieved. All TNCs should make systematic evaluations of their own manufacturing operations, office buildings, and vehicle purchase policies in order to assess the potential for energy conservation. Those assessments could include consideration of measures such as cogeneration in existing buildings and manufacturing operations, redesign of lighting systems, use of recycled materials and use of efficient motor drives. Analyses should be done both for existing operations and for proposed new investments. Consideration should be given to the use of the best available technology for energy conservation and reduction of pollutant emissions. If such technology is not adopted, the reasons should be clearly set forth. Corporations should provide life cycle costing information, so that informed consumer decisions regarding appliances and automobiles can be made. Energy efficiency strategies should be part of any reporting requirements.

No strategies to control greenhouse gas emissions, be they international, national or local, can be effectively implemented without a far better pool of information about the causes of the emissions, and the ways they can be reduced.

TNCs should routinely collect and disclose information and provide as complete analysis as possible regarding the environmental effects, including extent of emission of greenhouse gases, about their products, whether these are fossil fuels, automobiles or aluminium ingots, and about the production processes themselves.

For products, TNCs should prepare generic environmental impact statements. Such statements would not only include evaluations of the impacts of the products under various anticipated conditions of use, but would also examine a broad range of alternative technologies and approaches which are available to address the same needs. Not building a plant or selling a product should also be considered as an option in some circumstances.

Cost-benefit analyses should also be included to the extent that it is possible to quantify costs and benefits. The costs which are not quantifiable in defensible ways should be qualitatively discussed.

Information about the environmental impact of production processes should be specific to the plant under consideration. It should include comparative data on other plants manufacturing similar items within the operations of the TNC, as well as the environmental impact and costs of using the best available technology.

Generally, corporations should make sufficient information public on a routine basis so as to enable independent analyses to be made of their products and processes.

Since TNCs operate in many countries and jurisdictions, they should file disclosures of technical information with a central United Nations agency. The resulting database would enhance the ability of countries and communities to weigh the costs of proposed new energy development and industrial plants in economic and environmental terms. Such information could assist in the development of locally-based industries in poorer countries with otherwise limited technical resources. Generally speaking, a more informed debate about both environmental and economic issues would help increase the range of choices for development in an environmentally sound direction.

For corporations, supplying environmental impact information would promote important introspection. The failure of corporations to analyse the alternative forms of their product or alternative production strategies in light of their environmental costs is one of the most persistent problems in combating environmental damage. Being required to develop this database and analysis of environmental impact should move corporations to take a more holistic perspective of their role in the world, including their environmental role, than they would otherwise do.

Other benefits would be assisting Governments to provide corporations with a level regulatory playing field. Some of the changes, which will be necessary to reduce greenhouse emissions, may provide benefits to certain subsectors, while reducing the competitiveness of other sectors. Conservation measures, in particular, may come into conflict with the interests of fossil-fuel-producing TNCs, as well as the interests of TNCs that produce many other goods, such as automobiles, because they lower demand and require considerable investment, some of which would otherwise be declared as profits. In the long run, environmental protection will also require a more complete restructuring of the entire energy industry: moving to renewable energy sources, such as solar-derived electricity and hydrogen, and highly efficient energy utilization. In the interim, investments in conservation need to be complemented by investments in production and transportation structures, which are compatible with a long-run phase-out of fossil fuels. With adequate information, Governments can enact regulatory measures which affect corporations on an equal basis.

The following sections outline the kinds of information the three broad classes of corporations vendors of equipment, energy-producing corporations and energy-consuming corporations should be expected to supply. More specific information will be required from particular corporate sectors.

Vendors

Vendors include corporations which produce and sell electricity-generation equipment or cars or other operations which play an intermediate role in the use of energy and greenhouse emissions. It also includes corporations such as fertilizer manufacturers, which sell a product that contributes directly to greenhouse emissions.

Depending on what they are selling, these corporations should supply analyses which should include the following:

(a) A generic analysis of the extent to which their type of product may be contributing to greenhouse gas emissions, as well as other environmental problems;

(b) A specific analysis of their (indirect or direct) contribution to greenhouse emissions based on market share and efficiency of product;

(c) An analysis of the alternatives they have considered and their contribution to greenhouse emissions and other environmental problems, for example, how much more efficient could their cars be;

(d) Analysis of improvements in energy efficiency, reduction of emissions and other environmentally desirable goals, which could be achieved with investments in the best available technology;

(e) Any environmental problems, and the energy and economic costs of disposal of the product expected to be incurred at the end of its useful life. Also, information about alternative designs and products as they concern the environmental and economic aspects of waste management;

(f) An analysis, using energy efficiency, greenhouse gas emissions and other environmental criteria of each of production operations, transportation structure, and office buildings.

Energy-producing corporations

This category includes corporations involved in extracting or refining fossil fuels.

Reports should include the following:

(a) Calculations of the carbon dioxide, methane and other trace-gas emissions resulting from production, flaring, venting and transport activities, as well as from leaks;

(b) Calculations of the greenhouse gas releases occurring from use of the fuels;

(c) Analyses of the technical options available for reducing all greenhouse gas emissions from production, transportation and leaks.

Energy-consuming corporations

This includes all corporations which are involved in the use of energy either through direct fossil-fuel consumption or through their use of electricity. They should be required to provide the following:

(a) An analysis of the greenhouse emissions and other environmental problems that result from their energy use. Electricity-users need to compute the environmental costs of their energy use on the basis of oil-generated electricity, since oil is generally the fuel at the margin.

(b) An analysis of the potential for energy conservation in their production process both through measures such as cogeneration and through measures such as recycling goods in their process rather than producing from scratch.

CHAPTER III

BACKGROUND ON GLOBAL WARMING AND STRATOSPHERIC OZONE DEPLETION

Within the last decade, the environmental threats of global warming and ozone depletion have attracted worldwide concern. It is now widely recognized that the build-up in the atmosphere of gaseous pollutants may change the environment of the Earth in ways unimaginable only a few decades ago.

The first study showing that the burning of fossil fuel might lead to climate change was done by a Swede, J. Tyndale, and published in *Philadelphia Magazine, Journal of Science* in 1861. That study focused on local climatic variations, however. The first study on global climatic changes due to carbon dioxide emissions was done by G. Callendar in 1938. [12] Thus, for about half a century, the potential that human activities could seriously change the Earth's climate has been known.

However, awareness and serious study of the global environmental implications of human activity on a widespread and politically significant scale dates from the late 1960s. Prior to this, coal production and use, oil production and gas-venting and flaring were carried out in substantial ignorance of their potential for disrupting the global climate.

Knowledge about the effects of other gases on global climate change is even more recent. The role of chlorine emissions from CFCs and other sources in ozone depletion was first hypothesized in 1973. [13] It is only 16 years since V. Ramanathan first hypothesized the role of CFCs in global warming. [14] Since then the role of other trace gases like nitrous oxide and methane has also been studied. These investigations reveal that the problem of global warming is very complex and a number of trace gases contribute to it, and that ozone depletion, global warming and other environmental problems are closely linked through various physical, chemical and biological processes which are only now being understood.

12 G. Callendar, "The artificial production of carbon dioxide and its influence on temperature", *Official Journal of the Royal Meteorological Society*, vol. 64 (1938), pp. 223-237.

13 First published in F. Sherwood Rowland and Mario J. Molina, "Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone", *Nature*, vol. 249, No. 5460 (28 June 1974), pp. 810-812.

14 V. Ramanathan, "Greenhouse effect due to chlorofluorocarbons: climate implications", *Science*, vol. 190 (1975), pp. 50-51.

A. Greenhouse gases and the threat of global warming

Recent predictions suggest that the growing concentrations of gases which trap heat in the atmosphere, such as carbon dioxide, may cause the Earth's temperature to rise by as much as 1.5 to 3K by the middle of the next century. Those estimates, which reflect only the apparent (transient) warming, were based on moderate "conventional wisdom" scenarios for the five major greenhouse gases (CO_2, N_2O, CH_4, CFC-11, CFC-12).[15]

If the atmospheric concentration of these greenhouse gases were to remain constant after 2050, an additional warming would occur as the oceans equilibrate with the atmosphere. This additional warming is reflected in even higher equilibrium warming estimates.

An early analysis by the National Academy of Science, which considered only carbon dioxide, projected that a doubling of atmospheric carbon dioxide levels would result in an equilibrium temperature rise of 1.5 to 4.5K.[16] Since 1880, the concentration of carbon dioxide already has increased by 25 per cent. For the highest world energy projections, this much warming would have been locked in by the middle of the next century.

While energy projections have been lowered since the 1970s, subsequent estimates of equilibrium warming recognized the importance of greenhouse gases other than carbon dioxide. The combined effect of carbon dioxide and other trace gases was estimated to result in an equivalent doubling of carbon dioxide concentrations, committing the Earth to the same equilibrium warming by 2030-2050.[17] A 2.5K warming would make the Earth warmer than it ever has been in the 2.5 million years since the appearance of humans on Earth.[18]

Such a warming would have an enormous impact on natural ecosystems, including both cultivated crops and forest areas. Projected associated rises in the sealevel by 1.5 to more than two metres would flood many heavily populated low-lying coastal areas by the end of the next century.[19] Since 1800, the concentration of carbon dioxide alone in the atmosphere has increased about 25 per cent. By 2030, accumulations of greenhouse gases may lead to an equivalent doubling of carbon dioxide concentrations, if the current growth in emissions continues. The full range of potential climatic changes which may result from such a dramatic build-up is not yet well understood. For instance, some possible instabilities

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15 See J. E. Hansen et al., "Global climate changes as forecast by the Goddard Institute for Space Studies three-dimensional model, *Journal of Geophysical Research*, vol. 93 (1988), pp. 9341-9364; and Krause, Florentin, et al. *Energy Policy in the Greenhouse*, vol. I, "From warming fate to warming limit; benchmarks for a global climate convention", International Project for Sustainable Energy Paths (August 1989). For example, Krause et al. based their estimates on implementation of the Montreal Protocol and on "low" global energy projections by the World Energy Conference and IIASA.

16 The National Academy of Science first projected that a doubling of an atmospheric carbon dioxide level would result in an equilibrium temperature rise of 1.5 to 4.5 degrees C (NAS, *Carbon Dioxide and Climate. A Scientific Assessment* (Washington, D.C., National Academy Press, 1979).

17 V. Ramanathan, R. J. Cicerone, H. B. Singh and J. T. Kiehl, "Trace gas trends and their potential role in climate change", *Journal of Geophysical Research*, vol. 90 (1985), pp. 5557-5566; and Robert E. Dickinson and Ralph J. Cicerone, "Future global warming from atmospheric trace gases", *Nature*, vol. 319, No. 6049 (9-15 January 1986), pp. 109-115, indicate that the combined effect of the build-up of a range of greenhouse gases (including but also in addition to carbon dioxide) could commit the Earth to an equilibrium temperature rise of approximately this amount by 2030-2050.

18 See Krause et al. (1989) and W. Bach, J. Pan Krath and J. Williams, eds., *Interactions of Energy and Climate* (Dordrecht, The Netherlands, Reidel Publishing Co., 1980).

19 J. S. Hoffman, D. Keyes and J. G. Titus, *Protecting Future Sea-Level Rise* (Washington, D.C., Environmental Protection Agency, 1983).

in atmospheric responses may stimulate runaway effects and changes in atmospheric composition so radical that their implications cannot even begin to be modelled.[20]

B. Chlorofluorocarbons and stratospheric ozone depletion

Damage to the Earth's stratospheric ozone layer has already been recorded. Chlorofluorocarbons and other human-made chemicals have significantly depleted the Earth's stratospheric ozone layer, which shields the Earth from deadly ultraviolet radiation. Fifty per cent depletion in stratospheric ozone is now measured over Antarctica during the Antarctic spring, and significant perturbation has been measured over the Arctic. Moreover, a cumulative overall depletion of 1.7 per cent to three per cent, and depletion of five to six per cent during the winter, has occurred at northern mid-latitudes since 1969.[21] Every one per cent decline in ozone is associated with a two per cent increase in damaging ultraviolet-B solar radiation. Thousands of additional cases of skin cancer and hundreds of thousands of additional cases of cataracts each year, as well as damage to the human immune system, plants, animals and ecosystems are the predicted results of a three per cent increase in ultraviolet radiation.[22] Severe world-wide ozone depletion, which cannot be entirely ruled out given current uncertainties about the depletion process, would amount to biological and economic catastrophe. For instance, radiation due to a 20 per cent ozone depletion would be so intense that it would cause severe burns in two hours of exposure and make it impossible for people to work and animals to graze outside during the daytime.[23]

C. The pollutants

Industrial society has played a central role in the development of these problems. The increasing concentrations of gases, which are responsible for both the threat of global warming and for ozone depletion, are the result of human activities, largely from industrial energy use, though also from agriculture. Greenhouse and ozone depleting gases include:[24]

1. *Carbon dioxide*. Carbon dioxide is naturally present in the atmosphere as part of the Earth's biogeochemical carbon cycle. Sources of carbon dioxide include the aerobic respiration of humans, plants and animals and the combustion of fossil fuels and biomass. Land use alteration can also result in net increases in atmospheric concentrations. Natural sinks of carbon dioxide include the oceans, plant life, which fixes atmospheric carbon through photosynthesis, and the soils.

   The natural balance of carbon in the atmosphere has been upset by human activities over the last century and a half. Human combustion of fossil fuels and the clearing of forests appears

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20 See, for example, Wallace S. Broecker, "Greenhouse surprises", in Dean Edwin Abrahamson, ed., *The Challenge of Global Warming* (Washington, D.C., Natural Resources Defense Council, 1989).

21 Ozone Trends Panel, *Executive Summary of the Ozone Trends Panel* (Washington, D.C., National Aeronautics and Space Administration, March 1988).

22 Arjun Makhijani, Anne Makhijani and Amanda Bickel, *Saving Our Skins: Technical Potential and Policies for the Elimination of Ozone-Depleting Chlorine Compounds* (Washington, D.C., Environmental Policy Institute/Institute for Energy and Environmental Research, 1988), pp. 9-10.

23 Ibid., p. 11.

24 D. J. Wuebbles and J. Edmunds, "A primer on greenhouse gases", report No. DOE/NBB0083, United States Department of Energy (Washington, D.C., March 1988).

to be resulting in release of six billion to nine billion metric tons of carbon per year. Atmospheric carbon concentrations are increasing at the rate of approximately 0.4 per cent annually, which involves the atmospheric retention of three billion metric tons of carbon per year on top of the roughly 700 billion metric tons currently present. The four billion to six billion metric tons from human emissions which are not being retained in the atmosphere are primarily being sequestered in the oceans.

The combustion of coal, oil and natural gas currently contributes about 5.5 to 6 billion metric tons of carbon per year to the atmosphere in the form of carbon dioxide. Coal and oil combustion each account for about 40 per cent of the total fossil fuel emission and natural gas about 20 per cent. Natural gas yields only 50 per cent as much carbon dioxide as coal and 70 per cent as much carbon dioxide as oil for the same energy produced. [25]

An additional source of growing carbon concentrations in the atmosphere is the widescale destruction of forests and other changes in land use. This is calculated to contribute an additional 0.5 to 3 billion metric tons of carbon per year to the atmosphere, and accounts for about nine per cent of the current warming effect of anthropomorphic greenhouse gases. Between 11 million and 15 million hectares of forest are cleared every year in the tropics. Forest-clearing results in the release of carbon to the atmosphere, little of which is recaptured in new growth.

On a weighted basis, carbon dioxide accumulations contribute about 50 per cent of the current warming effect of greenhouse gases.

2. *Methane*. Molecule for molecule, methane is 25 times more effective as a greenhouse gas than carbon dioxide.

Methane is a product of anaerobic respiration, that is, it is emitted during organic decomposition in the absence of oxygen. Methane is released from landfill decomposition, from water-logged agricultural fields and rice paddies, from wetlands and in the digestive tracts of animals. Methane emissions may be increasing owing to the increase in global temperature over the last century, since this leads to faster decomposition.

About 15 per cent of methane emissions are released from underground reserves during oil and coal mining operations and from natural-gas leaks during mining and transport. Methane is the primary component of natural gas. There is considerable uncertainty regarding the various sources and sinks of methane.

The atmospheric concentration of methane is about 1.7 parts per million (ppm). This is about 2.5 times pre-industrial levels, which had been relatively constant at about 0.7 parts per million for the previous 100,000 years; the increase is believed to be a result of human changes in land use and leaks from fossil-fuel production and landfills. Concentrations are currently increasing at the rate of about one per cent per year. Additional contributions to greenhouse gas accumulations may arise from chemical reactions of methane in the atmosphere.

25 Carbon dioxide emissions from fuel use, in millions of tons of carbon per exajoule are, respectively: gas, 13.8; oil, 19.7; coal 26.9. J. Edmonds and J. Reilly (1983), "Global energy and carbon dioxide to the year 2050", as cited in Irving Minzer, *A Matter of Degrees: The Potential for Controlling the Greenhouse Effect* (Washington, D.C., World Resources Institute, 1987), p. 48.

On a weighted basis, methane accumulations contribute about 20 per cent of the current warming effect of greenhouse gases.

3. *Chlorofluorocarbons*. (CFCs) and similar compounds, like methyl chloroform and other replacements for CFCs including hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). The greenhouse effect of these compounds per molecule relative to carbon dioxide equals several hundred to 20,000, depending on the compound. CFCs and kindred compounds are also the principal contributors to stratospheric ozone depletion.

   CFCs, halons and related chlorinated compounds are human-made chemicals designed for use in refrigeration and air conditioning, to propel aerosols and blow foams and to clean electronics and metal components, as well as for many miscellaneous applications. In the late 1980s, more than one billion kilograms of CFCs were being released into the atmosphere each year. It will take on the order of 100 years for natural processes to remove many of them from the atmosphere.[26]

   On a weighted basis, CFC accumulations are estimated to contribute about 15 per cent of the current warming effect of greenhouse gases. Some recent research indicates that CFCs and related compounds may play an even larger role.

   Concern about the impact of CFCs and halons on the ozone layer has resulted in international agreements to reduce the use of those compounds. Use of the most ozone-damaging compounds are likely to be phased out within the next decade, but their effects, and the effects of less-damaging replacements which continue to be used, will continue to be felt for many decades.

   Current concentrations of ozone-depleting atmospheric chlorine (which has been increasing owing to the breakdown of CFCs in the stratosphere) are about 3.4 parts per billion by volume (ppbv), more than five times pre-industrial levels.[27] Failure to regulate substitutes for CFCs and HCFCs could result in the additional build-up of chlorine in the atmosphere and continued contributions to greenhouse warming.

4. *Nitrous oxide*. The greenhouse effect per molecule of nitrous oxide relative to carbon dioxide is about 230. Although its annual increase in concentration is around 0.25 per cent, the lifetime of this compound is 160 years. The result is that its contribution to global warming has doubled in the 1900s alone, and now stands at approximately six per cent of the total.

26 Atmospheric lifetimes of the major chemicals involved are included below (from United Nations Environment Programme, *Scientific Assessment of Stratospheric Ozone*, 1989 (July 1989). There are the "e-folding" lifetimes that is, the period after which a compound's atmospheric concentration has declined to 1/e (about 37 per cent) of its original level.

Compound	Lifetime (years)
CFC-11	60
CFC-121	20
CFC-113	90
Carbon tetrachloride	50
Methyl chloroform	6.3

27 Approximately 0.6 ppbv of atmostpheric chlorine is due to methyl chloride emissions from the ocean and also from biomass burning. The remainder of the 3.4 ppbv of chlorine found in the atmosphere is almost exclusively from human-made chemicals such as CFCs.

Nitrous oxide also circulates in a biogeochemical cycle through the air, soils, organisms and the oceans. Considerable uncertainties exist in the global budget of nitrous oxide and its exchanges. Roughly 25 per cent of anthropomorphic emissions seem to be the result of fossil-fuel burning. The rest stems from agricultural activities, including the use of nitrogenous fertilizers, which appear to increase the amount of nitrogen which circulates into the air.

5. *Tropospheric (lower atmospheric) ozone and nitrogen oxides (NO_x).* Tropospheric ozone is a greenhouse gas. Nitrogen oxides do not contribute directly to the greenhouse effect, but are important in the formation of tropospheric ozone. Sources of those gases include photochemical smog, fossil-fuel burning, burning of forests and other organic matter, and lightning. Tropospheric ozone concentrations are exacerbated by upper atmospheric (stratospheric) ozone depletion. The interactions are complex and difficult to predict, but the contribution to the greenhouse effect from those sources is thought to be about 10 per cent.

D. The causes

As can be seen in the above descriptions, most greenhouse gases, including carbon dioxide, methane, nitrous oxide, water vapor etc. are present naturally and are emitted into the atmosphere, transformed chemically there and reabsorbed into soil and water by various physical, chemical and biological processes or "biogeochemical cycles". Natural emissions and the corresponding levels of greenhouse gases in the atmosphere are essential to the maintenance of the present climate and radiative balance of the Earth. Human impacts can thus be both direct, for example, releasing carbon dioxide from fossil fuel burning or releasing chlorofluorocarbons, or indirect, through interference with natural biogeochemical cycles, for example, through deforestation. Both kinds of effects must be taken into account when considering how to alleviate human impacts.

Figure I shows the relative contribution of various human activities to the warming effect of greenhouse gases. Almost 60 per cent can be attributed to energy use. Most of this is the result of carbon dioxide released through fossil-fuel combustion. Fossil-fuel production and combustion (and inefficient biomass combustion) also result in significant releases of trace gases, such as methane and nitrous oxide, which contribute to greenhouse gas accumulations.

Figure II shows the relative contributions of various greenhouse gases to the past and current warming effect. Determining the greenhouse gas emissions reductions which will be necessary to stabilize or alleviate calculated global temperature increases from this warming effect is an enormously difficult matter, because of the complexity of the biogeochemical cycles and climate feedback effects involved. Some goals suggested by recent climate stabilization studies are the following: [28]

(a) A 50 per cent to 80 per cent reduction in carbon dioxide emissions;

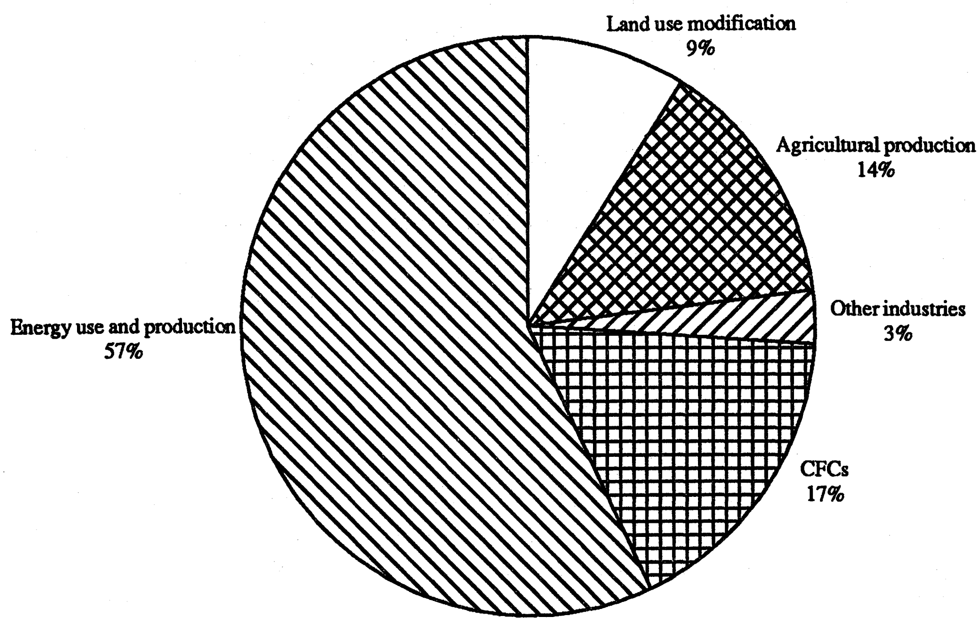
(b) A 10 per cent to 20 per cent reduction in methane emissions;

(c) Complete elimination of CFCs and halons;

(d) 80 per cent to 85 per cent reduction in N_2O emissions.

28 Krause et al., (1989); J. C. Titus, ed., *Effects of Changes in Stratospheric Ozone and Global Climate*, vols. I-IV (Washington, D.C., United States Environmental Protection Agency/UNEP, 1986).

Figure I. Activities contributions to global warming

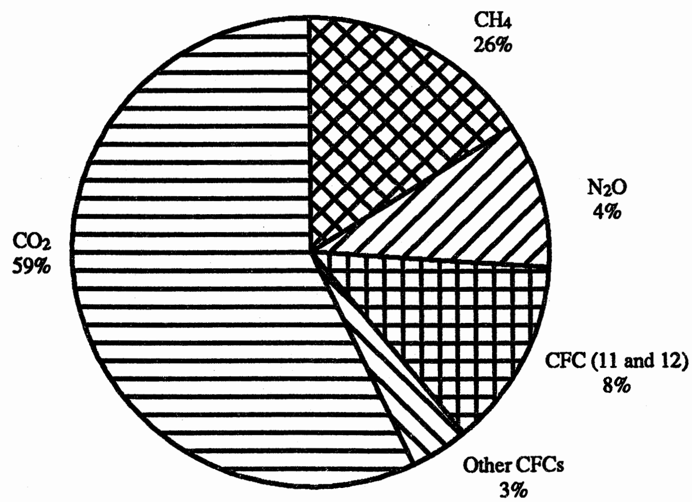


Source: United States Environmental Protection Agency, 1989.

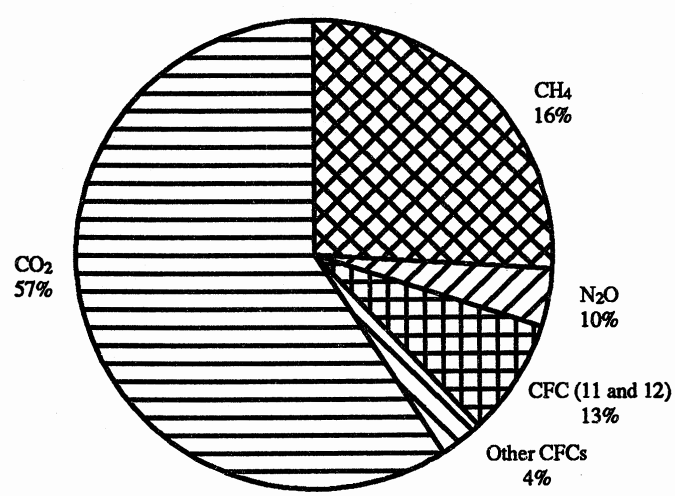
Serious action to reduce greenhouse gas emissions has lagged considerably behind analyses indicating that the build-up of those gases would affect the Earth's climate. There are a number of economic, political and social structural reasons for that lag. Some of the reasons involve corporations and their production and marketing policies.

Figure II. Greenhouse gas contributions to global warming

1880-1980



1980s



Note: **Based on estimates of the increase in the concentration of each gas during the specified period.**

PART TWO

Case studies

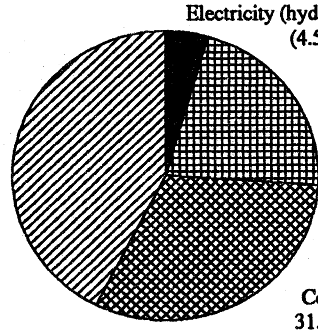
CHAPTER IV

FOSSIL FUEL PRODUCTION

A. Introduction

Fossil-fuels provide about 85 per cent of the world's total energy use. They provide 95 per cent of the energy use in industrialized countries, though only about 55 per cent of the energy use in developing countries, where biomass is used extensively. [29] Combustion of petroleum oil, natural gas and coal are the overwhelming source of carbon dioxide in the atmosphere, the source of half of the projected global warming resulting from the accumulation of greenhouse gases. Among those fuel types, the contribution to greenhouse gas accumulations varies significantly. Natural gas releases 70 per cent as much carbon per unit of energy produced as oil and only half as much as coal. The other major sources of energy in the world, which include nuclear and renewable fuels such as hydropower, are not direct sources of greenhouse gas emissions. Figure III shows world-wide production divided by fuel type for commercial energy sources. Figures IV and V show energy production and consumption by region.

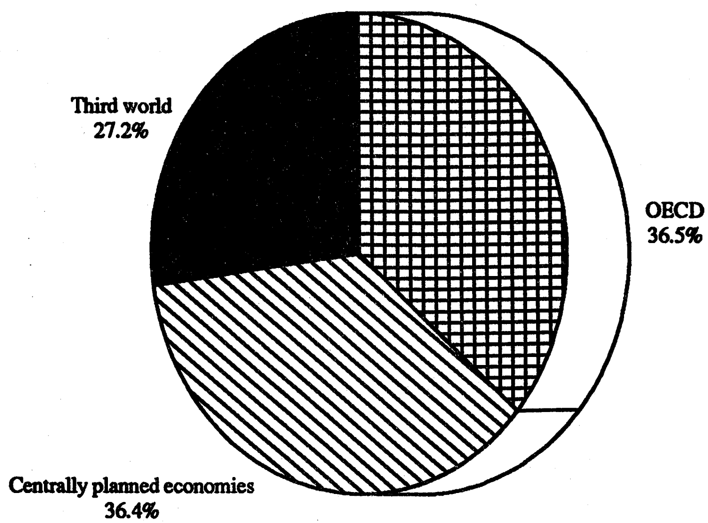
Figure III. Global commercial energy production
(277,900 Petajoules)



Source: United Nations, Statistical Office, 1987.

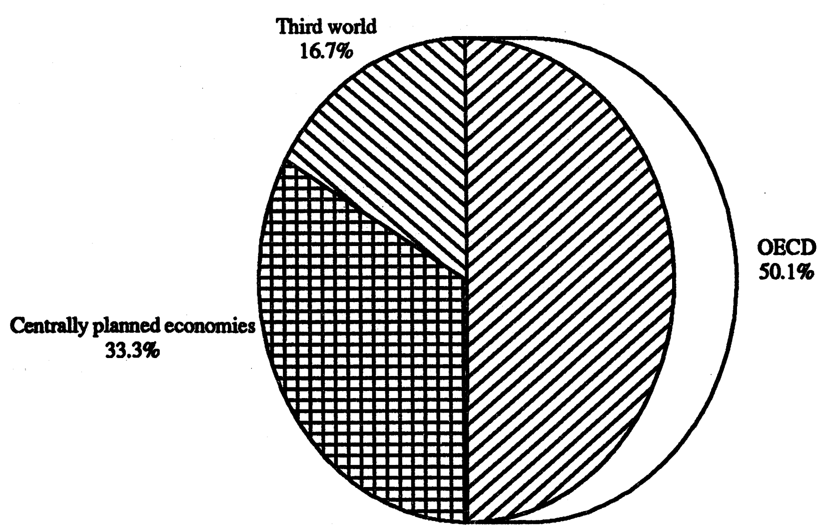
29 Environmental Protection Agency, *Global Climate*, op. cit., p. IV-13.

Figure IV. Global commercial energy production
(277,900 Petajoules)



Source: United Nations, Statistical Office, 1987.

Figure V. Global commercial energy consumption
(267,600 Petajoules)



Source: United Nations, Statistical Office, 1987.

Corporations play a role in the complex system of world fuel markets, where at different times some fuels are produced and promoted over others. They have had a major impact on choices of fuels as well as the efficiency of their use, throughout the world. This has substantially shaped both historic and present greenhouse gas emissions. There are, in addition, specific kinds of production methods which have historically been employed and which result in substantial greenhouse emissions. Those methods involve direct emissions of methane and other greenhouse gases during production and transportation, and emissions from the energy which must be used to extract, refine and transport fuels.

TNCs directly control about 50 per cent of the oil business, the most important area of commercial energy production, and have significant interests in the production of other fossil fuels. Some of the key corporations involved include Exxon (United States), Mobil (United States), Chevron (United States), Texaco (United States), Royal Dutch Shell (Netherlands) and British Petroleum (United Kingdom).

B. The fuel production industry

TNCs have played a central role in extraction, refining and marketing of fossil fuels. Their influence continues to be considerable, though patterns of ownership have changed substantially over the last two decades.

That influence has been most profound in the oil industry. Between 1945 and 1970, the industry was dominated by the so-called "seven sisters": Exxon, Mobil, Standard Oil of California, Texaco, Gulf Oil, Royal Dutch Shell and British Petroleum. Those corporations effectively monopolized the industry for a quarter of a century, in part through early concession agreements with oil-producing Governments in the Middle East, which gave ownership and exploratory rights. As John Blair would note in his 1976 review of the industry, control was supplemented in a variety of ways, including a "web of cartel arrangements set up in most of the world's consuming countries", and "boycotts, intimidation, and the active support of governmental bodies, particularly the U.S. State Department". As a result, they were able to shut out most of their competition and determine production levels and world prices to a significant extent.[30]

By 1970, these companies controlled virtually all oil in the developing world and all stages of refining and distribution outside the centrally planned economies. In addition, they owned 60 per cent of the production of crude oil in the industrialized countries.[31] Control was most profound in Western Asia, from which operations were focused almost exclusively on export to the European-North American market, since consumption was largely in those countries. Yet with the dramatic assertion of the power of OPEC in 1973, that pattern began to change. By 1981, the "big seven" held only 20 per cent of the market, while other major corporations held another 20 per cent of production. The remainder was in the hands of the oil producers themselves.

As a result of that challenge, there is more national ownership in oil-exporting countries, both within and outside of OPEC, as well as in oil-importing countries with considerable refining capacity (like Brazil and India). Those State-owned enterprises, however, enter into joint ventures and production-sharing agreements with TNCs. Onshore exploration and production for oil and gas by national bodies is well developed in many countries, including Argentina, Brazil, People's Republic of China, India, Mexico

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30 John Blair, *The Control of Oil* (New York, Vintage Books, 1978), p. 28.

31 Michael Tanzer, "Growing instability in the international oil industry", *OCAW Reporter* (September-October 1989), p. 6.

and the Soviet Union. Yet the control of production within all countries varies considerably. For example, petroleum production in Mexico is State-owned. In India, it is mostly State-owned, but sometimes it is produced with TNCs in production-sharing agreements. In OPEC, most oil fields are nationally owned, but they are operated by TNCs.

Though oil production within the OECD countries is largely in the hands of TNCs, ownership of coal resources in those areas is more diverse. For instance, in the United States, coal is owned mainly by TNCs, while in the United Kingdom, coal resources are owned by the State. Some State-owned companies of oil-producing third countries have started to take on the character of TNCs, through their growing interests in refining and marketing. They have acquired some downstream refining and marketing operations abroad and are becoming more horizontally integrated, as, for example, in the production of petrochemicals.

Overall, oil-producing developing countries utilize both national control and joint national-TNC ventures to produce fossil fuels, whereas production within OECD countries, as well as from offshore sites world-wide, remains largely in the hands of TNCs. The centralized economies are the only countries in which TNC involvement is not substantial, though even here there are some joint-production agreements.

TNC control has undergone considerable evolution over the last two decades. One of the most significant changes since the 1970s is the consolidation of TNC power within OECD itself. The ten-fold rise in oil prices in the 1970s, which came with OPEC, also increased the profits and revenues of TNCs. Although they lost most ownership rights within the OPEC countries, they used a portion of the profits from the price increases to acquire more oil and gas exploration rights within OECD countries - witness the vast expansion of North Sea oil production in the 1970s. Some of the profits were used to develop deep-sea-drilling technology, which could be used to exploit resources in the marine commons. Some were used to buy up existing fossil-fuel resources from other companies. Within the past two decades, oil and gas TNCs have become major owners of coal resources and coal production operations in the United States, as well as in other areas.

Outside of OECD, TNC influence remains most profound in offshore drilling, where their control of technology is very great. Even for onshore technology, they have a considerable technological edge in sophisticated methods of exploring for oil prior to drilling, which decreases the chance that exploratory holes will be dry. They also have great financial advantages by being able to mobilize large quantities of capital both from retained earnings and from external sources, such as the bond markets and transnational banks.

Within the OECD countries, TNCs have expanded their roles at various stages in the domestic oil production process. Vital pipelines, such as the Alaska line, are owned by the largest TNCs and are an important source of their influence. In addition, in a gradual process since the 1970s, most local gasoline outlets, particularly within the United States, have become vertically integrated with their TNC suppliers (previously, control of refineries and local marketing arrangements was less concentrated). Downstream operations which involve the use of oil and gas for chemical production are also owned by TNCs whether outright or in joint ventures.

In addition, traditional energy TNCs have also become involved in the development of the nuclear industry. A considerable portion of uranium resources has also come under the control of oil-producing TNCs. For instance, Exxon owns substantial uranium resources through its subsidiary Exxon Nuclear. Similarly, Chevron owns and operates uranium mines. In the 1970s a number of companies, such as

Mobil Oil and Atlantic Richfield, invested in the areas of solar cell technology and geothermal energy. However, the other biggest oil and gas TNCs (that is, BP and Shell) have never owned commanding shares in any of the alternative fuel areas.

The 1980s and early 1990s have been a period of particularly rapid transition for the industry. The collapse of OPEC prices in the early 1980s resulted in a substantial drop in profits for both national Governments and TNCs. That contributed to a sense of instability within the industry, and the once-untouchable TNCs have become vulnerable to an immense wave of corporate take-overs.

As can be seen in table 2, within the oil industry alone, major oil producers have acquired each other at a phenomenal rate over the last decade. Gulf Oil, a former "seven sister", was acquired by Chevron in 1984. In several cases, major TNC energy-users have also acquired oil companies: DuPont, a TNC which produces energy intensive chemicals (plastics, synthetic fibers, CFCs etc.), is now also one of the largest oil companies in the world, having acquired ownership of Conoco in 1981.

Table 2. Concentration of ownership in the United States oil industry

1980 Rank(s)	*Top 25 oil companies (United States)*	*Changes since 1980*
1	Exxon	No change
2, 3	Royal Dutch Shell, Shell Oil/USA	Shell USA acquired by Royal Dutch Shell
4, 5	Superior, Mobil, Conoco	Superior acquired by Mobil in 1984
6	Conoco	Conoco acquired by DuPont in 1981
7-8	Sohio, BP	Sohio acquired by BP in 1987
9-10	Getty Oil, Texaco	Getty Oil acquired by Texaco in 1984
11-12	Chevron, Gulf	Gulf acquired by Chevron in 1984
13-14	Amoco, Tenneco	Tenneco partly sold to Chevron, Amoco in 1988. Amoco now the largest gas-reserve holder in the United States
15-16	Cities Service Occidental-Petroleum	Citgo acquired by Occidental in 1982
17	Arco	No change
18-19	General Americal Oil Phillips Petroleum	General American Oil acquired by Phillips in 1983
20-25	UnoCal, Sun, Marathon, Amerada Hess, Texas Oil and Gas, Murphy Oil	Marathon Oil acquired by USX in 1982. Texas Oil and Gas merged with USX in 1985

Source: Peter Nulty, "Big oil faces a big squeeze", *Fortune* (9 October 1989).

In this era of upheaval, corporations are facing critical questions about their future investment plans. One trend within the United States seems to be a retreat from their diversification into renewable energy fields. For example, Atlantic Richfield sold its subsidiary Arco Solar, the largest United States manufacturer of photovoltaic, to a corporation of the Federal Republic of Germany in 1989. Mobil and Amoco are the only United States fossil-fuel producers remaining in this field, and their interests are not nearly as large.

At the same time, many companies are looking to expand their oil interests abroad again. As a recent article in *Fortune* magazine noted "with geology and environmental concerns diminishing the prospects for exploration and refining in the United States American companies are spreading out even farther across the globe in search of new reserves and new customers".[32] Producing oil overseas is considerably cheaper than domestic production. Charles Blackburn of Maxus Energy estimates that the price of discovering new oil overseas is roughly half of what it costs in the United States. Furthermore, growing industrial markets abroad are offering a rich new source of customers. For example, oil consumption in Taiwan Province of China and the Republic of Korea has recently grown at about 20 per cent per year.[33] Instead of looking to new energy areas, the United States-based oil producers seem to be viewing these new markets for fossil fuel as primary areas of expansion.

These plans have important ramifications for future energy use, particularly considering how powerful the overall TNC presence remains in this area. Although profits are off, TNC performance in the 1980s has been far better than that of the state companies of the oil-producing countries, which seized control of resources in the 1970s. OPEC alone saw revenues fall by three quarters from 1980 to 1986; the TNC drop was about half that, and cash flow (net profits after taxes plus depreciation and amortization) remained a steady $35 billion between 1980 and 1986, despite the drop in paper-profits.[34]

The powerful TNC energy producer has become a fixture in the international economy. The economic and political influence of those corporations must be taken into account in any efforts to protect the global environment, since their investment decisions and the political pressure they can exert are likely to have long-term impacts on emissions of greenhouse gases.

C. Fuel-production practices and greenhouse emissions

As noted initially, fossil fuels are the primary source of greenhouse gas emissions in the world. The impact of energy-producing TNCs on those overall emissions has clearly been substantial. This section considers some of the ways in which TNC fuel producers contribute more directly to greenhouse emissions through the process of fuel production.

Substantial greenhouse gas emissions occur from:

(a) Energy use in production, processing, refining and transportation of fossil fuels (carbon dioxide);

(b) Coal mines and abandoned mines (methane);

32 Peter Nulty, "Big oil faces a big squeeze", *Fortune*, (9 October 1989), p. 106.

33 Ibid.

34 Tanzer, op. cit., p. 6.

(c) Venting of natural gas (primarily methane);

(d) Leaks of natural gas at the well-head, and from the transmission and distribution system (methane);

(e) Flaring of natural gas (that is burning at the well-head), (carbon dioxide and methane).

It takes considerable amounts of energy to produce, process and transport fossil fuels. As a rule of thumb, processing, transportation and distribution (other than electricity generation) consume about 10 per cent of the fossil fuels which are produced. Since about 80 per cent of the total carbon dioxide emissions come from fossil fuels and 10 per cent of that is associated with production, processing and transportation, it can be estimated that about eight per cent of all carbon dioxide emissions are associated with various aspects of fossil-fuel production.

The proportion of methane emissions associated with fossil-fuel production is a matter of considerable debate. The following rough estimates have been given by the United States Environmental Protection Agency: [35]

(a) Approximately 50 million tons of carbon dioxide are released to the atmosphere from flaring of natural gas (this is a minor part of the problem of carbon dioxide emissions);

(b) Approximately 20 million to 50 million tons of methane are released from leaking and venting natural gas;

(c) About 25 million to 45 million tons of methane are released each year from coal mines.

Emissions of that size could contribute significantly to the build-up of methane in the atmosphere. Besides aggravating the problem of global warming directly, the products of the various chemical reactions of methane in the atmosphere also contribute to the build-up of yet other greenhouse gases. Thus, methane emissions from fossil-fuel production are a serious problem.

Many of those emissions are preventable. Flaring and venting of natural gas (which is principally methane) at the well-head remains a problem in the developing countries, despite the obvious waste and emissions problem. The primary interest of TNCs in exploiting the large oil and gas fields in the developing countries has been to secure cheap oil for the OECD market. Secondarily, those same companies have also marketed oil in the developing countries. That has been more profitable in the short run than investing in a complex structure of pipelines and developing uses for natural gas. As a result, natural gas has been vented or flared.

That pattern of wasting natural gas, while producing and marketing oil, also prevailed in the United States well into the twentieth century. It was only in the 1950s that markets for natural gas were fully developed and the practice of venting and flaring the gas was drastically reduced. That was because, at the request of oil companies, the Government interceded to set a minimum price on natural gas, which made its initial marketing profitable. Similar inducements have not been available in the developing countries, where petroleum-derived kerosene is still generally utilized for cooking instead of natural gas. This also continues, though natural gas, under typical conditions of use, is generally cleaner and safer and often cheaper than kerosene.

35 Environmental Protection Agency, *Global Climate*, op. cit., pp. IV-26, 27.

Venting and flaring, together with insufficient attention to leaks from pipelines, improperly capped wells etc. are all contributing significantly to the build-up of methane in the atmosphere. This is not only dangerous from the point of view of global warming, but increases in methane concentrations can stress the capacity of the atmosphere to cleanse itself of pollutants generally. Halting wastage of natural gas and drastic reduction in the leaks associated with its use are imperative if such environmental threats are to be diminished. Those measures are especially important since they are effective steps which can be taken in the short term.

D. Restructuring in the fossil-fuel production sector

If, as it appears, energy TNCs remain focused primarily on expanding the marketing for fossil fuels, they will have little incentive to contribute to efforts to reduce the massive greenhouse emissions which result from the widespread use of fossil fuels.

But, this continued pattern of market expansion for the fossil fuels that contribute most significantly to global warming, oil and coal, is in the long run, unacceptable. In the intermediate term, using natural gas efficiently may be preferable to using other fossil fuels, if investigation shows that this does not substantially increase methane emissions from leaks in the supply system.

The TNCs which control the exploitation, production, transportation and marketing of oil and coal need to realize that their future lies in developing a mix of sustainable energy sources. If they do not come to that realization, if the companies who control fossil-fuel production and marketing, that is, the largest and most powerful TNCs in the world, do not diversify into renewable, safe energy sources, they will forever resist attempts to limit the growth of the fossil-fuel market.

There are good economic reasons, however, why fossil fuel TNCs should be committed to developing renewable, safe energy sources. There will be costs associated with the impact that global warming will have on the climate and on the rising of the seas. Losses may be incurred at offshore drilling platforms, for example. Shipping facilities may be adversely affected by the rising seas. Increases in temperature will affect the market for heating oil. Consumer demand for efficient and cleaner cars will add costs to the distribution and marketing of fuel. Those dangers could be opportunities for growth and market expansion in new investment areas.

New markets will open up in solar heating and cooling systems. Using more locally-available energy sources could positively affect transportation and transmission costs. The potential growth in the market size of renewable energy is enormous, since the market is clearly so unsaturated.

It is clear that only through a level of cooperation among sectors with different self interests that has never yet been achieved will it be possible to alter energy production, transport and consumption patterns. It is dangerous to wait to see exactly when and the extent to which the dire predictions of flooding, cancer, destruction of agriculture, for example, come true. The major and most powerful economic institutions in the world today, however, will not just walk away from their economic base. To ensure the necessary conversion and restructuring, Governments will have to create the necessary incentives and controls.

However, the costs of that conversion will have to be equitably shared. The costs cannot be simply passed on to the people in the form of increased prices, decreased wages and greater debt. Developing countries are already suffering too much to sustain much increased economic burden. Similarly, in industrialized countries, long-term economic growth requires an educated, trained, productive, uncynical population, which can exercise its consumer power to improve the daily quality of life.

Below are some preliminary ideas for guidelines for the TNCs which produce and distribute fossil-fuels. These principles are not complete. They are meant as a starting point for discussion among the interested parties, to begin to design effective strategies for a revolutionary conversion of the world's energy base. The principles are aimed at TNCs, not Governments.

E. Transition planning measures

In order to consider measures aimed at limiting emissions from fossil-fuel production, companies need to make a complete and thorough analysis of the source and extent of emissions from extraction, processing, refining and transportation of both oil and coal. Once that internal analysis has been made, the company should design a strategy, including the development of new technologies, for decreasing emissions as much as possible and for capturing and utilizing otherwise wasted by-products such as heat.

A thorough analysis of gas venting and flaring in areas where it is still going on would, in most cases, reveal the economic desirability, as well as the environmental benefits, of trapping and utilizing the gas. Moreover, as nationally-owned companies have taken more of the lead in oil and gas production, more attention has been focused on reducing wastage of gas in atmospheric emissions, since it is to their advantage. Venting from existing gas wells should be stopped immediately.

F. Transition investment measures

In the long run, conversion from dedication to fossil-fuel energy sources to the use of alternative, renewable safe energy sources is key to preventing global warming and the global environmental degradation related to industrial pollution. Therefore, transition measures can and should be taken by TNCs and other large energy producers. Future-oriented companies should be making new investments in less greenhouse-gas-generating sources of energy, such as solar, geothermal, cogeneration, as well as environmentally safe exploitation of natural gas. Although some alternative sources of energy are relatively competitive in price with fossil-fuels, demand is still too limited to generate the necessary widespread use. Therefore, new investments in alternative renewable energy sources should be geared towards making the source economically competitive and marketed for widespread use. Displacing of oil and coal with expanded use of natural gas may be a good transition strategy.

Other transition investment strategies include investing in the necessary R&D, to increase the efficiency of energy storage technologies; investing in R&D aimed at increasing the efficiency of energy transportation systems (particularly at this time for natural gas and electricity); and investing in the necessary R&D to decrease production leakages (for example, from abandoned coal mines, valves, welds, pipes etc.). Improved storage and transport efficiency will also be useful for the long-term.

For the ultimate survival of the planet, however, the commitment of new investments in alternative sources of energy must be coupled with a decrease in investments and exploitation for oil.

CHAPTER V

TRANSPORTATION: ROAD VEHICLES

A. Introduction

Transportation is a major consumer of energy and contributor to environmental degradation, and the ways in which energy is consumed are heavily determined by TNCs. Fossil-fuel-burning road vehicles are predominant in transportation, and TNC influence over the whole transportation infrastructure is apparent given their majority share in the world-wide production of road vehicles.

Transportation accounts for 27 per cent of global energy use and is responsible for the emission of about 1.1 billion metric tons of carbon per year in the form of carbon dioxide, or 20 per cent of all carbon emissions from fossil fuels.[36] Industrialized countries are responsible for two thirds of the total carbon dioxide emitted from transport world-wide (figure VI). The United States alone emits more than one third of the total, while all the developing countries together produce less than one fifth. Within the transportation sector, hydrocarbon fuels account for over 90 per cent of energy demand. Almost all of this consists of petroleum products, except in China and India, where large quantities of coal are used to power trains.

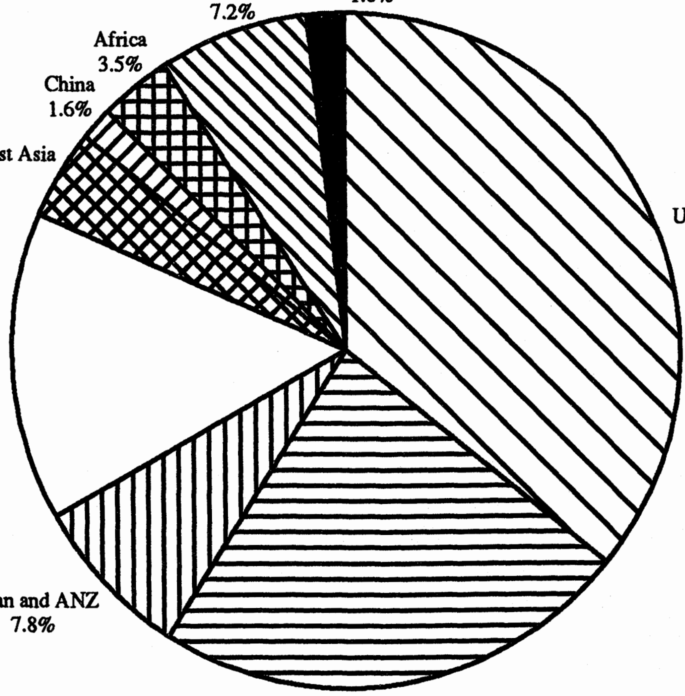
The extent of TNC activity in the transport sector can be seen from the proportion of commercial energy demand met by oil-based fuels for internal combustion engines: over 99 per cent in the OECD countries and over 90 per cent in much of the developing world. In the United States, 60 per cent of the oil products consumed in transportation are used for automobiles and light trucks.[37]

TNCs dominate the automotive industry, which also produces engines for bus transportation and for rail. Just 13 corporations supply 80 per cent of the total world market. Five of them (General Motors, Ford, Toyota, Nissan and Peugeot) sell half of all vehicles and the two largest (General Motors and Ford) control nearly 30 per cent of the world market. Those companies have increasingly internationalized their production, both individually and in joint ventures between them, in order to compete in an increasingly global market. The largest corporations (General Motors and Ford) are integrating their production

36 Environmental Protection Agency, *Global Climate*, op. cit., pp. IV-28, 32.

37 Deborah Bleviss, *The New Oil Crisis and Fuel Economy Technologies* (New York, Quorum Books, 1988), p. 7.

Figure VI. Global transport emissions of CO_2



Source: Michael Walsh, 1989.

world-wide, producing different components in different countries. Japanese firms (Toyota, Nissan, and Honda) have been selling vehicles abroad for many years and are now producing components or are entering joint ventures with foreign firms to overcome restrictions on imports of Japanese cars. European firms are merging or are combining with their Japanese or American rivals in order to become competitive in size and strength.

As a result of those combinations and joint ventures, there are now business associations and capital participation between most automobile manufacturers. Equity participation ranges from a low per cent (Isuzu and Suzuki, for example) to 100 per cent (General Motors and Vauxhall, for example).

Through the size of their market share of vehicle production and through their design and production standards, TNCs determine the fuel economy and emissions standards of those vehicles. In the United States, they have influenced pertinent government regulations to obtain an easing of vehicle efficiency standards for the cars they produce. They thus carry considerable responsibility for the persistence of low fuel efficiency in transportation relative to what could be achieved and for the heavy dependence of transportation upon oil.

TNC automakers have also had a role in reducing the possibilities of alternative modes of transportation. This ranges from extensive automobile advertising to augment market demand, to deliberate collusive action among companies to reduce the competition from other modes of transport, particularly from rail.

B. Evolution of dependence on road vehicles

In the United States, automobile corporations played a major role in the decimation of rail transport.[38] In the 1920s, when the United States market for cars showed its first signs of saturation, vehicle, oil and tire producers adopted specific strategies to create additional demand for road vehicles by diverting rail passengers and freight to buses, cars and trucks.[39] General Motors, in particular, set up intercity bus services starting in 1926 and, in 1932, began buying up, operating, and then converting electric railway and streetcar systems to diesel buses. General Motors was instrumental in the formation of the Greyhound Corporation, which by 1930 had successfully pressured six major railroads to replace their trains with buses.

Success with intercity buses moved General Motors to use similar approaches within cities, acquiring and replacing local electric transit systems with buses. When it was censured in 1935 for this self-serving action by the American Transit Association, it then shifted to more indirect methods and combined with other corporations to achieve this same end. The world's largest electric streetcar system in New York City was converted to buses in only 18 months. From 1936 to 1945, a holding company, organized by General Motors together with Firestone Tire, Standard Oil and Mack Truck, bought up and destroyed streetcar systems in 45 cities in the United States.[40] Congressional anti-trust evidence notes that:[41]

"To preclude the return of electric vehicles to the dozens of cities it motorized, General Motor extracted from the local transit companies contracts which prohibited their purchase of 'any new equipment using any fuel or means of propulsion other than gas[oline]'".

In 1947, the corporations involved were brought to trial in the Federal Court in Chicago and found guilty, but General Motors was fined only $5,000, and its treasurer, who had played a key role in the monopoly, was fined $1.

Despite that ruling, General Motors continued to dieselize electric transport until 1955. Over the 19 years from 1936, the number of electric streetcars had been reduced from 40,000 to 5,000. As the head of the General Motors bus division then stated, "The motor coach has supplanted the interurban systems and has for all practical purposes eliminated the trolley".[42] Now 19 cities are planning to reintroduce trolley systems at enormous cost, sometimes along the same routes that were dismantled.

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38 For an overview, see D. J. St. Clair, *The Motorization of American Cities* (New York, Praeger, 1986).

39 Those strategies have been extensively documented by Bradford D. Snell, "American Ground Transport: A Proposal for Restructuring the Automobile, Truck, Bus and Rail Industries", published evidence for the United States Senate Antitrust and Monopoly Subcommittee hearings on ground transportation industries, (1974), pp. A-1A-103, from which the materials are taken.

40 A. Kimbrell, "Car culture: driving ourselves crazy", *The Washington Post* (3 September 1989).

41 Snell, p. A-31, citing United States v. National City Lines, *1951 Trade Cases*, para. 62,757 at 64,237 (ND ILL).

42 Ibid., p. A-35.

Some of the proposed systems, such as that of Los Angeles, cover only one quarter of the area served by the earlier dismantled networks.

Yet the switch to the motor coach was not in itself enough for the corporations involved. Buses were also less profitable than cars: 35 cars can replace a single bus and increase the automakers' revenue 10 times. Several cities sued General Motors for not only: [43]

> "Setting higher-than-competitive prices for its diesel buses, receiving millions of dollars annually in monopoly profits... [but also] ...disregarding technological innovations in propulsion, pollution control and coach design, which would help attract patrons out of their automobiles."

Similarly destructive strategies for freight transport were followed by the corporations. From 1939 to 1972, United States railroads lost not only 50 per cent of their passenger traffic, but also nearly 75 per cent of all freight revenue. In addition, the General Motors diesel locomotives were less durable, less efficient and more polluting than the electric locomotives they replaced.

Relative profitability of road or rail transport is also substantially affected by government subsidizing of different elements in the total cost, such as in the construction of highways. In 1932, the president of General Motors played a leading role in establishing the National Highway Users' Conference with a view to channeling state and local gasoline taxes and highway taxes solely for highway purposes, and developing a continuing programme of highway construction.

Whether the near total transfer to automobiles can be justified even in economic terms has been the subject of considerable debate. A 1974 Congressional study evidenced an unremitting economic case against road vehicles, but it was insufficiently documented. A more thorough study by St. Clair [44] indicated that buses were less economical than streetcars, at least on heavily-used lines. [45]

Moving from rail to road transport also incurs external social and environmental costs, which are not generally factored into the comparison. These are problems which are associated with the ways in which the destruction of public rail transport and the encouragement of road transport and private vehicles over it contributed to dispersed suburban living patterns. Some experts argue that the corporate ultimate goal was the fundamental structuring of urban areas so as to open them up to the automobile. [46] Spatial dispersion causes people to need cars and makes public transport more costly and less efficient to run.

One attempt to calculate the external costs of moving traffic from rail to road indicated a five-fold increase in energy requirements, and a fuel cost increase of 10 per cent of the total spent on motor vehicle transportation. [47] Dependence on highways has also hindered innovations in high-speed rail transport (such as those being made in Europe and Japan).

43 Ibid., p. A-37.

44 St. Clair, op. cit.

45 More recently, a counter-argument has been advanced by D. Lipson, suggesting that buses were more profitable and that the intervention of National City Lines of General Motors therefore served to accelerate a demise of mass transit which was already in course. (See "General Motors, National City Lines and the Motor Bus: The Motor Bus' Role in the Decline of Mass Transit in the United States", B.A. thesis, Harvard). St. Clair disputes those calculations.

46 St. Clair, op. cit., p. 172.

47 These costs were reported by Snell, based on information provided by Rice, "System energy and future transportation", *Technology Review* (1972).

Most important for this study, the shift towards automobile transit and associated dispersed living patterns have contributed significantly to increases in global carbon emissions. In addition, pollution control under these circumstances is more difficult and more expensive, since it is harder to install emission-control devices on 100 million transient vehicles than on the much smaller number of stationary power stations needed for electric transport. Finally, the large portion of the population who cannot drive (those disabled, too poor, young or old to drive) have their mobility reduced by the sparseness of public transport facilities.

Finding ways to reverse those historical shifts in modes of transportation is of major importance. In the meantime, it is also crucial to accelerate improvement in the fuel efficiency of road vehicles.

C. Vehicle fuel efficiency

Even without shifting to rail, transportation by road could be operating with fuel efficiencies several times greater than those common today. Although the major motor manufacturers have all developed prototypes (table 3), which get about two to four litres/100 km., they have resisted targets of only 7.6 to 8.8 litres/100 km. for the vehicles they currently produce (table 4). One analyst estimates total fuel savings of up to two thirds over the next 30 years if the top end of that range is widely adopted. [48]

Vehicle manufacturers made improvements in fuel consumption immediately following the oil price rises in the 1970s, because consumer desire for greater fuel efficiency was evident and regulations were imposed. Improvements decreased, however, once oil prices levelled and fell in the 1980s. The largest motor manufacturers have generally not seen it as in their interest to increase fuel efficiency in these circumstances, particularly in the absence of regulation.

The United States-based TNCs, in particular, have been notoriously slow to incorporate improvements into their production lines. With the oil price slump in the mid-1980s, they saw no consumer demand to do so. Trade unions also played a role, in their attempt to retain employment for their

Table 3. Automobile fuel economies: historic and present passenger vehicles
(Litres/100 km.)

Year	*United States*	*Japan*	*Federal Republic of Germany*
1973	16.6	10.4	10.3
1978	11.8	8.8	9.6
1985	11.7	7.8	7.5

Source: Environmental Protection Agency, *Global Climate*, 1989, p. VII-40.

48 Walsh, "Global trends in motor vehicles and their use implications for climate modification", an assessment prepared for the World Resource Institute's Climate, Energy and Pollution Programme (Washington, D.C., 1988), p. 37.

Table 4. Automobile fuel economies: high-efficiency prototype passenger vehicles
(Litres/100 km.)

General Motors TPC (gasoline)	*Toyota AXV (diesel)*	*Volvo LCP 2000 (diesel)*	*Renault Vesta II*
3.85 city	2.54 city	3.73 city	3.01 city
3.17 hwy	2.13 hwy	2.40 hwy	2.19 hwy

Source: Adopted from Deborah Bleviss, *The New Oil Crisis and Fuel Economy Technologies* (New York, Quorum Books, 1988), p. 96.

membership. Other causes of low pursuit of fuel efficiency by United States automobile manufacturers have been: low perception of benefits, low degree of competition, low means of capitalization, low commitment to research and development, views of the future availability and price of energy and product liability concerns. They even moved to reduce government regulatory pressure on fuel economy. Their lack of interest caused small companies innovating in fuel technology to sell out to European and Japanese producers.

TNCs have also directly contributed to differences in emission levels between countries. For example, Ford Motors (United Kingdom) recently refused to install catalytic converters to reduce nitrous oxide emissions from cars made in the United Kingdom, [49] although those are mandatory on their cars in the United States. Similarly, Volkswagen in Brazil does not produce the same advanced model as they do in Europe or the United States. [50]

The largest improvements in fuel efficiency were brought about by regulation, rather than by increases in oil prices. Various kinds of regulation have been instituted around the world, including fuel taxes, fuel economy standards, speed limits, and taxes on vehicles with high fuel consumption. In the United States and Japan, vehicle fuel efficiency standards have been enforced by legislation. The vehicle fuel efficiency changes which occurred in the United States in the mid-1970s reflect the efficacy of the legislative approach there. In the United States, corporate average fuel efficiency (CAFE) standards legislated in 1975 set progressively higher targets for manufacturers' new lines of vehicles, with financial penalties for failure to meet the targets. The CAFE programme is considered one of the most successful world-wide and is credited with 20 per cent of the oil reduction achieved by International Energy Agency signatories between 1979 and 1983.

Despite the success of the CAFE programme in the United States, corporate pressure and unsympathetic United States administrations helped to limit its subsequent impact. The CAFE goal for 1985 was 27.5 mpg (or 8.55 liters/100 km) for passenger cars. Yet, after General Motors and Ford failed to meet the 1984 and 1985 targets, they were able to get the standards reduced (to 26 mpg) for 1986-1988,

49 P. Stevenson, op. cit., description of results of Greenpeace Air Toxics Campaign in the United Kingdom.

50 United Nations Centre on Transnational Corporations, *Transnational Corporations in the International Auto Industry* (United Nations publication, Sales No. E.83.II.A.6), p. 93.

and also succeeded in reducing their fines for the previous years. The Reagan Administration even requested Congress to eliminate the CAFE programme altogether.[51]

In addition, the CAFE standards have structural flaws which have made them less effective in increasing fuel efficiency overall. One of the problems with the standards is that they set a single average for the entire carfleet. This favoured producers of smaller cars who could, based on averaged figures, avoid making improvements. It also has permitted manufacturers to use a single highly efficient prototype in one case, imported from Japan specifically for this purpose to offset the inefficiency of other models kept in production. Targets for percentage improvements would therefore be more effective. Such targets are used in Japan, differing for each weight category of vehicle.

A different kind of regulatory strategy includes increases in fuel prices or taxation, which may reduce the amount that people drive or increase their preference for more fuel efficient cars. Cars have tended to be smaller and more efficient in countries where gasoline prices are higher. In Italy, for example, where fuel prices have been more than twice as high as those in the United States, fuel efficiencies are about 25 per cent higher.[52] The impact of fuel taxes, however, is reduced as cars become more efficient and require less fuel. Moreover, this tends to be a highly regressive form of taxation.

Global regulation of car and light-truck fuel efficiencies could have an enormous impact on greenhouse emissions. The lack of globally consistent standards or targets for fuel economy impedes the implementation of the best available technology. In the developing countries, low fuel economy is exacerbated by the greater age of vehicles, lower levels of vehicle maintenance, poorer tires or the recourse to bias-ply instead of radial tires, and lower quality and maintenance of roads.

Requiring manufacturers to maintain certain minimum emission standards and fuel efficiency world-wide would not only reduce global warming. It would also help to reduce air pollution, which has become particularly severe in urban areas of the developing countries, like Mexico City. The largest increases in numbers of automobiles are expected to occur in developing countries, where vehicle ownership is currently the lowest. In 1985, for example, there were only six cars per 1,000 people in Asia, 12 in Africa, 56 in Latin America, and 43 in the Middle East, as compared to 573 in the United States.

D. Restructuring the automotive sector

Improvements in the way vehicles are used and in the vehicles themselves are vital to alleviating the present levels of greenhouse gas emissions and the contribution to other forms of environmental degradation, such as urban air pollution. For the short term, increased fuel efficiency, less total numbers of vehicles and fewer miles driven will be vital to reducing carbon emissions. It can be generally stated that all three of these are possible, whether by improvements in vehicle efficiency or in the development of rail and other alternatives to road-based or fossil-fuel-dependent vehicles.

Corporate action to promote those changes will probably need to be supported by government action, which has proved to be one of the most effective ways of achieving dramatic changes in fuel efficiency. Similarly, if past experience is any model, the long-term potential for switching to better forms

51 Bleviss, op. cit., p. 229; and Walsh, op. cit., p. 32.

52 Bleviss, op. cit., p. 162.

of transportation and more efficient urban settlement patterns will also depend to a large extent on what actions and guidance are provided by national and international political bodies.

While the first line of attack is greater efficiency, more miles to the gallon, this is not the long-term solution.

Major TNCs manufacturing road vehicles have generally resisted legislation regarding safety standards, as well as fuel efficiency. This has been especially true in the United States. Instead of resisting efficiency standards, TNCs should be promoting their more vigorous application so that a transition can be made to vehicles which are many times more energy efficient than those on the road today. The transportation sector has the potential to provide major reductions in carbon dioxide emissions, both though efficiency improvements, and also through the use of energy efficient electric vehicles, particularly if those are partly solar-powered. Corporations must urgently start developing high efficiency prototypes and putting them into production.

Like the energy-producing sector, the automotive sector will ultimately and necessarily have to diversify from reliance on carbon emitting fossil fuels to cleaner energy sources, and it will need to convert away from reliance on growth of the individual car market to the development of low-cost and clean mass transport systems. Therefore, new investment in cars with low fuel efficiency needs to decline, while expanded investments in mass transit systems need to increase significantly. In order to support that transformation, Governments need to remove hidden subsidies and biased regulations which support and strengthen road and individual transport, and provide financial resources to strengthen the alternative. That is especially critical for developing countries, where urban areas, as a result of the lack of mass transportation systems and an aging polluting automotive fleet, have become increasingly toxic for the local population.

TNCs which operate in developing countries and which stand to benefit from the market growth potential in developing countries for private cars have a particular responsibility, first, to ensure that fuel-efficiency standards and pollution-control devices are applied globally, and second, to make pollution-control technology for application to an older fleet available at low cost. TNCs should provide pollution-control technologies and equipment for older cars in developing countries through their existing marketing and distribution channels. This would be possible through existing distributorships and gas stations. In addition, TNCs should conduct systems analyses which include economic and environmental costs of poor tires, poor roads, older vehicles etc. These would provide a basis for developing countries to make reasonable decisions about the structure of transportation systems.

It would be wise for TNC automotive manufacturers to act now to lower the impact of this sector on global warming. International regulation may be imminent through a possible global climate change convention. Like the Montreal Protocol, greenhouse gas emissions may be reduced by intergovernmental agreement. The current long R&D lead times for basic models may be a liability in the face of possible CO_2 taxes and the international targets for limiting greenhouse and ozone depleting gases.

Mandatory car recycling may occur, particularly for vehicles with air conditioners. National and international regulation could create inducements for increasing the fleet of efficient and comfortable vans and buses as part of expanded mass transportation systems.

Global warming and the related ocean rise could generate unexpected costs if road transportation is disrupted or if manufacturing and distribution facilities in coastal areas are affected.

What happens in Eastern Europe is particularly important, since it has been predicted that car sales in Eastern Europe will double within five years. Some automobile executives predict that, by the end of the decade, the market will grow to seven million cars a year.[53] That could mean increased urban pollution and increased danger to the global warming problem. Or, companies could use this as an opportunity to make the investments necessary to initiate practices that will be in line with the emerging global standards.

Finally, transportation TNCs benefit from operation in a global market. This should give them greater flexibility in terms of investment decisions which impact greenhouse gas emissions. Investments in environmentally sound buses, subways and trains could offset diminished investment in individual automobiles. And for all forms of transportation, TNCs should observe minimum universal standards on emissions and fuel efficiency in their global production and market operations.

53 Steven Greenhouse, "Fiat's thrust into Eastern Europe", *New York Times* (5 August 1990) sect. D, p. 1.

CHAPTER VI

ELECTRICITY GENERATION

A. Introduction

Electricity generation is an intermediate sector which converts fuel into a mobile, and highly versatile form of energy. It is an energy-consuming industry in that it uses large quantities of various fuels to produce electricity, and an energy-producing industry in that its output is a form of energy.

Worldwide, almost 10 trillion kilowatt hours of electricity were produced in 1985 (not including electricity generated by biomass-fired plants). Of this total, 64 per cent was produced by conventional fossil-fueled thermal-generating plants, 20 per cent by hydroelectric plants, and 15 per cent by nuclear power plants. About 0.3 per cent was generated by geothermal and wind-energy stations. [54]

Electricity generation accounts for about 1.7 billion metric tons (or 30 per cent) of carbon emissions from the consumption of fossil fuels. The principal fossil fuels used are coal and oil. Hydropower does not involve direct emissions of greenhouse gases. However, hydropower causes other kinds of environmental damage. Large dams submerge large areas of land, often forested areas. The concerns about loss of species, loss of agricultural land, associated loss of jobs and flooding of villages and towns are well known. In addition, creation of lakes without cutting forests can result in increases in emissions of methane, a powerful greenhouse gas.

TNCs are not generally involved directly in the production of electricity, which is usually the province of nationally-owned or privately-owned enterprises not controlled by TNCs. While there may be considerable foreign ownership of the stock of privately-owned utilities, as for example in the case of United States electric utilities, the control over which is still exercised primarily at the national or state level, TNCs are involved in it in two different ways: through the production of fossil fuels, discussed above, and through the manufacture of electricity generation, transmission and distribution equipment. Increasingly, some service TNCs, such as Bechtel, undertake the complete design and construction of power plants. TNCs also influence electricity demand through influencing the structure of electricity

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54 United Nations, *Energy Statistics Yearbook, 1985* (United Nations publication, Sales No. E.86.XVII.13).

consumption. That is the subject of a separate case study on energy-intensive metals production (see chapter VII below).

Among the major TNC manufacturers of electrical generation equipment are the following:

(a) United States-based companies: General Electric, Westinghouse, Babcock and Wilcox, Bechtel;

(b) European companies: Siemens, ASEA Brown Boveri, Alsthom-Atlantique, General Electric (United Kingdom);

(c) Japanese companies: Mitsubishi.

A number of other countries possess small to medium-size corporations, which export electrical-generation equipment. Those, however, usually operate under licence to larger TNCs or have technology that is essentially similar. Some of those are TNCs, while others are based in one country. An example of the latter would be India's Bharat Heavy Electrical Limited (BHEL).

B. Structural issues

A number of factors influence the world-wide dependence on fossil-fired electricity sources. Several major negative tendencies historically encouraged by the current energy infrastructure include a lack of emphasis on developing the full potential of energy-efficiency improvements, such as cogeneration; an emphasis on large centralized generating stations; and an emphasis on fossil fuels as opposed to non-carbon-based energy sources like solar and other renewable energy sources. These tendencies are discussed below.

Energy efficiency, cogeneration and generating station size

Although energy efficiency is usually considered an issue relevant to energy consumers rather than energy producers, issues of efficiency also merit some discussion in relation to the generation of electricity. Since energy consumers are generally not interested in energy *per se*, but in the services which energy provides, the form in which energy is delivered is highly influenced by decisions made by energy-providers. Since the overall efficiency of the energy system is dependent on the efficiency of energy production as well as energy consumption, it is important to consider the role of the production side.

It has generally been more profitable, other things being equal, for both TNC manufacturers of generating equipment and utilities to encourage consumers to use more rather than less energy. For instance, in the United States, public utility revenues and profits were set as a percentage of investments. The greater the energy demand, the greater the need for investments in energy-producing equipment, the larger the profits. Also, since a number of the manufacturers of electricity-consuming appliances are TNCs, which also produce and sell electrical-generating equipment (for example, General Electric, Westinghouse), improving the energy efficiency of appliances would only tend to reduce the demand for the generating equipment those TNCs also sell. Thus, many TNCs have had little internal interest historically in making the appliances they produce more energy-efficient.

TNCs sell inefficient electrical appliances and lighting technologies that bloat electricity use without economic benefit. Efficiency standards for electrical end-use equipment, fuel switching from electricity to gas in water heating, space heating, and other end-uses, and the use of insulation to reduce air-conditioning needs are very important technical options directly involving what large electrical TNCs produce and sell.

Since United States based TNCs were the dominant ones in the years immediately after the Second World War, the pattern of production and demand within the United States came to play a very large role world-wide. This happened both directly through sales of products by transnational corporations, as well as through policy institutions, such as the World Power Conferences, at which the United States methods of utility planning and design became influential all over the world.

An important way to increase the efficiency with which energy is produced is the use of cogenerating technologies. Cogeneration involves the simultaneous production of both usable heat and electricity. At an electric generating station, for example, a cogenerator makes productive use of the waste heat energy (which would otherwise be lost) by using it to heat water or indoor living space. Combining the production of both electric and thermal energy in one unit creates substantial energy savings. For example, replacing a diesel electric generator and an oil-fired furnace by a single diesel cogenerator can reduce total fuel use by at least 25 per cent. [55]

Unfortunately, the industry has barely begun to tap the energy savings potential of cogeneration. Even as recently as 1986 in the United States, for example (a number of years after the passage of modest federal legislation designed to encourage cogeneration), only 18,000 megawatts of electric capacity was provided by cogenerators. Although that amount represented 73 per cent of United States capacity of non-utility-power, it represented only about 3.3 per cent of the total United States electricity supply. [56]

Although the potential for expanding cogeneration is large internationally, the actual potential is less than it would be in principle because of the pervasive tendency towards the use of large-scale, centralized generating stations, which make the productive use of the waste heat less practical.

That tendency towards large plants has been profitable both for TNC manufacturers of generator equipment, as well as for public utilities. This is true for the same reason that electricity generators have usually had a positive incentive to increase the supply of energy rather than to encourage a reduction in demand, because profits are set as a percentage of investments. Thus, the larger and more capital-intensive the plants, the larger the profits.

Large-scale electricity-only power plants were installed in preference to more efficient and smaller-scale site-specific schemes based on cogeneration technology. Electric utilities in the United States and elsewhere generally did not look favourably upon such schemes and saw them as competitors in an arena where the "natural monopoly" had been granted to them. As a result, natural gas and oil were used to raise steam in industry and to provide heat in large commercial and residential buildings and complexes (but not to generate electricity), while coal was emphasized as the primary fuel for the central station electricity-generating plants.

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55 United States Office of Technology Assessment, *Industrial and Commercial Technology Assessment Cogeneration* (Washington, D.C., United States Government Printing Office, February 1983), pp. 222-223, as cited in Nancy Rader, Ken Bossong, Alex Antypas and Scott Denman, *Turning Down the Heat: Solutions to Global Warming* (Washington, D.C., Public Citizen, September 1988), p. 57.

56 Based on "EEI: Over 25,000 MW of non-utility capacity was in service as of 1986", *Electric Utility Week* (New York, McGraw-Hill, 15 August 1988), p. 13; and analysis in Rader, et al., op. cit., p. 57.

Because separate energy sources were used to raise steam heat and to produce electricity, when a single cogeneration plant might have been sufficient to provide both, far more energy was consumed than necessary. The generation of electricity along with heat in a vast section of the commercial and industrial sector, as well as a substantial portion of the residential sector, can be done using cogeneration technology.

Historical TNC investments in large-scale generation have thus resulted in much higher carbon dioxide emissions, and much greater fossil fuel production, than would otherwise have been necessary. The same approach, emphasizing large-scale generation, was also adopted in the nuclear arena. In many cases, particularly in the United States, that has involved considerable financial losses for the owners of utilities, as well as electricity consumers, as nuclear-power plants have proved to be far more expensive than originally anticipated.

The problems of large-scale generation, in preference to cogeneration with supplementary power-exchange with the electric grid, are compounded in developing countries. That is because electric grids in developing countries are much smaller, and reliable operation requires that single generators be a small fraction of total grid capacity. One rule of thumb is that generator size should not exceed 5 per cent of the grid size. Yet because the sizes of generators being used in the major markets of the OECD countries were large, the TNCs tended to market those same sizes in developing countries. An illustration of the extreme problems that this can cause is provided by the four generators that were installed at the Akosombo dam by the Volta River Authority in Ghana. The firm (uninterrupted) power supply requirements contract for a nearby aluminium production plant meant that, for many years, most of the power supply to the rest of Ghana came essentially from one or two generators. Any interruption of power to the aluminium potlines involved contractual penalties, so that, in effect, the whole country was on interruptible power when one or two generators were down in order to ensure continuous power to the aluminium facility. Had the generator size been much smaller, considerable losses to the Ghanaian economy over several decades could have been avoided. (See Chapter VII below, for a more detailed discussion of the problems associated with the Akosombo dam project and the aluminium production plant.)

Even in the OECD countries, generator size should have been much smaller. A 1977 study by Ed Kahn of the Pennsylvania-New Jersey-Maryland grid, argued that the optimal generator size for the grid was not 1,000 megawatts, the typical size being installed during the 1970s for central station case-load plants, but only 400 megawatts. [57] At this smaller generator size, the reserve margin (the standard measure of surplus capacity for a grid) required for a given reliability (loss-of-load-probability) would be the smallest possible.

Energy sources: fossil vs. non-carbon fuels

Historically, both utilities and vendors of electric-generating equipment have relied extensively on non-renewable carbon-based fossil-fuel sources, a practice which has resulted in extensive greenhouse gas emissions.

This has been true despite the fact that, in the long run, the resource base (that is, the amount of economically recoverable energy reserves) for non-carbon based renewable energy sources (such as

57 Testimony before the New Jersey Board of Public Utilities, Docket No. 762-194 (1977).

hydropower, various solar technologies, including wind energy, biomass energy and geothermal energy) is enormous. The annual renewable resource base in the United States alone exceeds 80,000 quads. That compares with an estimated United States coal resource base of 10,000 to 15,000 quads total, and an oil and gas resource base of 123 quads total. [58] (By comparison, the total world consumption of energy in 1985 was equal to approximately 270 quads.)

Although some of those technologies are very mature and have been in existence for many years (particularly hydropower), it has only been in recent years that some energy companies have begun to take significant steps to implement the range of other, less developed renewable technologies, whose potential, for the most part, had been largely ignored.

In the United States, for example, non-hydro renewable electric capacity has experienced tremendous growth, expanding almost nine-fold from a capacity of 1,109 megawatts in 1980, to over 9,500 megawatts in 1989. [59] As those technologies have begun to slide down the learning curve, costs have dropped dramatically, and many technologies once considered "exotic" are now competitive or near-competitive with conventional electric supplies. Wind-electricity prices have fallen by more than a factor of three since 1980, and now stand at seven to nine cents per kWh; solar thermal electric power now costs eight to 12 cents per kWh in the most favourable locations. Comparable conventional gas or oil peakload electricity costs between 6.4 and 9.1 cents per kWh. Photovoltaic electricity, while not yet cost competitive, has dropped precipitously from the 1980 cost levels of $1.50 per kWh to 20 to 40 cents per kWh today, and has the potential to become cost competitive by the late 1990s. [60]

A large part of the reason for the phenomenal growth in United States renewable electricity supplies is legislation passed in the United States in 1978, which was designed to encourage the implementation of cogeneration and renewable energy technologies. [61] That stimulated the formation of dozens of renewable energy companies in the United States and persuaded several energy-sector TNCs (for example, Atlantic Richfield, Mobil) to devote some resources to that area. This legislation and the (mostly small) companies it helped create achieved in a few short years what the utilities and huge energy-sector TNCs clearly had the resources to do, but, for the most part, chose not to do until federal legislation showed the way.

Unfortunately, United States renewable energy sources are once again facing a hostile environment that may undercut their potential at just the time when interest in non-polluting energy sources is growing rapidly. United States government investments in renewable energy R&D have declined by 90 per cent since 1980. Many of the United States federal incentives put in place in the late 1970s have also lapsed. As a result, some of the smaller companies may have difficulty surviving. Some of the large TNCs, which should take a long-term view and stay in the market, are instead getting out of the renewable business. For example, the Atlantic Richfield Company was the world's leading manufacturer of photovoltaic cells until 1989, when it sold its Arco Solar division to Siemens, a TNC in the Federal Republic of Germany.

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58 United States Department of Energy, *Renewable Energy Research and Development Outlook* (Washington, D.C., United States Department of Energy, Office of Conservation and Renewable Energy, February 1985), vol. 1, p. 33.

59 Nancy Rader, et al., *Power Surge: The Status and Near-Term Potential of Renewable Energy Technologies* (Washington, D.C., Public Citizen, 1989), p. II-3.

60 Ibid., pp. II-7, II-8.

61 The Public Utility Regulatory Policies Act of 1978, known as PURPA. The law, passed as part of the National Energy Act, required utilities to purchase power from qualifying independent renewable and cogeneration facilities at premium rates.

A recent survey of United States renewable energy companies found that, unless the United States situation changes, construction of renewable plants is poised for a significant decline in the early 1990s.[62] Thus, whether the momentum developed over the last decade in United States renewable electricity supplies is translated into a powerful tool for combating greenhouse emissions may depend on government or regulatory action to preserve an option that has been given inadequate emphasis by TNCs alone.

United States utilities have recently engaged in demand-side management programmes that sponsor end-use equipment with higher than average efficiency. As a rule, those programmes involve interactions with manufacturers, a number of them TNCs. For example, utilities have recruited the co-operation of Phillips Lighting Company in compact fluorescent lamp retrofit. That co-operation is a very positive example of how TNCs could become part of the solution of environmental problems.

Some technologies in the turbine industry are not being commercialized, though they offer a small cost advantage over existing technology and significant greenhouse benefits. For example, General Electric has testified before the California Energy Commission that it is willing to develop the highly efficient (52 per cent or more) highly modular (110 MW) intercooled steam injection gas turbine technology. That technology is an example of how cold war military spending could be turned, at least in this instance, into environmental benefit. The technology would use mass-produced high-performance aircraft turbines, which have benefited from military research and now outperform steam turbines by a growing margin.

From the United States example, it is clear that the question of whether the world's energy and environmental needs can be satisfied by these non-carbon-emitting renewable energy sources depends not so much on whether the energy resources are there, but whether the world's political and economic institutions will take the steps necessary to further develop and implement the technologies which will extract those resources. Experience so far suggests that, although TNCs have the capability to help implement those solutions, they are unlikely to do so unless intergovernmental and governmental policies are enacted which provide incentives for action.

C. Restructuring the electricity-generating sector

Although the generation of electricity contributes a substantial portion of the world's emissions of greenhouse gases, there is a wide range of alternatives, many of which are already available today, that have the potential to displace significant amounts of those emissions.

Global warming will impact costs in the electricity-generation sector. Patterns of electricity demand may change as climate changes. Predictions about the severity of storms and generally more climate extremes would particularly affect the distribution and transmission networks of this sector. Investments in locally-based energy-generating units would be among the protective measures to take. Diversification of investment into a variety of generation modes may be the wisest economic course.

Cogeneration is one clear strategy for limiting greenhouse gas emissions and promoting energy efficiency. Therefore, a major effort should be made to expand the cogeneration capacity. However, to vastly expand the cogeneration capacity will require investment in small-scale and site-specific electricity-generation schemes. A thorough analysis of plants and facilities should be made to determine

62 Williams and Porter, op. cit., p. 3.

where investments in cogeneration could be most profitable and efficient. The development of cogeneration may be most effectively promoted by instituting a proper structure of prices and contracts.

At the same time, investment is required in alternative energy-generating capacity, such as wind, solar cell, thermal and photovoltaic systems. Equipment is needed for those systems as well. TNCs which produce electricity-generating equipment should plan their entry into these new markets. They should invest in R&D technologies and the equipment necessary for developing renewable energy sources — such as biomass, small hydropower, various solar options, wind energy and geothermal energy.

Moreover, it is clear that the kinds of equipment that are developed and available to utilities, other industries which generate electricity and the institutions which regulate them, determine, in large part, the electricity-generation option. TNCs which manufacture, design and build power plants have a large responsibility not only to design and manufacture the kinds of equipment necessary for producing efficient and clean energy, but to develop the market for such equipment. Particularly for developing countries, TNCs should provide information and analysis about those choices, focusing on the fact that generators should be designed and built in relation to the particular grid in which the generator is being installed, in order to optimize energy efficiency and production capacity.

The information needed includes evaluations of the greenhouse gas emissions and other environmental problems related to the proposed method of generation in comparison to others. The evaluation should include other fuels, cogeneration, and an analysis of the energy conservation potential to supplement, complement or replace the proposed generation.

Every manufacturer of generating equipment, as well as corporations like Bechtel, which design and build generating stations, should provide information and cost/benefit analysis of a particular approach. That should include the full array of related costs, such as nuclear waste disposal and known accident risk in the case of nuclear power, for example. In addition, companies need to analyse the financial risk under various generation and conservation options. Factors which must be considered are: (a) lead times of construction and realization of capacity, (b) uncertainty due to national and international regulatory environment, (c) variation in costs introduced by the size of equipment relative to grid size.

In the final analysis Governments, development agencies and public utilities have a critical role in generation choices. Contingencies and costs in case of shortage and surpluses and the ability of the electricity system to deal with them should be included in the decision process. Those actors should mandate the development of power-planning models of the "least cost" variety, which are biased towards conservation rather than supply. These can be effective, as shown, for example, in the state regulatory level least-cost planning initiatives in the United States. Examples include profit incentives to utilities promoting electrical efficiency, and specific regulatory surcharges for emissions and other uncontrolled environmental impacts. Those mechanisms for incorporating environmental externalities improve the relative competitiveness of "clean technologies".

CHAPTER VII

PRODUCTION OF ENERGY-INTENSIVE METALS

A. Introduction

The production of metals is a highly energy-intensive industry and therefore should be of great interest to environmental policy makers concerned about reducing carbon emissions. Since TNCs control a large portion of the metals-production industry, this sector is well-suited for study.

World-wide, the production of aluminium, copper, and iron alone account for about 20,500 petajoules of energy consumption annually, or over 7 per cent of total global commercial energy use. Thus, metal production, as a single industrial sector, is responsible for an exceptionally large fraction of carbon dioxide emissions. Table 5 lists the levels of production and total energy consumption associated with all stages of production (that is, including mining, smelting, and other processing) for these three important metals. Although steel production consumes the most energy overall due its high levels of production, the aluminium production industry is the most energy-intensive. For this reason, a case study is conducted on the effects of aluminium production. First, however, a brief overview is provided for copper production and iron and steel production.

B. Copper production

Total world production of refined copper grew an average of 3.2 per cent per year, from 4.5 million metric tons in 1960, to 8.5 million metric tons in 1980. Growth of production in developing countries during this same period (4.3 per cent) was over twice as fast as in the OECD countries. By 1980, developing countries were producing over 22 per cent of the world's copper, the bulk of it from Chile, Peru and Zambia. In addition, over half of the world's copper reserves are in developing countries. The United States and Canada, among the industrialized countries, hold large shares of copper reserves (18 per cent and 6 per cent, respectively). [63]

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63 United Nations, *Mineral Processing in Developing Countries* (United Nations publication, Sales No. E.80.II.B.5), pp. 27, 28.

Table 5. Production of world metals and energy consumption

	Energy intensity (Gigajoules/metric ton)	*Production [a] (10^6 metric tons) (1986)*	*Total energy Petajoules*
Aluminium	279.0 [b]	15.3	4 270
Copper	130.3 [c]	9.6	1 250
Steel	2.1 [d]	710.0	14 980
Total	411.4	734.9	20 500

a/ United States, Department of the Interior, Bureau of Mines, *Minerals Yearbook, 1986* (1988), vol. I, pp. 91, 303, 539.

b/ 1979 figure, assuming a conversion factor of 11 million joules per kWh for electricity use (which accounts for 65 per cent of energy consumed in aluminium production). The best available technology as of 1979 was estimated to consume about 224 gigajoules per metric ton of aluminium produced. From the Aluminum Association Inc., *Energy and the Aluminum Industry* (April 1980), as cited in United Nations, *Mineral Processing in Developing Countries* (United Nations publication, Sales No. E.80.II.B.5), p. 24.

c/ Battele Columbus Laboratories, *Energy Use Patterns in Metallurgical and Non-Metallic Mineral Processing* (June 1975), as cited in United Nations, *Mineral Processing in Developing Countries*, op. cit., p. 35.

d/ The amount of energy used in producing steel varies widely with the process used, from 10 gigajoules per metric ton at an efficient modern scrap-based plant to an average of over 42 gigajoules per metric ton for primarily ore-based integrated plants in China. The figure 21.1 gigajoules is taken from the energy-intensity of United States scrap-based steel mines in 1988. (Marc Ross and Liu Feng, "The energy efficiency of the steel industry in China", unpublished draft submitted to *Energy: The International Journal* (1990), table 10, p. 21.

It takes 0.3 kilograms of fuel oil and 1.65 kWh of electricity to produce a kilogram of copper. With electricity selling at about eight cents per kilowatt hour and the cost of fuel oil ranging from 22 to 34 cents per kilogram, the energy costs of copper production are in the range of 19.8 to 23.4 cents per kilogram. With total smelter and refinery operating costs (not including capital costs) of about 50 cents per kilogram, it appears that the basic variable costs in copper smelting and refining are energy costs. [64]

Smelting and refining account for about 41 per cent of the total energy consumed in the production of copper, while the reminder is consumed primarily by mining and ore concentration. The energy use in each of the various stages of copper production is shown in table 6.

Some of the principal TNCs involved in copper production include Nippon Mining, Japan; Phelps Dodge, United States; Atlantic Richfield Corporation (the parent company of Anaconda), United States; British Petroleum (the parent company of Kennecott), United Kingdom; and Mitsubishi Metals, Japan.

C. Iron and steel production

In the 20 years between 1960 and 1980, world production of iron ores and concentrates more than doubled, from 223 million metric tons to 452 million metric tons (by iron content). Total world raw steel production in 1980 was over 650 million metric tons.

64 Ibid., pp. 33-34.

Table 6. Energy use in copper production in the United States [a]

	Energy consumption		*Energy type (percentage)*			
	Gigajoules per metric ton	*Percentage*	*Electricity*	*Gas*	*Oil*	*Other*
Mining	25.1	19.2	42	1	35	22
Concentrating	49.1	37.7	73	6	1	20
Smelting	44.3	34.0	11	48	24	17
Refining	9.5	7.2	43	15	39	2
Melting and Casting	2.3	1.7	NOT AVAILABLE			
Total	130.3	100.0				

a/ United Nations, *Mineral Processing in Developing Countries* (United Nations publication, Sales No. E.80.II.B.5), p. 35, citing Batelle Columbus Laboratories, *Energy Use Patterns in Metallurgical and Non-Metallic Mineral Processing* (June 1975).

Iron ore reserves are vast, and at the present rate of extraction, are sufficient to cover world needs for at least 200 years. Approximately 31 per cent of these reserves can be found in developing countries. The greatest developing country reserves are in Brazil (17.5 per cent of the world total), followed by India (6 per cent) and Liberia (2.2 per cent). Of the OECD and CMEA countries, the USSR has the largest reserves (30 per cent) followed by Canada (11.7 per cent), Australia (11.5 per cent) and the United States (3.9 per cent).[65]

Steel production in developing countries in 1980 accounted for about 47 million metric tons, or about 7.2 per cent of the total. This amount has increased since then, however, especially owing to expansion of capacity in Brazil and Venezuela. During the 1980s, Brazil began operating a new mine-steelworks complex at Carajas, and by 1986, had essentially doubled its steel production from levels in the early 1980s to some 20 million metric tons. Brazil's steel plan calls for another doubling of Brazilian steel production by the year 2000.[66]

A few of the major TNCs involved in steel production include USX (formerly US Steel), United States; LTV Corporation, United States; British Steel Corp., United Kingdom; and Nippon Steel Company, Japan (the largest in the world).

The amount of energy consumed in steel production varies widely, and depends on the process used and on the mix of scrap metal and iron ore in the feed material (the use of scrap metal reduces energy intensity). The best-practice classical technologies for reduction of iron oxides already approach the

65 Ibid., pp. 37-38.

66 United States Department of the Interior, Bureau of Mines, *Minerals Yearbook 1986*, vol. III, table 1, p. 135; see also p. 148.

theoretical thermodynamic limit of 7.6 gigajoules per metric ton of iron, so achievement of much lower energy intensities than the lowest already achieved is not likely.

Many iron and steel plants in operation do not achieve performance comparable to best-practice, however, and there is considerable room for improvement. The energy-intensity of United States scrap-based steel plants in 1988 averaged 21.1 gigajoules per metric ton, for example, while Japanese steel plants consumed about 25 per cent less. By comparison, the International Iron and Steel Institute scrap-based plant required only 10.1 gigajoules per metric ton. [67] The problem has been that high levels of performance require very high capital costs. New reduction technology is being developed, however, which would allow the industry to achieve energy intensities comparable to best-practice classical technologies at substantially lower cost and with fewer of the environmental problems associated with standard processes.

D. Aluminium production: general overview

Aluminium is one of the most energy-intensive industries in the world. It takes 12 to 20 kilowatt hours of electricity to produce one kilogram of aluminium from alumina (aluminium oxide) during the smelting process. Much smaller, but still considerable amounts of energy are required to mine and then process the ore (usually bauxite) into alumina. The energy used in each of the various stages of the production of aluminium is shown in table 7.

Table 7. Energy use in aluminium production
(Percentage)

	Energy consumption [a]		*Energy type* [b] *(percentage)*		
	Gigajoules per metric ton	*Percentage*	*Electricity*	*Natural Gas*	*Other*
Mining	2.3	0.6	6	40	54
Alumina	44.5	17.1	12	80	7.5
Smelting	193.6	68.6	85	3	12
Fabrication	38.6	13.7	38	51	11
Total	279.0	100.0	65	24	11

a/ United Nations, *Mineral Processing in Developing Countries* (United Nations publication, Sales No. E.80.II.B.5), p. 24, citing the Aluminum Association, Inc. *Energy and the Aluminum Industry* (1980).
b/ Ibid., citing H.W. Lownie, *et al.*, Battelle Columbus Laboratories, *Development and Establishment of Energy Efficiency Targets for Primary Metal Industry* (1976).

67 Ross and Feng, "The energy efficiency of the steel industry in China", unpublished draft submitted to *Energy: The International Journal* (1990), table 10, p. 21.

At three cents per kilowatt hour, it takes between 36 and 60 cents of electricity to produce a kilogram of aluminium metal from alumina. The price for aluminium metal varies a great deal, of course, but about $2 per kilogram was a typical price in the 1980s. The average price of electricity for medium-scale industrial users in the United States in the mid-1980s was about five cents per kilowatt hour, but aluminium companies generally have been consumers of much higher volume and have been located in lower-cost areas, with significantly lower prices of electricity.

World production of aluminium in the 1980s has been in the vicinity of 15 million metric tons. Thus, annual electricity use due to the production of aluminium is about 250 billion kilowatt hours. World generation of electricity in 1985 was 9,675 billion kilowatt hours. Of this, about 3,500 billion kilowatt hours was industrial electricity use. Thus aluminium ingot production constitutes about 7 per cent of industrial electricity use, which is a very large fraction for a single industry. Of course, additional energy, including electricity, is required to process further the aluminium ingot into finished products.

Since much of the electricity used world-wide in the production of aluminium comes from hydropower (about 40 per cent), it appears at first glance that, despite the high energy intensity of aluminium production, the impact on greenhouse emissions is disproportionately low. That is misleading, however, since the use of hydropower for the production of aluminium often means that it cannot be used for other energy consumption needs, which then must be met by greenhouse emitting fuel sources. Thus, based on the fact that aluminium smelting consumes about 1 per cent of the world's energy, it can appropriately be considered to be responsible for an equivalent fraction of the world's carbon emissions, or about 55 to 60 million metric tons of carbon.[68]

The principal producers of aluminium are the United States, the Soviet Union and Canada.[69] However, the principal producers of bauxite, the primary ore, are Australia, Brazil, Guinea, Jamaica, the Soviet Union and Suriname.[70]

Outside of the centrally planned economies, the production of aluminium is controlled by TNCs. The principal TNCs involved include: Aluminum Company of America (Alcoa), United States; Kaiser Aluminum and Chemical Corp, United States; Aluminium Limited, Canada (Alcan); Reynolds Metals Company, United States; Pechiney Ugine Kuhlmann (PUK), France; and Swiss Aluminum (Alusuisse), Switzerland. Together, these six TNCs control 63 per cent of mine capacity, 66 per cent of alumina refining capacity and 54 per cent of aluminium smelting capacity.[71]

The division of aluminium mining and manufacturing generally falls into the classic pattern of primary products production in developing countries and processing and production operations in the industrialized countries. However, in the last three decades manufacturing has also shifted to developing countries for a variety of reasons. In the case of the production of aluminium, the prospect of cheap electricity has been the principal attraction. But, despite the positive expectations of economic growth of a shift to the high "value-added operation" of aluminium refining, unexpected (although not entirely unpredictable) environmental, social and economic costs have tempered the optimism.

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68 Based on the fact that total annual carbon emissions due to energy production are approximately 5.5 to 6 billion metric tons per year. Here, as throughout the text, it is assumed that one kilowatt hour of electricity requires 11 million joules of thermal energy input.

69 *Minerals Yearbook 1986*, op. cit., table 14, p. 111.

70 Ibid., table 18, p. 154.

71 United Nations, *Transnational Corporations in the Bauxite/Aluminium Industry* (United Nations publication, Sales No. E.81.II.A.5) p. 1.

Two different examples of the impact of aluminium production in developing countries are considered below. While not comprehensive surveys, these two cases illustrate the common features of some of the problems encountered in disparate places and times with the aluminium production practices of transnational corporations.

E. The Grande Carajas Programme in Brazil

The Grande Carajas Programme is a Brazilian development programme, with investments totaling $28.1 billion. It has significant investments in mining and metallurgical components, including the aluminium production plant in Sao Luis, undertaken by Consorcio Alumar, a consortium which includes Alcoa. [72]

The 6240 MW Tucurui hydroelectric dam, the fourth largest in the world, is the first of a series of eight large dams planned by Electronorte, the state-run power company, to supply electric power for those projects. Unfortunately, poor attention to environmental concerns during dam construction is leading to a number of problems. The construction of the Tucurui dam flooded 243,000 hectares and displaced 20,000 of Brazil's indigenous population. Since the construction of the dam, malaria in the area has increased, and decomposition of the uncleared forests in the reservoir threatens to acidify the waters to the point where they will affect the turbines. In addition, the decline of fishstocks downstream because of the dam is ruining the livelihood of many fishing villages, and unprotected watershed forests in the catchment area are also being rapidly deforested. [73]

Energy-intensive metallurgical production facilities like the Alumar aluminium plant will receive electricity at heavily discounted rates, while other domestic consumers will pay market rates. Further, even though as of 1985 the Tucurui dam was providing a 25 per cent surplus, the electricity is not going to native industries in the south. Instead, it is being sold to the foreign aluminium-smelting companies in the north at 85 per cent of the cost price, a subsidy estimated at $230 million which is being paid by the Brazilian consumers. [74]

One of the undesirable consequences of this plan is that, of 11 local iron- and cement-producing plants being built in the region, only two will depend on electricity from the Tucurui dam. The remainder are to be powered by charcoal produced directly from timber cut from the local forests, and will consume at least 1.1 million metric tons per year, or fully 16 per cent of national production. According to a document issued in 1986 by the Planning Secretariat of Brazil, the then-current annual output (90,000 metric tons) of charcoal of the Greater Carajas region alone would have to be increased by 1,300 per cent. [75] Not only does that means an increase in direct carbon emissions due to the burning of charcoal, but also the destruction of 1.5 million hectares of forest. That will further exacerbate the large and growing problem of global deforestation, a trend which, among its many ecological impacts, contributes indirectly to atmospheric carbon dioxide build-up by reducing the capacity to remove carbon from the atmosphere.

72 Dave Treece, *Bound in Misery and Iron: The Impact of the Grande Carajas Programme on the Indians of Brazil* (London, Survival International, 1987), pp. 14-17.

73 Ibid., pp. 6, 81-83.

74 Ibid., p. 17.

75 Secretaría de Planejamento/CODEBAR (1986), Problemática do carvaô vegetal na area do Programma Grande Carajas: versao preliminar. Cited in footnote 74.

F. The Valco project in Ghana

Another perspective on the effects of the operation of an energy-intensive industry in developing countries is provided by the case of the Volta Aluminium Company (Valco), which produces aluminium ingots in Ghana. Much of this analysis is based on the situation as of 1982. Since that time, a number of changes have occurred which have resulted in improvements in the Ghanaian aluminium production situation. Those figures, however, illustrate the kinds of problems which can persist for prolonged periods and still exist in many places and, as the Grande Carajas Programme in Brazil illustrates, continue to be introduced in new areas.

The Akosombo dam in Ghana was built with a World Bank loan soon after the country's independence. It was to be Ghana's central project of modernization and independence. Two transnational aluminium companies became interested in the possibility of cheap electricity. As a result, almost all the electricity produced by the dam was to be dedicated to the production of aluminium by the Volta Aluminium Company (Valco), 90 per cent owned by Kaiser Aluminum and Chemical Company and 10 per cent owned by Reynolds Metals Company.

The dam flooded roughly two million acres of Ghanaian land, much of it forested, creating Volta Lake. The flooding displaced large numbers of people, many of whom were not properly resettled. The huge lake divided the country north-to-south, which made transportation difficult and costly. Soon schistosomiasis, a debilitating parasitic disease which had not been much in evidence before, and river blindness, became endemic around Volta Lake.

Valco was able to negotiate some of the cheapest electricity in the world in a guaranteed requirements contract where the price could not be changed. The electricity had to be delivered or else there would be stiff financial penalties. As a result, when Ghana's own electricity needs grew, it was unable to take more electricity from the dam. It had to build far more costly hydroelectric and fossil-fuel-generating stations. The situation became stark in energy terms in the early 1980s, when Ghana was selling a huge amount of electricity on a firm basis, as required by the contract with Valco, for only $14 million, while needing to import the oil equivalent of the same amount of energy for $180 million. (The oil was used mainly for transport and not for the generation of electricity.) While Valco paid only half a cent per kilowatt hour for firm power, the other industries and people of Ghana paid 4 to 16 times as much for unreliable and interruptible power. Normally firm power is much more expensive than interruptible power. Moreover, in the same period, Kaiser, Reynolds and other TNCs were paying much higher and rising prices for electricity in Europe, Japan and United States.

But Ghana could not change the terms of the contract, remove the immense subsidy and get a better price for its electricity. Based on 1982 prevailing prices of aluminium, and operation of the plant at 80 per cent capacity (four potlines out of five), approximate estimates of Valco's operations in Ghana for 1982 were as set forth in table 8 (each figure is rounded to the nearest five million).

This is not the profit actually reported by Valco. The profit reported was based on the legal artifact that Valco never owned the alumina or the aluminium, but was only paid a fee for processing by its shareholders, Kaiser and Reynolds. This allows for manipulation of the reporting of profits. In addition,

Table 8. Estimated Valco balance sheet, 1982
(Millions of dollars)

Income	
Ingot sales at $1,700 per metric ton	270
Expenses	
Costs of alumina	60
Costs of electricity	15
Interest and depreciation	15
Wages	10
Shipping	20
Total expenses	120
Profits	
Pre-tax profits	150
Taxes and payments	25
After-tax profits	125

management fees and charges paid by a subsidiary to its principal shareholder, Kaiser Aluminum and Chemical, were deducted by Valco, which are not shown here.[76]

Ghana received wages, taxes and electricity charges amounting to about $50 million. Yet in the same year, 1981, Ghana spent $180 million to import oil, which contained the equivalent amount of energy,[77] to replace the electricity sold to Valco for about $14 million. Loans taken to build the dam had to be repaid (on the order of $10 million per year). Further, the cost to Ghanaians of electric power was higher than the cost to Valco. Table 9 shows the electricity tariffs in Ghana in 1982.

The revenue which Ghana lost owing to underpriced electricity sales was roughly $50 million per year. Additional losses to the economy arose from the necessity of supplying uninterrupted power to Valco, and disrupting domestic production instead.

Along the way, Ghana, short of foreign exchange, fell into debt. Cocoa was cultivated on an even wider scale, taking up large amounts of land. Gold, bauxite and other extractive export-oriented industries were built or expanded and they consumed more electricity. Thus, oil consumption was increased, as were foreign exchange bills, debts, pollution and greenhouse gas emissions.

If one included all the quantifiable costs, including loss of production, the costs of diseases, underpricing of electricity etc., but excluded the indirect costs from indebtedness and skewed economic and industrial structure and skewed import-export structure (Valco's aluminium is exported, and Ghana

76 Fui S. Tsikata (ed.), *Essays from the Ghana-Valco Renegotiations, 1982-1985* (Accra, Ghana, Victoriaborg Press, 1986). The post-1982 data on Valco are drawn from this source, unless otherwise stated.

77 Based on the thermal input it would take to generate the same amount of energy at the rate of 11 million joules per kilowatt hour. The energy in a barrel of oil costs about $32 per barrel.

Table 9. Approximate electricity tariffs in Ghana, 1982

Sector	*Cents per kilowatt hour*
Valco	0.5
Mining sector and textile mills	0.7
Residential	2.0 to 4.0
Small light and power	5.0 to 8.0
Large light and power (industrial tariff)	2.5 to 4.0

has had to import aluminium to meet its needs), the losses to Ghana annually might well amount to several hundred million dollars.

At the same time, as was set forth in table 8, Valco's annual profits in 1982 were approximately $125 million. (Annual profits vary, of course, depending on production and the price of aluminium.)

That situation persisted for about two decades. Since 1985, after three years of hard negotiations, a considerable improvement in the terms was achieved, including an increase in the power tariff to about two cents a kilowatt hour.

Even so, given Ghana's difficult situation with respect to foreign exchange and the heavy drain caused by oil imports and borrowing to build new power-generating stations, modernization of the production of aluminium so as to reduce per unit energy consumption would save Ghana enormous amounts of additional money and energy. For instance, the technology installed at Tema uses about 17.5 kilowatt hours per kilogram. Technology that has been available for over a decade can reduce this to 13 kilowatt hours per kilogram. Even further improvements may be available in the future; for example, a new smelting process developed by Alcoa is expected to consume slightly less than 10 kilowatt hours per kilogram.[78] Such improvements would allow for a direct reduction in the use of oil for electricity-generation, which is Ghana's most expensive source of energy.

G. Restructuring in the energy-intensive metals production sector

It is clear that, in many cases, action taken to reduce the level of greenhouse gas emissions will help alleviate the other associated environmental problems, such as deforestation, increases in the spread of disease and subsidization of TNC operations at the expense of local populations and Governments of host countries. Thus, if, in the future, metal producers were to invest in more energy-efficient production facilities and increased recycling of existing scrap, the need for huge, environmentally destructive dams, for example, would be reduced. A number of smaller, less destructive dams, for example, could suffice

78 David Williams, President, IIT Research Institute, Chicago, Illinois, private communication of 5 March 1990.

for both the remaining metal production and other local energy needs. The need to import expensive fossil fuels or to deforest the local countryside to meet energy needs could be reduced, and the suffering from a higher incidence of tropical diseases and from dispossession of land would be mitigated.

Further, if development policies required that full environmental impacts be assessed and factored into the cost-benefit analysis beforehand, shortsighted projects which incur long-term heavy hidden social and environmental costs in exchange for lesser but more easily predictable short-term financial gain could be avoided altogether. As part of the environmental assessment, an analysis should be made of all energy conservation options and their costs and benefits, not only for the enterprise, but also for the country in which the operation is taking place. Thus, the opportunity costs to Ghana, for example, of not investing in more efficient production of aluminium would be calculated by Valco.

Another important question for the energy-intensive metals and chemical industries is the extent to which those industries need to manufacture new materials at all. The manufacture of new chemicals and metals is typically very energy-intensive, causing substantial greenhouse gas emissions. Further, a great deal of destruction of land, considerable emissions of toxic chemicals and water pollution have also been characteristic of those industries.

Internal recycling and reuse of toxic materials, motivated by pollution-control regulations, have reduced emissions in many industrial plants in recent years. This shows that the potential for recycling is great. Recycling aluminium, steel, copper and plastics takes far less energy than making new products and, therefore, has the potential for substantially reducing greenhouse gas emissions. Companies need to analyse the potential for production of similar quantities of materials by recycling (using local and/or imported scrap metal) both in the country where operations have been proposed or are taking place as well as in the countries where it has been proposed to market the product. In order to determine the most energy efficient and cost effective alternative, companies would also need to analyse the greenhouse gas emissions and other environmental implications of each metal and of the other materials which could fulfil similar functions.

Finally, if direct electricity subsidies were removed from the production of aluminium, alternative products such as high-strength plastics might become more price competitive with aluminium-related products and reduce projected future demand for aluminium. In general, TNC investments in energy-intensive metals may need to decrease, while additional investments in high-strength alternatives and in aluminium recycling factories may be more constructive.

CHAPTER VIII

OZONE DEPLETION AND CHLOROFLUOROCARBONS

A. Introduction

Chlorofluorocarbons (CFCs) are anthropogenic chemicals which are highly stable and non-flammable. They are used in refrigeration and air-conditioning, as aerosol propellants, for blowing foams and as solvents for electronics and metal-cleaning. Use has expanded over the last half century to more than a billion kilograms a year in the late 1980s. World uses are shown in figure VII. CFCs, halons, carbon tetrachloride, methyl chloroform and some of the CFC substitutes are the source of virtually all stratospheric ozone depletion. They are also responsible for 15 per cent of the global warming problem (figure II) and perhaps more, according to some researchers.

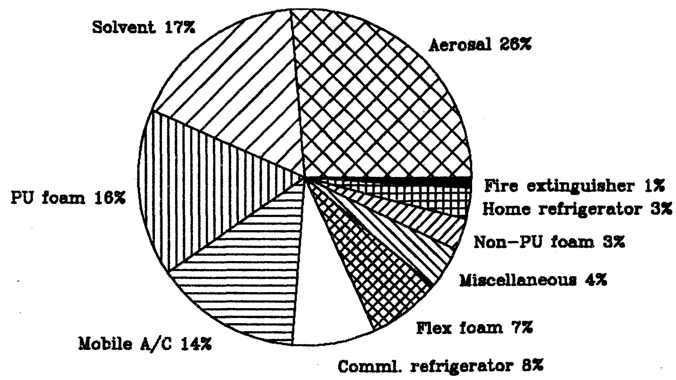
CFCs are produced almost exclusively by large chemical corporations, most of which qualify as transnationals. One chemical company alone, E. I. DuPont de Nemours and Company accounts for 25 per cent of world production; it produces CFCs in six countries in addition to the United States. Yet CFCs are only 2 per cent of DuPont's business; the company's overall sales in 1988 were $32.9 billion. A list of producers in non-centralized economies is found in table 10. [79] TNCs are also heavily involved in the intermediate consumption of CFCs. CFC use in refrigeration systems means that they are primarily used by a few large corporations such as General Electric in the United States, that produce electrical appliances. Roughly one quarter of CFC use in the United States is in automobile air-conditioning, again a market controlled by a few transnational corporations. Many CFC solvent-users are major transnational electronics firms.

CFCs are of particular interest to the present study because the international movement to phase out CFCs provides an important example for future efforts to phase out other greenhouse gases. More international progress has been made on reducing the danger from those compounds than on any other effort to protect the global environment. In 1987, the major consuming countries agreed to drastically reduce their use of ozone-depleting chemicals through the Montreal Protocol, an international agreement sponsored by the United Nations Environment Programme. The following section considers the ways in

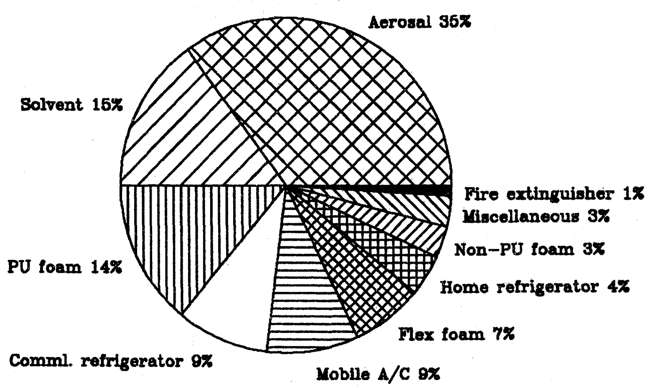
79 Douglas Cogan, *Stones in a Glass House* (Washington, D.C., Investor Responsibility Research Center, 1988), p. 82.

Figure VII. World uses of regulated CFCs, 1985

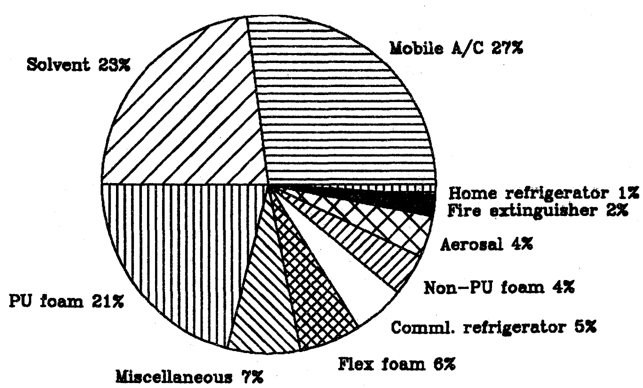
World uses of regulated CFCs, 1985
Total use 1,036 million kg.



Uses of regulated CFCs outside the United States
Total use 736 million kg.



Uses of regulated CFCs in the United States, 1985
Total use 300 million kg.



Source: Arjun Makhijani, *et al.*, *Saving Our Skins: Technical Potential and Policies for the Elimination of Ozone-Depleting Chlorine Compounds* (Washington, D.C., Environmental Policy Institute/Institute for Energy and Environmental Research, 1985).

Table 10. Producers of CFCs
(Market economies)

Parent company	*Home country*	*Subsidiary (country)*
Akzo Chemie B.V. [a/]	The Netherlands	None
Allied-Signal Corp. [a/]	United States	Allied Inc. (Canada) Quimobasicos S.A. (Mexico)
Asahi Glass Co. Ltd. [a/]	Japan	None
Atochem S.A.	France	Pacific Chemical Industries (Australia), Atochem Espana (Spain), Produven (Venezuela)
Australian Fluorine Chemical Pvt. Ltd.	Australia	None
Daikin Kogyo Co. Ltd. [a/]	Japan	None
E.I. du Pont de Nemours & Co. Ltd. [a/]	United States	Ducilo S.A. (Argentina) Du Pont do Brazil S.A. (Brazil) Du Pont Canada Inc. (Canada) Du Pont Mitsui Fluorochemicals Co. Ltd. (Japan) Halocarburos S.A. (Mexico) Du Pont de Nemours N.V. (Netherlands)
Essex Chemical Corp. [a/]	United States	Racon Inc. (United States)
Hoechst AG [a/]	Federal Republic of Germany	Hoechst Iberica (Spain) Hoechst do Brazil Quimica e Farmaceutica S.A. (Brazil)
ICI PLC [a/]	United Kingdom	African Explosives and Chemical Industries Inc.
I.S.C. Chemicals Ltd. [a/]	United Kingdom	None
KaiserTech	United States	None
Kati-Chemie Aktiengesellschaft [a/]	Federal Republic of Germany	Kati-Chemie Iberia S.A. (Spain)
Monteriuos S.p.A. [a/]	Italy	None
Navin Fluorine Industries	India	None
Pennwait Corp.	United States	None
Shawa Denko K K. [a/]	Japan	None
Société des Industries Chimiques du Nord de la Grèce, S.A.	Greece	None

Source: Douglas Cogan, ***Stones in a Glass House*** (Washington, D.C., Investor Responsibility Research Center, 1988).

a/ Member of International Toxicity Testing Consortium.

which international bodies, corporations, private citizens and non-governmental organizations have interacted in the development of the Protocol, which, in addition to protecting the ozone layer, will be the world's first major step towards a reduction of greenhouse gas accumulations.

B. The CFC phase-out

In the United States, concern about CFCs began in the early 1970s, when two researchers at the University of California, Sherwood Rowland and Mario Molina, suggested that the widely-used "wonder chemicals", though benign to the immediate user, could be damaging the ozone layer.

The news captured the public's imagination. The extensive publicity which surrounded the problem led to the widescale boycotting of aerosol grooming products, which seemed a frivolous use of dangerous chemicals. Although DuPont and other producers responded with full-page advertisements questioning the scientific evidence supporting the ozone-CFC connection, they were unable to stem the concern, which eventually permeated legislative circles. In 1978, the use of CFCs in most aerosol spray cans was banned in Canada, Sweden and United States.

The aerosol bans had a significant impact on ozone-depleting emissions from the three industrialized countries that instituted them. However, the ban did not spread beyond those countries for about a decade, and use of CFCs as aerosol propellant has remained the single greatest use of CFCs to-date. Moreover, new uses for the CFCs, particularly for blowing foams, soon pushed CFC use back up above 1977 levels, even in countries participating in the aerosol ban.

In the meantime, waning regulatory interest in limiting ozone depleting chemicals in the United States in the early 1980s reduced the pressure on corporations to look for substitutes for CFCs. Research by chemical companies on alternatives to CFCs stopped abruptly in 1980. As a DuPont spokeswoman would note: [80]

> "In the absence of regulations, there was nothing to drive the search for alternatives because there was no market demand. Given that nothing was drawing customers to buy them, research was scaled back."

Then in the mid-1980s, the situation began to change again. In 1984, the Natural Resources Defense Council, a United States non-governmental organization, filed a law suit against the Government of the United States for not conforming to the regulatory process which the Carter Administration had published in the Federal Register a few months before the 1980 elections. The success of that suit caused a renewal of regulatory pressure within the United States. At the same time, new scientific findings were suggesting that the problem was not merely hypothetical. In 1985, an article appeared in the British journal *Nature* on the work of the British Antarctic Survey describing the discovery of an enormous "hole" in the ozone layer over Antarctica, a 50 per cent depletion over an area greater in size than China. Scientific and public concern intensified. In the following year or two, most major CFC producers revitalized their programmes for research on alternatives.

The same pressures which were leading corporations to reinvigorate their research efforts in the mid-1980s were also building a movement for international regulation. In the wake of a changing

80 Kathleen H. Forte, Senior Public Affairs Specialist, DuPont External Affairs Division, telephone communication, 26 May 1988. Quoted in Makhijani et al., op. cit., pp. 12-15.

scientific and political atmosphere, the Vienna Convention for the Protection of the Ozone Layer, of 22 March 1985, and the Montreal Protocol on Substances that Deplete the Ozone Layer, of 16 September 1987, were adopted. The Montreal Protocol promises international reductions in the use of CFCs and halons. It initially required a 50 per cent cut in CFC use by 1998 and a freeze in the use of halons by industrialized countries. It went into effect on 1 January 1989, after having been ratified by the major CFC using and producing countries. It was subsequently renegotiated to move up reduction target dates, include additional compounds, and to provide financial relief to developing countries to meet the goals of the Protocol.

The Protocol is the first agreement of its kind, and it has highlighted important issues for the corporate community. From their initial position of strenuous opposition to any regulation, some corporations found themselves nominally supporting international measures. United States-based corporations which felt they had been adversely affected by the 1978 aerosol ban tended to see international regulation as preferable to a United States ban, since it could provide a "level playing field" in which to operate. Indeed, a major issue on the United States agenda for the 1987 Montreal discussions was that countries representing 90 per cent of the world-wide CFC consumption ratify the Protocol before it took effect, thus equalizing the costs to world companies of a CFC phase-down and equalizing the opportunities for substitutes. [81] Countries representing two thirds of the CFC market was the number finally agreed upon.

More recently, the DuPont corporation has gained enormous goodwill by agreeing to changes in its operations prior to international regulation. In response to the dramatic evidence in March 1988 that ozone depletion had already occurred over inhabited latitudes, DuPont announced that it would support a complete phase-out of CFCs—before either the United States or the EEC announced a similar intention. Many other major corporate participants have followed this lead, though it has not been universal. The corporations which are more reluctant to change are those for which CFC production represents a large proportion of their sales and where research on alternatives has lagged behind that of DuPont.

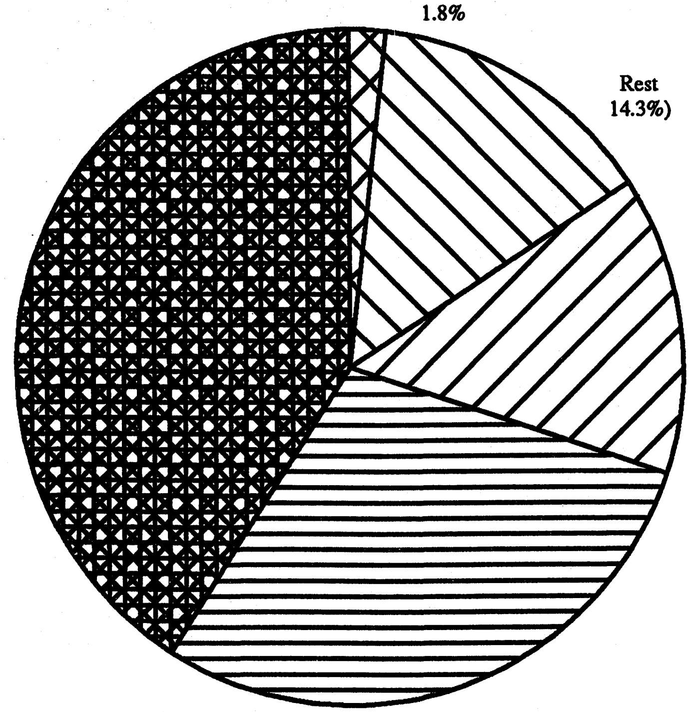
In any case, the movement has gained a momentum of its own which promises to result in even more rapid reductions in CFC use than those mandated by the Montreal Protocol. With the possibility of a complete phase out of CFCs imminent, not only the producing chemical corporations, but many of the using industries have become involved in the phase-out process. For instance, a number of large electronics corporations that use CFCs as a solvent, including AT&T and Northern Telecom, have announced that they will be phasing out the use of CFCs on their own by 1994. Automobile manufacturers, such as General Motors and Nissan, have also announced that they expect to be marketing auto air-conditioning systems which do not use CFCs by 1994.

Almost all major user groups have announced joint research and development efforts on alternatives. Since a complete phase-out of most ozone-depleting chemicals through international regulation now seems inevitable, there is a concerted effort within the transnational corporations to find alternatives, and their large financial bases allow considerable exploration. Thus, corporations have shown that, in the face of impending regulation, they can effectively fill the technical void and quickly develop new technologies.

81 Sharon L. Roan, *Ozone Crisis: The Fifteen-Year Evolution of Sudden Global Emergency* (New York, Wiley, 1989), pp. 208-209.

Figure VIII. World distribution of CFC use, 1985

Total use: 1,036 million kg.



Source: Makhijani et al., *Saving Our Skins: Technical Potential and Policies for the Elimination of Ozone-Depleting Chlorine Compounds* (Washington, D.C., Environmental Policy Institute/Institute for Energy and Environmental Research, 1988).

In June 1990, the Montreal Protocol was formally amended and strengthened. CFCs and halons will now be phased out by the year 2000. Carbon tetrachloride, a chemical not included in the original Protocol, will be phased out by 2005. A new financial mechanism has been agreed to which will provide between $160 million and $240 million over an initial three-year period to support efforts to reduce the use of ozone-depleting substances in developing countries. As a result, India and China, developing countries which were reluctant to participate in the original Protocol because of the lack of funding for a technology transfer plan, recommended ratification of the Protocol. [82]

82 United States Environmental Protection Agency, "Agreements reached in London to strengthen the Montreal Protocol" (July 1990).

C. Restructuring in the CFC sector

The Montreal Protocol provides an important blueprint for future measures to protect the global environment and suggests some of the key interactions which need to occur between citizens, scientists, policy makers and corporations to make such a global agreement effective. It has generally proved a flexible instrument of international policy.

Responsible corporate behaviour will involve going beyond the measures which are included in the Montreal Protocol, probably even beyond its revised format. In addition, the way in which issues of technology transfer to developing countries are addressed will send important messages about the ability of the world community to answer the energy needs of developing countries.

Many of the necessary steps on this issue have already been taken, particularly at the international level and also within corporations. Four issues, however, should be acted on by CFC user industries.

(a) Corporations should halt the use of CFCs as rapidly as possible, long before any international deadlines if possible. This is clearly feasible in almost all industries with the possible exception of refrigerator manufacturers;

(b) Corporations should halt the use of other chemicals also known to be highly damaging to the ozone layer, such as methyl chloroform or carbon tetrachloride, before international deadlines;

(c) Corporations which produce materials that store CFCs or even CFC alternatives, such as producers of polyurethane foam and refrigerators, should be expected to work on methods to recycle and recover those products and, if feasible, they should be held responsible for recovering them;

(d) HFCs and HCFCs should be used to replace CFCs as little as possible. They should not be used in aerosol spray cans, since other alternatives are clearly available. For other more vital uses, they should be viewed strictly as interim substitutes. In general, corporations should seek to replace CFCs with materials which are as benign as possible in all environmental, health and safety respects.

CHAPTER IX

INORGANIC NITROGEN FERTILIZERS

Nitrogen fertilizers are a growing source of greenhouse gases. Like transport, this is an area in which a structural dependence has been created on a product which is produced by a restricted number of TNCs and which has profound environmental and social costs. In addition to contributing to global warming, the use of nitrogen fertilizers results in excess nitration and contamination of water supplies.

Nitrogen fertilizers contribute to global warming by augmenting the natural flux of nitrous oxide from the soil into the air. Fertilizing land increases its nitrous oxide emissions by at least two and sometimes as much as 10 times the natural rate. [83] Accumulations of nitrous oxide will only decline slowly even if emissions are curtailed because of its long life (150 years). Nitrogen fertilizers also add to the emission of methane by reducing the capacity of micro-organisms in the soil to absorb methane. [84]

In addition, the production of nitrogen fertilizers is energy intensive and adds to global warming through the emission of carbon dioxide. The fertilizer industry accounted for 1.5 per cent of total commercial energy consumption (or 4.9 exajoules) by the late 1970s. It can be presumed that the amount of commercial energy consumed has increased since the late 1970s, because nitrogen fertilizer output is now two thirds higher. Of the total amount of energy currently used by the industry, 73 per cent was used for nitrogen fertilizer production, 5 per cent for phosphate production, 3 per cent for potash production, and 19 per cent for packaging, transportation and application. The World Bank estimates that a savings of 10 to 25 per cent in energy consumption is possible in the fertilizer industry. [85]

World production of inorganic nitrogen fertilizers has been rising steadily, increasing five times since the 1960s (table 11). A third of this is used in Asia, where China is the largest consumer world-wide. Another 20 per cent is used in the Soviet Union and Eastern Europe, 14 per cent in Western Europe, 13 per cent in North America, and 5 per cent in Africa and Latin America together. Future increases are

83 J. N. Pretty and G. R. Conway, "Agriculture as a global polluter" (London, International Institute for Environment and Development, Sustainable Agriculture Programme, 1989). Briefing paper.

84 A. Steudler, R. D. Bowden, J. M. Mello and J. D. Aber, "Influence of nitrogen fertilization on methane uptake in temperate forest soils", *Nature*, vol. 341, No. 6240 (28 September 1989), pp. 314-315.

85 R. Heath, J. Mulckhuyse and S. Venkataraman, *The Potential for Energy Efficiency in the Fertilizer Industry* (Washington, D.C., World Bank, 1985), p. 2.

Table 11. World consumption of nitrogen fertilizer
(Thousands of metric tons)

Region	*1965*	*1975*	*1987*
North America	4 379	8 340	10 406
Western Europe	4 274	7 236	11 196
Eastern Europe/USSR	3 310	10 776	16 043
Asia and Oceana	3 286	9 283	28 181
Latin America	683	1 816	3 897
Africa	511	1 073	1 944
Total	16 443	42 441	75 565

Source: FAO, *Fertilizer Yearbook, 1988.*

expected to occur largely in developing countries, at a projected growth rate of 5 per cent per year as compared with 1 per cent per year in the developed market economies. [86]

The technology for producing nitrogen fertilizers and much of their international trade and marketing are controlled by a small number of TNCs, including Badische Aniline and Soda Fabrik (BASF) (based in the Federal Republic of Germany), Imperial Chemicals Industries Ltd. (ICI) (United Kingdom), DSM (Netherlands), Exxon and W. R. Grace (United States of America). In ammonia production, the concentration of TNCs is lower than in other types of fertilizer production, but it is also increasing the fastest. Other transnational corporations have major interests in fertilizer plant design and engineering, such as Kellogg, Fluor, Braun and Foster Wheeler (United States); Uhde, owned by Hoechst (Federal Republic of Germany); Stamicarbon, owned by DSM, and Technimont, a subsidiary of Montedison (Italy). Kellogg is a leading designer and contractor for ammonia plants. Kellogg technology is used in many large-capacity plants. Other TNC producers of fertilizers include Mitsubishi (Japan), Norsk-Hydro (Norway), which is 51 per cent state-owned, and controls a major share of the European market and is expanding into the United States. [87]

Control over the industry is concentrated among those TNCs. Even where a growing trend towards minority equity has decreased their ownership of the facilities, those corporations maintain a particularly significant role in the development and application of technology and specialized engineering. [88] That is

86 W. F. Sheldrick, *World Nitrogen Survey* (Washington, D.C., World Bank, 1987), p. xvi.

87 United Nations Centre on Transnational Corporations, *Transnational Corporations in the Fertilizer Industry* (United Nations publication, Sales No. E.82.II.A.10).

88 Ibid., p. 41.

particularly the case in ammonia and urea production, which uses the most complex technology in the fertilizer industry. A small number of TNCs control the technology for producing catalysts, and the techniques they use are closely guarded secrets. Thus, even in countries like India, where the growth in domestic demand in the 1960s and 1970s stimulated expansion of productive capacity and state ownership and the activities of TNCs were reduced, their role nevertheless remained crucial, since they controlled pre-investment studies, plant design and engineering, and had responsibility for plant construction and the initial operations. Corporations involved in this industry have generally retained knowledge of critical technology and have licensed only those aspects necessary to fulfil their contracts. [89]

A. The role of TNC in the growth of fertilizer use

TNCs, together with Governments and development agencies, were instrumental in creating a demand for commercial nitrogen fertilizer. This began in the United States after the Second World War, with the development of a nitrogen fertilizer industry to make use of capacity for producing nitrogen for explosives. Before the Second World War, the application of agrochemicals was negligible. In 1942, well before the end of the War, a huge surplus of nitrogen production capacity was anticipated. The President of the American Society of Agronomy, in his address to the annual meeting, said that: [90]

"As a direct result of the war, the capacity of our synthetic ammonia plants has been enormously increased. There seems little question but that after the war there will be available for use as fertilizer at least twice as much nitrogen as we have ever used and at a price much less than we have ever paid... The possible industrial and agricultural implications of this development are considered by some industrial leaders large enough to have an effect on our post-war economy, 'comparable to the discovery of a sixth continent'."

In the 25 years after the war, United States output of nitrogen fertilizer increased by 1,050 per cent. [91] The number of firms producing ammonia in the United States increased from seven in 1940, to 65 in 1966.

Increased use spurred dramatic increases in yields of corn-grain, and a reduction in acreage harvested. [92]

- "Mechanization and chemical technology... accelerated the vicious cycle of innovation, increased production, depressed prices, further innovation. While farmers on the treadmill's leading edge survived and even prospered, attrition rates were high. Between 1935 and 1960, the number of farms in [the Corn Belt] declined by 35 per cent. Tenants, in particular, were hard hit, and over that period the number of tenant operations was reduced by 62 per cent."

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89 Ibid., p. 49.

90 R. Bradfield, "Our job ahead", *Journal of the American Society of Agronomy*, vol. 34, No. 12, p. 1070.

91 B. Commoner, *The Closing Circle* (New York, Alfred A. Knopf, 1971), p. 143.

92 J. R. Kloppenburg, *First the Seed: The Political Economy of Plant Biotechnology* (Cambridge, Cambridge University Press, 1988), pp. 118-121.

- As the harvested acreage declined, "the intensive use of nitrogen fertilizer allowed 'agribusiness' to just about meet the population's need for food, and at the same time to reduce the acreage used for that purpose".[93]

Nitrogen fertilizers were subsequently promoted in the mid-1960s in developing countries as the 'Green Revolution'. This was implemented largely by American scientists working in the Rockefeller Foundation- and Ford Foundation-funded International Agricultural Research Centers. In their structures, those Centers resembled the public agricultural research agencies in the United States and followed similar strategies for agricultural modernization, including the use of fertilizer.

Nitrogen fertilizers rose from 28 per cent of the world fertilizer market in 1950, to 64 per cent in 1981. Statistics show that, after 1965, the growth in fertilizer consumption slowed in the United States and accelerated in Asia (table 11). There it reached 34 per cent annual growth in 1966/67, with another upsurge in the period from 1977 to 1979. The Green Revolution greatly raised the energy intensity of cultivation, not only in fuels for machinery, but also in hydrocarbon feedstocks for agricultural fertilizers. Energy inputs went from 0.5 calories to produce a calorie of food in traditional food systems, to nine calories in modern technological systems.[94]

The results were remarkable. Many Asian countries were able to eliminate rice and wheat imports within a few years. Yet they also incurred huge economic, social and environmental costs. The high-yielding varieties depended on expensive irrigation, intensive fertilizer use, monoculture, mechanization, and chemical pesticides. Poorer farmers who had less access to inputs, extension services and credit frequently could not compete and fell into debt. Many had to give up their farms.[95] Problems for both poorer farmers and poorer countries became severe when prices increased:[96]

> "The 'energy crisis' ... resulted in greatly increased fertilizer prices and severe shortages occurred in many areas. Many poor countries with foreign exchange difficulties had to cut back on imports."

Those problems were accompanied by negative environmental impacts. Deleterious effects included health hazards from excessive nitration and from pesticides, and deterioration in water quality. More recently, it is understood that environmental damage included greenhouse gas build-up, both from vast quantities of nitrogen emitted from the soil, and from the increases in the energy intensity of production.

The 'Green Revolution' was exported by the home country Governments of TNCs through development assistance institutions and financing arrangements, using TNC technologies, expertise, marketing and production facilities. In that way, foreign markets quickly developed. In India, the Ford Foundation financed and promoted intensive agricultural development by means of packages of seeds, implements, fertilizers and pesticides.[97] After the 1966/67 drought, the United States Secretary of Agriculture was sent to India to try to open up its market to United States fertilizers, based on prior

93 Commoner, op. cit., p. 150.

94 A. Pearse, *Seeds of Plenty, Seeds of Want: Social and Economic Implications of the Green Revolution* (Oxford, Clarendon Press, 1980), p. 227.

95 B. Glaeser, *The Green Revolution Revisited: Critique and Alternatives* (London, Allen & Unwin, 1987), p. 2.

96 Pearse, op. cit, p. 227.

97 Ibid., pp. 80-81.

Bechtel studies of the Indian fertilizer industry. [98] The United States Agency for International Development gave large loans to finance the import of fertilizer. The United States and the World Bank: [99]

"Put a great deal of pressure on the... Indian Government to encourage multinational corporations to invest in local production capacity [of fertilizer]. The Indian Government changed its policy abruptly in December 1965 to permit these firms to price and distribute their products in India."

Similarly, in Indonesia in 1967, technical expertise was provided by the Ford Foundation and USAID, and much of the agricultural development programme was contracted out to large commercial agribusiness corporations. The programme, like a number of others, resulted in practices which benefited the participating corporations at the expense of groups who were supposed to benefit. According to one researcher: [100]

> "By the end of 1969, opposition to this programme was widespread amongst the more enlightened officials and intellectuals, and there was active resistance by the peasantry.... The cultivator was drafted into the programme without choice, delivered a standard 'package' without consideration of local soil/climate specifications and given a subsistence loan in cash. His crops were indiscriminately submitted to aerial spraying of pesticides and a share of his crop was requisitioned, equal to one sixth of a standard anticipated harvest, in repayment of the loan he had not requested... Complaints from cultivators revealed that supplies were frequently 'diverted', that the subsistence loan was not always paid, that the aerial spraying killed animals and fish, and that the one sixth crop repayment frequently bore no just relation to what had been received."

A similar programme in the Philippines was more effective at recruiting participants. Yet here too, the programme was clearly focused by its World Bank sponsors on increasing the use of fertilizers in absolute terms, with little concern for the resulting economic or environmental costs. The programme: [101]

> "Hooked thousands of tenant farmers into an allegedly more productive and clearly more expensive rice-growing technology dependent on escalating inputs of inorganic fertilizers, pesticides, and herbicides... [increasing indebtedness of farmers did] 'not reduce the use of cash inputs such as fertilizer and pesticides. Between 1975 and 1977 new...credit declined by 80 per cent while fertilizer consumption increased by 12 per cent.' This, the [World] Bank noted with approval, was the main virtue [of the programme]: Increases in rice production and fertilizer consumption are notable successes (emphasis added). The new rice technology... created severe problems for Philippine agriculture, including loss of fertility through the massive application of petroleumbased fertilizers, such as urea... resulting in sulphur deficiency... and zinc loses."

In both developing and industrialized countries, degradation of the soil has been followed by even greater uses of fertilizer to counteract the decline in soil productivity. For both environmental and social reasons, the cycle of indiscriminate dependence on inorganic fertilizer needs to be broken.

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98 H. Cleaver (Department of Economics, University of Texas, 1989), personal communication.

99 L. R. Brown, *Seeds of Change* (New York, Praeger, 1970), p. 58.

100 Pearse, op. cit., p. 93.

101 W. Bello, D. Kinley and E. Elinson, *Development Debacle: The World Bank in the Philippines* (San Francisco, California, Institute for Food and Development Policy, 1982), pp. 80-81 (citing The World Bank, "Sector survey of agricultural support services" (23 January 1980), pp. 5-8).

B. Restructuring in the inorganic nitrogen fertilizer sector

Active investigation of ways of reducing nitrogen fertilizer use is under way in many parts of the world. The European Community, for example, is moving to low-input farming, and calling for a tax on farm chemicals and on nitrogen, whose use has quadrupled over the last 30 years. [102] The United States Department of Agriculture issued a report in 1980 favouring organic farming, in which nitrogen fertilizers replace organic sources of nitrogen through crop rotation with leguminous plants. [103] Major TNCs, such as Shell, are moving into biotechnology research, investigating other plant means of nitrogen fixation. Other possible means of fertilization include the use of composed municipal waste. [104]

Alternative farming methods will take time and money to develop, and the transition to them will involve costs in the short term before longer-term benefits are reaped. It is difficult to generalize what those costs are going to be across the variety of types of farms, production methods, crops grown, climates, soils and other local conditions. Nevertheless, it has been estimated for cash grain farms in the midwestern part of the United States, organic farming may give slightly reduced yields of up to 10 per cent, but possibly less. [105] The reduction in output would occur mostly on monocrop cash-grain farms, because rotating crops to ensure regular alternation with nitrogen-fixing plants would result in less cash grain for export. Farms producing multiple vegetables would probably be only minimally compromised, if at all. On the positive side, it has been found that organic farms do better in dry years, and this could be especially important given the climate impact of global warming. Other benefits are soil improvement and greater system stability. A recent report by the United States National Research Council has reached similar conclusions.

Although the development of fertilizers and energy-intensive agriculture has helped the world to meet its need for food, this pattern of promotion by the suppliers of inputs and the Governments of both producing and consuming countries has often led to excessive, inefficient and inappropriate use of the chemicals. One result has been the increase in greenhouse gas emissions. Other environmental and social consequences include pollution of local and urban drinking water supplies owing to excess nitration, and rare anaemia in babies, which the World Health Organization has linked to nitrogen contamination. [106] That kind of capital-intensive agriculture has resulted in indebtedness of farmers owing to dependence on commercial inputs, including fertilizers. Measures that can reduce the need for commercial inorganic fertilizer may thus mitigate not only global warming, but also other negative environmental and social effects.

Increased technology transfer, which would result in more local control of the fertilizer technologies, may help to change that dependence. Moreover, pursuing alternative organic methods of plant nutrition can have important benefits for community health and the environment, including reducing greenhouse emissions. It could also reduce TNC control over agricultural production, increase competi-

102 European Community, "EC: Tax farm chemicals to curb environmental damage", *Reuters* (20 February 1990).

103 United States Department of Agriculture, "Report and recommendations on organic farming" (Washington, D.C., United States Department of Agriculture, 1980); and G. Yomberg (Beltsville, Maryland, Institute for Alternative Agriculture, 1990), personal communication.

104 V. Thorpe (International Federation of Chemical, Energy and General Workers' Unions), 7 March 1990, personal communication. Care must be taken to ensure that toxic materials are eliminated from the waste stream before composting.

105 United States Department of Agriculture, op. cit.

106 European Community and E. Kaluzynsha, "EC: nitrates boost food production but affect environment", *Reuters* (19 January 1990).

tion in the agricultural sector and reduce the costs of inputs to farmers in both developed and developing countries.

In the OECD countries, conversion to less fertilizer and pesticide-intensive programmes may be eased by the fact that there is currently excess food production capacity in many of those countries. It will be harder in much of the third world, where the financial situation is more difficult and where food supplies are already tight and production increases must be maintained. Significant reductions in use can, however, be obtained in many cases without undue effects on yields. Corporations could help, for example, by including information about alternative methods of fertilization and pest control in their literature, which is distributed to extension agencies and farmers.

A great many of the specific actions which need to be taken to reduce the use of nitrogen fertilizers while increasing organic farming need to be taken by institutions other than TNCs. These generally belong in the realm of governmental initiatives to promote organic farming, regulate the use of chemicals in farming, taxation of chemicals etc.

Since TNCs have been very active in promoting the use of chemical nitrogen fertilizers, they should undertake to carry out assessments of the damage that such use has already done, and what might be done to repair it. Such assessments should be in addition to any environmental assessments they undertake for new projects.

TNCs are now involved in developing plant varieties which are genetically engineered, many of which will be patented and will require even more dependence on inputs manufactured by TNCs. TNCs should perform comprehensive assessments of the energy, environmental and economic impacts of their new products. Those assessments should take due account of the seriously adverse long-term effects on soil and water of the previous generation of corporate-produced chemicals, as well the adverse impacts on income distribution and rural inequalities in the developing countries of much of the "Green Revolution".

In the context of present chemical fertilizer plants and applications, TNCs should make estimates on a country-by-country basis of how much the use of chemical fertilizers can be reduced by more efficient application and substitution by organic nitrogen and by the use of nitrogen-fixing crops. TNCs should also be making investments to reduce energy consumption in the manufacture of chemical fertilizers. Potential savings are estimated by the World Bank to be as high as 10 to 25 per cent.

CHAPTER X

PUBLIC POLICY AND THE ROLE OF CORPORATIONS: LESSONS FROM THE CASE STUDIES

The relative roles of governments and corporations in environmental stewardship are the subject of extensive literature and debate. The case studies presented above demonstrate a wide range of relationships between them, both in the creation of environmental problems and in the crafting of solutions.

The complexity of the relationship between Governments and corporations stands out particularly clearly. Corporations often want less government regulation in areas where such decreases will allow for larger profits. Yet the attitudes of Governments vary a great deal and within countries are subject to evolution, especially with changes in regimes or parties in power.

The case study of Valco in Ghana shows the evolving nature of government-corporate relations. At first, the Government and the TNCs agreed on the sale of cheap power for aluminium production in Ghana. Later, as losses to Ghana mounted and other problems became manifest, the Government wanted to increase electricity rates, but could not readily do so. Only after many years, and considerable economic and other losses, United Nations-assisted negotiations successfully changed the electricity rate.

The CFC example illustrates that as long as there was the threat of regulation of ozone depleting compounds in the United States, until about the middle of 1980, even non-United States based TNCs engaged in research into alternative chemicals. When the threat of regulation in the United States was lifted in early 1981, and they were similarly not under pressure from European Governments all major CFC-producing corporations, both in and outside of the United States, drastically reduced research and development of alternatives. That change in corporate policy coincided approximately with the change of administrations in the United States.

It was only after a non-governmental organization initiated legal action and the ominous warning of the Antarctic ozone hole in the mid-1980s that the Government of the United States again acted on this issue, followed by other Governments and by corporations. By 1987-1988, not only chemical producers, but user corporations began actively to research alternatives. Almost all the latter group of companies had previously been absent from the search for solutions, despite the fact that the loss of business to the users of CFCs in the event of a quick phase-out would be much greater than the losses to the CFC-producing corporations. In the face of the Montreal Protocol, however, many of those companies have embarked on vigorous programmes of research and development.

Contrasted with this success story is the automobile case study. Privatization of public transport and sale of private transport based on trolleys and railroads to motor vehicle manufacturers has imposed great economic and environmental burdens upon communities and upon the globe. Road transportation was encouraged by Governments, which built extensive networks of roads, but did not commit comparable resources to public transport or to railways, especially in the United States. As a result, the physical structure of transport today is geared to inefficient road vehicles and to petroleum, and it will take a great deal of time and expense to change to non-polluting and efficient systems. That pattern is partly the result of the general ignorance of environmental problems which existed earlier in the century, but it is also a product of the relative laxity of Government in the face of evidence that TNCs with a vested interest in oil-based road transport were destroying public transport systems. More recently, although Governments have made significant inroads in many countries in increasing the safety and reducing emissions from vehicles, they have failed adequately to encourage high-efficiency vehicles through efficiency standards. The case study suggests that Governments continue to treat powerful automotive companies too leniently, leaving considerable room for corporations to manufacture products which are far more polluting than the best available technology.

The fertilizer case study highlights a different kind of government-corporate interaction, which has been productive in some respects and detrimental in others. The study is an example of government-industry *collaboration* in the development and propagation of food-production technology, first in the OECD countries and then its dissemination in developing countries. While the greenhouse gas emissions aspect of the problem was remote and ill-understood until recently, other economic and environmental problems, such as salinization of land, excessive use of pesticides and consequent water pollution and injury to workers, as well as regressive income distribution, were largely ignored while Governments and corporations pursued increases in food production and rapid expansion of fertilizer and pesticide sales. Government collaboration with industry on the green-revolution project has done little to combat and, in some cases, has exacerbated those problems.

As with the structure of transport, the structure of food production today is so intimately connected with the use of chemicals that it will be difficult and costly to change it. In both cases, even if political bodies decide to make changes a priority, they are likely to be met with substantial corporate resistance and the transition may be extremely painful. The net result has been to narrow social choice in those vital areas.

In sum, there is no fixed relationship between Government and TNCs on any one issue, even when the same country and the same corporation are being analysed over time. The relationship evolves, due to various economic, social, political and legal factors.

Some general conclusions can none the less be drawn from the case studies:

1. Corporations have so far insisted on demonstration of significant environmental damage before they will commit to large environmental corrective expenditures;

2. Governments have, with some exceptions (notably the United States, Canadian, Swedish CFC-aerosol bans), been reluctant to act and have gone along with corporate insistence of proof of damage prior to resource commitments. In some cases government-corporate

collaboration has been close, and that has contributed to the creation or aggravation of greenhouse gas emissions (as with fertilizer and automobile use).

3. Without government regulation, it is difficult to get rid of products and processes which are producing significant pollution.

4. Citizen pressure and non-governmental organisation pressure, as well as analyses from the scientific community, have played a vital role in calling attention to the problems and creating an atmosphere in which Governments and corporations can find the necessary resolve to act.

5. Regulations at an international level are needed for global problems. While national regulations have reduced the scope of the problem, especially when large consuming countries like the United States restrain use, success cannot be achieved without near universal participation. Even in the relatively inexpensive case of CFC-use in aerosols, a failure of most heavy-use countries to promulgate regulations resulted in 2.5 billion kilograms of needless emissions of CFCs within the last decade.[107]

A restructuring of corporate policy with respect to the environment is clearly needed. These case studies suggest that success will require a combination of efforts taken by corporations and Governments at the national and international levels, as well as pressures from non-governmental organisations.

107 Arjun Makhijani, et al., op. cit.

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Climate Change and Transnational Corporations: Analysis and Trends

(ST/CTC/112)

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