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Summary of the Presentations at the International Workshop on Reducing Carbon Dioxide Emissions from the Developing World: Assessment of Benefits, Costs and Barriers

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J. Sathaye and N. Goldman, Editors

June 1991

APPLIED SCIENCE DIVISION

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REDUCING CARBON DIOXIDE EMISSIONS FROM THE DEVELOPING WORLD: ASSESSMENT OF BENEFITS, COSTS AND BARRIERS

October 4-6, 1990
Berkeley, CA

Edited by
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June 1991

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PREFACE

The "International Workshop on Reducing Carbon Dioxide Emissions from the Developing World: Assessment of Benefits, Costs and Barriers" was the second workshop held as part of a project being conducted by the International Energy Studies Group of Lawrence Berkeley Laboratory, in collaboration with experts from leading institutions across the developing world. The goal of the project is to analyze long-range energy consumption in developing countries and its potential contribution to global climate change. The U.S. Environmental Protection Agency (EPA) is supporting this work, the results of which already have made a key contribution to the technical analysis being used as the basis for discussion by the Energy and Industry Sub-group of the Intergovernmental Panel on Climate Change (IPCC).

The main purpose of this workshop was two-fold: (1) to discuss the feasibility of implementing the efficiency improvements and fuel switching measures incorporated into the long-term energy scenarios created for 17 developing countries and (2) to examine the costs and benefits of reducing energy-related carbon dioxide emissions generated by developing countries.

The workshop had approximately 35 participants from the United States and abroad, including energy experts from Africa, Asia, Latin America and the Middle East, staff members from the U.S. Environmental Protection Agency, Agency for International Development and Department of State, members of the International Energy Studies Group at Lawrence Berkeley Laboratory and selected specialists in particular areas. The summaries in this report were edited by Jayant Sathaye and Nina Goldman of Lawrence Berkeley Laboratory based on the materials provided by the presenters.

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INTRODUCTION AND WELCOME

Dennis Tirpak
Global Climate Change Division
U.S. Environmental Protection Agency

Since our last meeting, several changes have occurred in the international arena which bring us one step closer to negotiating climate change policy. First, Eastern Europe has gone through a major transformation and, second, further negotiations have taken place for the Montreal Protocol. Many industrialized countries have shown greater interest in carrying out studies on developing world energy use and carbon emissions.

This forum allows experts to exchange views and ideas and simultaneously to work together towards progress. The theme for the next few days will be how to move from broad strategies to more specific plans and from analysis to implementation. In other words: where do we go from here?

LONG-TERM SCENARIOS OF ENERGY USE AND CARBON EMISSIONS: SUMMARY OF RESULTS

Jayant Sathaye
Co-Leader, International Energy Studies Group
Lawrence Berkeley Laboratory

Energy use in developing countries has risen more quickly than in the industrialized world, with a consequent increase in the developing world's share in global modern energy use from 16 percent in 1970 to 24 percent in 1987. As a result, while the developing countries' share of carbon dioxide emissions is small today, it is growing rapidly. The following is a brief summary of the aggregate results derived from the work on long-term energy and carbon emissions[1] scenarios for China, India, Indonesia, Korea, Argentina, Brazil, Mexico, Venezuela, Nigeria, Ghana, Sierra Leone and the six members of the Gulf Cooperation Council (GCC).[2,3]

As shown in Table 1, in the scenarios the countries experience varying rates of population growth between 1985 and 2025. The fastest growth rates occur in Africa -- particularly in Nigeria and Ghana -- and in the GCC. In Korea and China, where the governments have implemented policies to control the expansion of the population, the growth rates remain significantly lower.

The economic growth rates correspond with national projections and/or expert judgement. GDP shows a wide variance across the study countries; and in each country distinct factors account for the differences in rates of growth. Argentina, for example, experiences a relatively slow increase in GDP as the foundation of its economy moves away from manufacturing and towards agriculture-based industry (Table 1). In contrast, Korea's development of its less energy-intensive industries continues to fuel high rates of economic growth between 1985 and 2025.

At $18,000, Korea's GDP per capita in 2025 equals roughly that of the United States in 1985. GDP per capita remains lower in the Latin American countries, where poor economic performance over the past two decades has tempered growth. In Africa and the GCC, GDP per capita grows even more slowly, due largely to the rapid expansion of the population (Table 1).

Alongside this economic growth, the primary energy supply in the 12 study countries rises

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1 Throughout this paper, the term "carbon emissions" refers to those emissions generated from commercial fuel use. Unless otherwise specified, carbon emissions from biomass are excluded from total emissions.

2 The GCC countries include: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates.

3 J. Sathaye and A. Ketoff (eds), *CO_2 Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term, Volume I: Summary*, Report No. LBL-29507REV., Lawrence Berkeley Laboratory, Berkeley, CA, December 1990; A. Ketoff, J. Sathaye and N. Goldman (eds), *CO_2 Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term, Volume II: Argentina, Brazil, Mexico and Venezuela*, Report No. LBL-30059, Lawrence Berkeley Laboratory, Berkeley, CA, December 1990; J. Sathaye and N. Goldman (eds), *CO_2 Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term, Volume III: China, India, Indonesia and Korea and Volume IV: Ghana, GCC Countries, Nigeria and Sierra Leone*, Report Nos. LBL-30060 and LBL-30061, Lawrence Berkeley Laboratory, Berkeley, CA, December 1990.

almost four-fold in the HE scenario and three-fold in the LE scenario, indicating significant potential for reducing energy use by 2025 (Table 2). Primary energy supply per capita in 2025 remains only a fraction of that enjoyed in the United States today. Consumption of energy grows more slowly than GDP in every country except for Indonesia and the GCC nations.

Table 1
Population, GDP and GDP per capita

Country	Population (Millions) 1985	2025	AAGR	GDP (1985 US$ Bn) 1985	2025	AAGR	GDP/Capita (1985 US$) 1985	2025	AAGR
China	1045	1420	0.8%	324	2840	5.4%	310	2000	4.7%
India	766	1692	2.0%	191	1347	4.9%	250	796	2.9%
Korea	41	50	0.5%	93	926	5.8%	2276	18400	5.2%
Indonesia	165	267	1.2%	84	280	3.0%	510	1050	1.8%
Argentina	31	47	1.1%	70	156	2.0%	2296	3294	0.9%
Brazil	132	214	1.2%	249	891	3.2%	1879	4163	2.2%
Mexico	77[a]	143	1.7%	189[a]	1000	4.4%	2470[a]	6980	2.7%
Venezuela	17[b]	34	1.7%	50[b]	248	4.0%	2943[b]	7318	2.3%
Nigeria	96	317	3.0%	75	373	4.0%	788	1176	1.0%
Ghana	13	43	2.9%	4.6	22.8	4.0%	343	533	1.2%
Sierra Leone	3.5	8.8	2.3%	0.9	2.9	3.0%	247	327	0.7%
GCC	16.3	66.1	3.5%	163	1084	4.7%	10200	16400	1.2%

AAGR = Annual Average Growth Rate; [a] 1984 data; [b] 1987 data

Table 2
Primary Energy Supply (EJ)

	1985	2025 High	2025 Low
Total	62	218	178
Coal	34%	38%	35%
Oil	28%	32%	31%
Natural Gas	6%	11%	13%
Biomass	22%	7%	6%
Nuclear and Geothermal	1%	3%	3%
Hydro and Other	9%	9%	11%

In both scenarios, the share of coal increases relative to that in 1985 as residential energy users replace biomass with coal and as the electricity generation process comes to rely more heavily on coal. The shares of all other fuels increase as well to compensate for the decreasing reliance on biomass sources.

By 2025, China will have to mine as much as 3.1 billion tons of coal compared to about 900 million tons in 1985. India will have to produce about 850 million tons of coal compared to about 150 million tons in 1985. Judging from the current local environmental problems with coal mining and coal use, this increase will require a substantial investment in coal clean-up technologies. Total oil demand in the 12 study countries increases from 8.4 million barrels per day (mbpd) in the base year to over 33 mbpd by 2025 in the HE scenario. The hydro capacity increases ten-fold in Venezuela and exhausts all the known hydro reserves in the country today. In China, hydro capacity approaches 225 GW by 2025, which would exhaust the hydro sites close to the population centers. A recent study, which estimated the capital costs for the energy sector for nine world regions, concluded that the expansion of the energy sector likely will be severely inhibited by capital scarcity.[4] Given the higher economic and energy growth rates assumed in our scenarios, the same conclusion applies.

In all but three of the country studies -- the GCC, Korea and Venezuela -- the primary fuel mix grows more carbon intensive over time. Increasing shares of nuclear energy in Korea, hydro power in Venezuela and natural gas in the GCC limit the increase in these nations' dependence on the more carbon-intensive fuels.

Accordingly, total carbon emissions increase four-fold across the 12 study countries, equalling 3.6 billion tons in 2025 according to the HE scenario. The low emissions scenario reduces total emissions to four fifths of the HE total (Table 3). China and India continue to emit the largest amounts of carbon in absolute terms. Because of the high energy use and continued dependence on highly carbon-intensive fuels, carbon emissions in the GCC increase more rapidly than in any of the other study countries.

Table 3
Carbon Emissions (Million Tons)

Country	1985	2025 High	2025 Low
Total	900	3635	2870
China	480	1700	1365
India	115	700	615
Mexico	75[a]	225	155
GCC Countries	60	400	330
Brazil	45	140	65
Korea	45	170	110
Indonesia	25	130	105
Venezuela	25[b]	65	55
Argentina	20	45	30
Nigeria	10	55	40
Ghana	1	4	3
Sierra Leone	--	1	1

[a] 1984 data; [b] 1987 data

About 80 percent of the carbon reductions achieved in the LE scenario stem from efforts to better the efficiency of energy use. Only in Venezuela do fuel substitutions lead to greater reductions in carbon emissions than efficiency improvements. These results suggest that the primary avenue for reducing carbon emissions in developing countries will be through improving energy efficiency and, only to a minor extent, through fuel switching.

4 *Assessment of a Global Energy Efficiency Initiative*, Draft Report, Lawrence Berkeley Laboratory, Berkeley, CA, 1990.

STUDIES TO SUPPORT THE IPCC AND OTHER CLIMATE CHANGE DISCUSSIONS

Paul Schwengels
Chief, Stabilization Branch
U.S. Environmental Protection Agency

This is an extremely exciting time to be working on major changes in energy programs in developing countries. I believe that an extraordinary commonality of interest is emerging among donor countries, developing countries, international financing institutions and private industry. All of these groups now have strong reasons for supporting the transfer of efficient and environmentally-benign energy technologies to developing countries.

Developing countries and multilateral development banks are recognizing that the capital requirements for increasing energy supply -- particularly electricity -- and the foreign exchange implications of increasing imports of fossil fuels will become a major constraint to continued economic development for many countries. Thus, for most countries, "business-as-usual" energy development is not sustainable on strictly economic terms.

In addition, the inefficient fossil-fueled energy systems in developing countries are major contributors to the growing local and regional environmental problems in these nations. There is growing recognition in many countries that economic development must be environmentally sustainable as well, and that traditional energy development often does not meet this test.

The industrialized countries are becoming concerned about the risks of global climate change. While recognizing that they themselves are the major historic contributors to greenhouse gas build-up, they also can see that rapid economic development in the developing world along traditional energy-intensive patterns could drive future growth in greenhouse gas emissions. The industrialized countries currently provide significant amounts of assistance to developing countries in the energy sector. The concerns about climate change provide strong incentives to these countries to intensify their energy-related assistance, to improve international cooperation in this area and, most importantly, to redirect energy assistance toward more efficient and cleaner technologies.

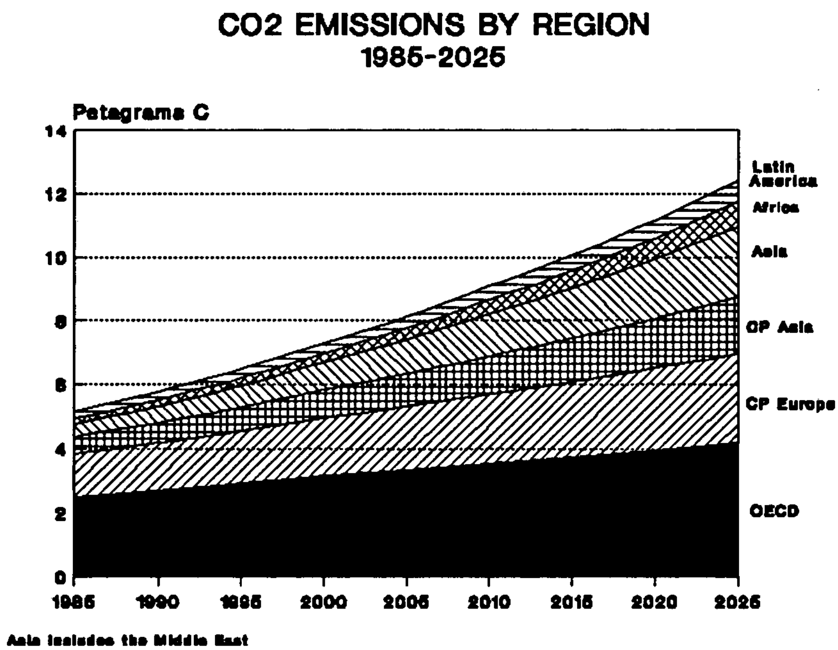
Enlightened and strategic-thinking private companies are beginning to create a market for "greener" energy systems with high growth potential in rapidly developing countries in the long run. These companies will increasingly perceive incentives to develop and transfer improved energy technologies which will position them to profit in these future markets.

For all of these reasons and more, the conditions are right to begin specific changes in energy policies, programs and technologies in developing countries. The results of the case studies and related analyses from the Lawrence Berkeley Laboratory (LBL) project can play an extremely important role in identifying these opportunities. There are many potential users of the information and we need to increase our efforts to ensure that it is being aggressively disseminated.

One key user for this information, of course, is the Intergovernmental Panel on Climate Change (IPCC). The Energy and Industry Subgroup (EIS) of the IPCC has developed scenarios of energy use and carbon emissions through 2025. These scenarios are intended to support additional analyses of key policy questions regarding the effectiveness and cost of alternative policy and technical measures for reducing greenhouse gas emissions. The scenarios have incorporated available results from the LBL case studies as part of the "bottom-up" approach. By focusing on individual country studies, they can recognize inherent differences among countries but still relate policies to the overall global problem of climate change.

The results of the scenarios show the share of global carbon emissions from developing countries increasing rapidly between 1985 and 2025 (Figure 1).[5] Despite this growing aggregate share, it is important to remember that CO_2 emissions per capita remain much higher in the industrialized countries -- particularly in North America and in Eastern Europe -- than in the developing world (Figure 2).[6] In Latin America, the developing region with the highest per capita emissions, carbon emissions per capita in 2025 remain at about one seventh of the projected 2025 level for North America.

Figure 1

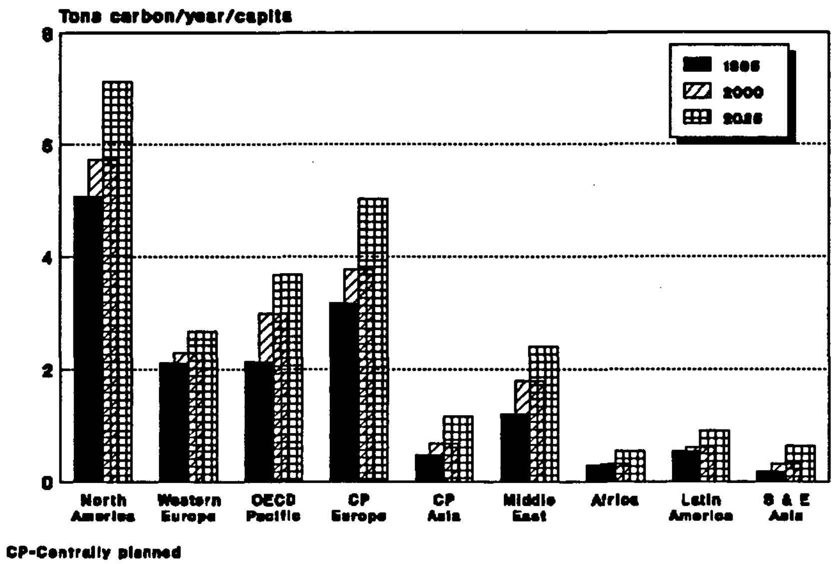


[5] Figure 1 data source: Intergovernmental Panel on Climate Change, Response Strategies Work Group, *Energy and Industry Subgroup Report*, U.S. Environmental Protection Agency, Washington, D.C., January 1991.

[6] Figure 2 data source: Intergovernmental Panel on Climate Change, *op cit*, Ref. 5.

Figure 2

CO2 EMISSIONS PER CAPITA
1985-2025



At September's meeting of the EIS in Paris, the participants identified priorities for future work. The members proposed the need for:

1) Improving energy and emissions data;
2) Carrying out more thorough cost and economic analyses;
3) Performing total greenhouse gas analyses (studies which discuss both CO_2 emissions and non-carbon emissions);
4) Going beyond modeling studies to identifying policy instruments; and
5) Promoting greater support for analysis in developing countries and Eastern Europe and greater involvement from these countries.

Looking forward to future work on the case studies, the analysis must be improved. Research should be carried out in greater detail with greater accuracy and should incorporate cost assessments, capital investment requirements and implementation analysis. As part of the transition from scenarios to implementation, we must begin working with the developing country governments. Most importantly, we must take advantage of every opportunity to focus on practical applications for improving the efficiency of energy use and reducing carbon emissions.

REVIEW OF MODELS ON ENERGY AND CLIMATE CHANGE

John Weyant
Director, Energy Modeling Forum
Stanford University

The Energy Modeling Forum recently has initiated a global climate change project. The purpose of the project is to summarize the work which has already been done on this topic and to evaluate the quality of the work.

Several critical issues arise in any effort to make credible estimates of the cost of greenhouse control strategies. First, a worldwide modeling framework must be developed because carbon emissions from particular regions affect the global atmosphere. The contribution of developing countries to total emissions is growing more rapidly than in the industrialized world. Because the data available on developing countries is quite poor at present, future efforts should focus on new data collection and modeling efforts in these regions. Second, all the major greenhouse gases -- CO_2, CFCs, methane and N_2O -- and not just carbon dioxide must be considered in future analyses. It is the overall concentration of all these different greenhouse gases in the atmosphere that ultimately will lead to global climate change. Third, an effective means for analyzing the various greenhouse gas control strategies must be developed.

In order to successfully carry out the final task, a method must be developed which integrates a top-down macro-economic approach with a bottom-up process engineering approach. When implementing the macro-economic approach, one must choose plausible ranges for future economic and population growth rates. The reason for this is that even small changes in these driving factors can have huge impacts on emissions projections over the 100 or more year time frames required to address the greenhouse gas problem. The implementation of the process engineering approach requires: an accurate characterization of the costs, performance and availability of current and likely future technologies; an assessment of the likely barriers to technology transfer of both existing and new technologies, particularly from the developed to the developing countries; and an evaluation of the impact of energy prices and greenhouse gas policies on new technological development.

The strengths of each of these two methods can overcome the weaknesses of the other. When attempting to model energy demand over a long time period, both the process engineering and macro-economic approaches offer different advantages. The process engineering approach provides a particularly effective means for examining the saturation of end-use energy demand (e.g. people are only physically able to drive so many hours per day), the effectiveness and production capacity of already existing technologies and the potential for phasing in these technologies in developing nations. The macro-economic approach integrates levels of fuel supply and demand, helps to determine the impacts of energy prices on the overall economy and provides a general framework for anticipating trends in technologies and behaviors that affect energy use. Hence, a combination of a top-down and a bottom-up approach will yield more credible results than either of these two methods can produce on their own.

ECONOMICS OF EFFICIENCY IMPROVEMENT AND CARBON REDUCTION IN NEW ENGLAND

Florentin Krause
Lawrence Berkeley Laboratory

LBL is currently carrying out a comparative analysis of alternative approaches for incorporating environmental externalities related to global warming and acid rain into the valuation of electricity resources. The analysis consists of a case study of the New England power system. Because the extent and impacts of global warming remain uncertain, the potential risks and damage cannot be calculated using a strict cost/benefit analysis, but require an insurance-buying perspective: a risk-minimizing reduction target is set, and this target is met in a least-cost way while satisfying electricity and reliability demands.

Some of the questions that guide this project include:

1) What resource mixes could deliver substantial (20 percent or more) carbon reduction over the next 15-20 years?

2) What would be the costs of implementing the carbon-reducing strategies? How do the costs for the different plans compare to each other?

3) How do these costs compare to utility plans that are not constrained by considerations of the greenhouse effect?

4) How will the implementation of these targets affect other policy goals (Will they create rate shock or hurt the region's economic competitiveness?)?

The four alternative carbon reduction supply curves shown in Figures 1a and 1b illustrate a key concept of our study: *some amount of carbon reductions could be achieved at low or negative net costs*. The top two figures (1a and 1b) show the supply curve as predicted on the basis of classical economic theory. The key assumption here is that the economy, and here the utility sector, is in least-cost equilibrium at the present time. This assumption means that all demand- and supply-side electricity resources are being employed in a manner that minimizes life-cycle costs and maximizes societal welfare. On the basis of that assumption, utility system costs can only go up as a result of carbon reductions -- although the differences between Figures 1a and 1b illustrate that some carbon reductions could be achieved at low cost within this model.

A different picture emerges from detailed engineering-economic analyses of low carbon resource cost and performance data. These kinds of data reveal that current patterns of electricity use do not represent a least-cost equilibrium; rather, a number of resource options that are considered cost effective under conventional neoclassical criteria are being under-utilized in providing electricity-related energy services. Among them are: demand-side efficiency investments, fuel-switching options at the point of end use and opportunities for cogeneration.

Informational, capital market and institutional barriers all account for the failure to fully employ these low carbon alternatives.

If a resource saves carbon and is cost-effective in terms of its life-cycle costs then the avoided costs more than pay for the carbon-reducing investment and the carbon reduction itself can be said to have negative cost. Figures 1c and 1d illustrate this concept. Once again, the supply curve of carbon reductions could be either steep or shallow. Also, market imbalances at the status quo starting point can be of different depths. For a range of carbon reductions, costs related to the more expensive resource options would be over-compensated or partially offset by the negative cost portions. Thus, a key question in determining the net cost of carbon reductions in the utility sector is the relative size of available resource potentials with positive and negative costs of carbon savings.

Technical options for reducing carbon emissions fall into two broad categories:

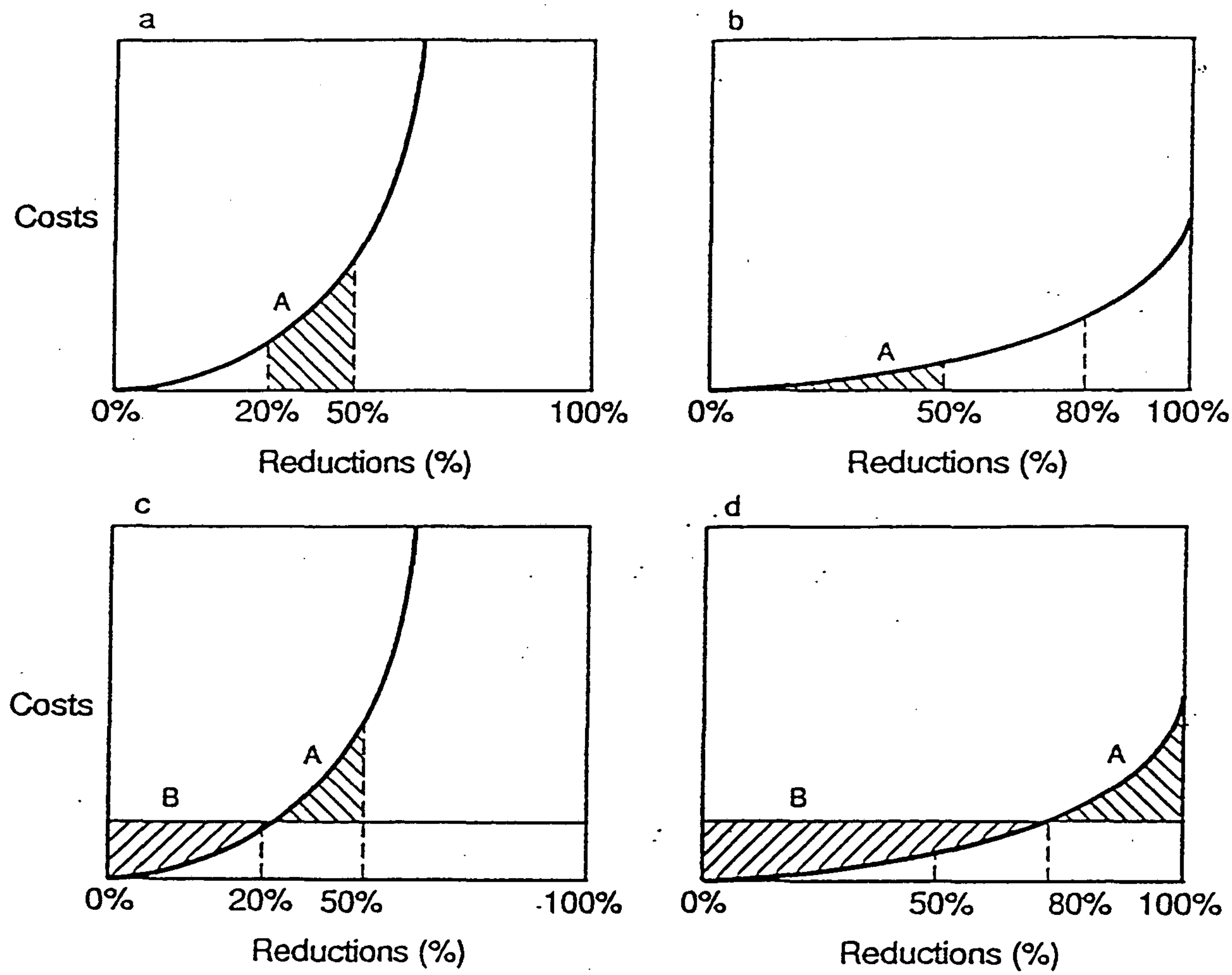
1) Demand-side Options. These include efficiency improvements, fuel switching at the point of end-use and recycling of energy-intensive materials.

2) Supply-side Options. These include more efficient fossil-fired thermal power plants, fuel switching or co-firing with gas in existing plants, cogeneration and non-fossil based generating technologies.

The study ranks the various thermal generating options that rely on different fossil fuels of different carbon intensity and have different net heat rates. It then amends the cost assessments using estimates of resource potentials.

The preliminary conclusions from this exercise suggest that the New England power sector could achieve a 20 percent reduction in carbon emissions in the next 15 to 20 years if patterns of resource acquisition are shifted. In order to reach this goal, utilities will have to expand programs to mobilize demand-side investments and vigorously pursue low carbon supply-side options such as gas-fired cogeneration, advanced gas central stations and biomass, wind and other resource projects. Cost estimates of implementing such a plan vary. From preliminary analyses, it appears that realizing the 20 percent reduction target will not necessarily lead to significant electricity bill or rate increases for New England rate payers. In fact, this reduction could possibly be achieved while reducing the cost of energy services below that of current resource plans.

Figure 1



Possible Shapes of the Supply Curve of Fossil Carbon Reductions

Source: Krause et al. (1990)

BARRIERS TO EFFICIENCY IMPROVEMENT AND FUEL SWITCHING IN KARNATAKA, INDIA

Amulya Reddy
Director, Institute of Management Studies
Indian Institute of Science

Implementing changes in energy efficiency involves a wide range of actors. Improvements, therefore, require actions at the lowest level of the consumer, through the highest level of the global agencies. Due to the multiplicity of participants, however, barriers to achieving these improvements can arise at every level. The following section defines the major barriers to improving energy efficiency in developing countries and identifies paths to overcome these challenges.

I. **Energy Consumers**. The implementation of energy efficiency improvements requires the participation of the ultimate consumer of energy in every sector. Yet many consumers lack the knowledge, finances or other tools necessary to use energy more efficiently. Included in this group are:

a. The Ignorant. Uninformed about the opportunities for efficiency improvements and unaware of the cost-effectiveness of conservation measures, the ignorant cannot appreciate the potential benefits available to them. The supply of relevant information to and, therefore, the education of the consumer through various channels (door-to-door canvassing, mail leaflets, newspapers, magazines, radio and television, demonstrations and training) can help surmount the barriers posed by the ignorant consumer.

b. The Poor and/or First-Cost Sensitive. Even when consumers know about the net benefits available to them, they often lack the funds necessary to invest in the typically more costly energy-efficient equipment. Innovative financing -- including first-cost loans and gradual payments -- may help combat financial constraints.

c. The Indifferent. Knowledgeable consumers often resist implementing efficiency improvements because their energy costs are not significant enough relative to their total expenditures to motivate change despite the potential importance of such improvements to society at large. In these cases, government intervention -- such as regulations, standards, labels and restrictions in supply -- can overcome the barriers.

d. The Helpless. This class of consumers has all of the above-listed tools necessary to implement efficiency changes but nonetheless is crippled by the problems that must be tackled in order to identify, procure, install, operate and maintain the associated devices and equipment. In order to eliminate this type of problem, the efficiency improvement industry must provide the consumers with the necessary know-how, by creating total hardware plus software packages.

e. The Inheritors of Inefficiency. Consumers who have the knowledge, capital, motivation and know-how to better their energy use, often have inherited inefficient devices or equipment.

Tenants, for example, often rent space in energy-inefficient buildings. By arming consumers with the ability to exert pressure on equipment providers to label equipment with energy performance levels, this barrier can be surmounted.

II. **End-Use Equipment Manufacturers** (The Efficiency Blind). Equipment manufacturers are commonly insensitive to the energy efficiency of the equipment they sell; rather, they tend to focus on achieving lower first costs, which often means lower efficiency levels. Government intervention, such as enforcing the labelling of end-use devices in order to inform prospective buyers about the energy consumption levels before they make their purchases, will help motivate consumers to consider purchasing more energy-efficient equipment, particularly if the financing of this equipment is tied to its energy efficiency.

III. **End-Use Equipment Providers** (The Operating-Costs Blind). Equipment providers often fail to consider the operating costs of the machinery they offer, because it is the consumer, not the provider, who ends up covering the operating costs. Ameliorating this problem will involve tying the approval of building designs and the securing of financing and loans to energy efficiency standards.

IV. **Energy Carrier Producers and Distributors**

a. The Supply Obsessed. The producers and distributors of energy carriers typically focus exclusively on the supply of their energy carriers and overlook the utilization of these carriers. They particularly tend to ignore the efficiency with which their energy carriers are used. This barrier can be overcome by changing the charter of the producers from suppliers of carriers to vendors of energy services and/or by supporting the growth of independent energy-service companies.

b. The Centralized Biased. Energy carrier producers often focus solely on centralized supplies. Thus, producers tend to overlook decentralized energy sources, particularly biomass. Producers must increase the scope of supplies to incorporate decentralized sources and then adopt least-cost planning so that less expensive non-centralized sources can find their place.

c. The Supply Monopolists. In many cases, laws exist which prevent the production of energy carriers by non-centralized producers. The implementation of PURPA-type incentives will encourage independent producers to produce energy carriers.

V. **Actual/Potential Cogenerators** (The Cogeneration Blind). Cogeneration offers a number of opportunities to improve the efficiency of generation of energy carriers. The enactment of PURPA-type laws that permit the export of cogenerated electricity to the grid at favorable prices can help tackle this barrier.

VI. **Financial Institutions**

a. The Supply Biased. The financial institutions which provide the capital for energy carriers are often as supply biased as are the producers and distributors. Three changes can help dismantle this barrier: shifting the emphasis from energy consumption and supplies to energy services; including efficiency improvements in the list of options for providing services; and pursuing least-cost planning processes.

b. The Unfair. The competition between supply increases of centralized and decentralized sources and conservation measures often remains unfair. Fair competition must be stressed through eliminating subsidies of energy supplies and ensuring correct pricing and the same terms of credits, benefits, incentives, etc.

VII. Government

a. The Uninterested Government. Most developing country governments perceive conservation as a rich country's issue, typically because the term is understood to mean making do with fewer energy services (i.e. less lighting in homes). In most developing countries, the saturation of energy services is far from sufficient at present. Governments in developing nations must be shown the economic advantages of pursuing least-cost energy planning and of making energy-efficient planning the core of their development strategies.

b. The Powerless Energy-Efficiency Agency. Even those governments interested in energy efficiency tend to create a separate government cell, department, agency or ministry for energy, thereby failing to imbue the department with the power necessary to enforce energy-efficiency decisions. By giving these responsibilities to agencies that are either outside or above the energy system and under the highest political authority, these actors can be more effective at implementing energy-efficiency strategies.

c. The Cost-Blind Price Fixer. Energy prices in developing nations often fail to correspond with the real costs of energy. This barrier can be surmounted by moving towards long-run marginal cost pricing and by ensuring that price increases are implemented along with efficiency improvements.

d. The Fragmented Decision Makers. Separate offices, departments, agencies and/or ministries often handle issues of energy supply and conservation leading to conflicts and grappling over funds. Efficiency improvements must be treated as part of the same investment decision as energy supply and must be made in the same office by the same decision makers.

VIII. International, Multilateral and Industrialized Country Funding/Aid Agencies

a. The Energy-Inefficient Technology Exporters. Following the oil shocks of the 1970s, many industrialized nations replaced inefficient equipment with more modern and energy-efficient technologies. In many cases, however, the old technologies were transferred to developing countries. Industrialized nations must help provide technology assessment to the LDCs, support energy-efficient technologies through aid and promote technological leap-frogging across the developing world.

b. The Supply Biased. Multilateral and industrialized country agencies tend to be supply biased. This slant stems from the conventional emphasis of these agencies on increasing energy consumption by increasing energy supplies. In order to dismantle this barrier, these agencies must shift their emphasis from energy consumption and supplies to energy services, include efficiency improvements in the list of options for providing services and pursue least-cost planning.

c. The Large-Is-Convenient Biased. Because of the plethora of paperwork involved in carrying out a huge number of projects, agencies prefer to support a few large projects as opposed to many small ones. This barrier can be overcome by providing funding to smaller agencies, which execute a large number of small projects.

d. The Project-Mode Sponsors. Aid agencies often offer project-oriented financial support and fail to support energy-efficiency programs that emphasize a large number of diverse and small-scale technologies to suit regional and local conditions. Aid must be reoriented from specific projects to broad programs for which the allocation of resources is largely the responsibility of locally-based institutions with goals in accordance with overall program objectives.

e. The Self-Reliance Underminers. Another reason why aid agencies often support projects over programs is that developing nations often lack the technological and management expertise to plan and administer such programs. Ultimately, however, the failure to involve the developing country institutions undermines the self-reliance of the participating country. The only way to ensure that the self-reliance of these countries is not undermined is to devote considerable and meticulous effort to the initiation, establishment and strengthening of indigenous capability in the areas of analysis and planning of energy technologies.

LEAST-COST STRATEGIES FOR REDUCING CO_2 EMISSIONS IN INDIA: SOME PRELIMINARY RESULTS[7]

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1 Introduction

Developing countries have considered a wide range of strategies to reduce their emissions of carbon dioxide, but none of these efforts have used an integrated approach to analyze the economic implications of these strategies. This work presents a linear programming (LP) model for evaluating alternative strategies for reducing CO_2 emissions from India's energy sector and for examining the implications of implementing each of these strategies in terms of foreign exchange scarcity and capital constraints.

2 Objectives

This exercise has the following objectives:

a) To estimate the cost of alternative strategies for curtailing India's energy-related carbon emissions;

b) To evaluate these options for alternative levels of CO_2 emissions in light of foreign exchange and capital constraints; and

c) To evolve a set of policy measures aimed at achieving economically-efficient and environmentally-acceptable patterns of energy production and use.

3 Scope and Coverage

The development of alternative strategies for lowering CO_2 emissions requires a detailed analysis of the following potential reduction measures:

a) Improving the efficiency of energy use through housekeeping measures as well as investments (e.g., the use of improved motors, light bulbs, stoves and engines);

b) Changing the product pattern as well as the technology mix in the manufacturing, transport, agriculture and household sectors (e.g., reducing the consumption of energy-intensive products such as aluminum, plastics and steel or using bio-technology or

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[7] This paper was prepared for the Second International Workshop on Energy and Global Climate Change based on work carried out by Nandita Mongia, University of Delhi; Ramesh Bhatia, Institute of Economic Growth, Delhi; Jayant Sathaye, Lawrence Berkeley Laboratory; Puran B. Mongia, Delhi School of Economics. With contributions from Ashok Gadgil, Lawrence Berkeley Laboratory, and Nandini Roychoudhury, Delhi.

organic manures in agriculture);

c) Selecting the optimum combination of imports and domestic production of energy-intensive products, including aluminum, steel, petrochemicals, fertilizers and heavy chemicals;

d) Encouraging desirable inter-fuel substitution by the consumers so as to reduce costs and CO_2 emissions;

e) Evaluating the economics of domestic production versus imports of crude oil, petroleum products, coal, natural gas, etc.;

f) Analyzing the economic and environmental aspects of electricity generation from various fuels (e.g., coal, natural gas and fuel oil), nuclear energy and hydro power; and

g) Improving the efficiency of electricity generation, transmission and distribution, including cogeneration, and of using oil products and coal.

4 Structure of the Model

The multisector linear programming model used here is a target-year type model where an objective function (e.g., costs, CO_2 emissions) is minimized subject to a given set of constraints (e.g., end-use requirements in consuming sectors, economic activity levels, investment fund availability and foreign exchange resources).

5 Results of the Alternative Exercises

Two types of results have been obtained:

a) Results suggesting optimum levels of various activities when different carbon reduction levels are considered.

b) Results analyzing the costs of abating carbon emissions at different levels.

The results indicate that when trying to reduce CO_2 emissions, the optimum strategy favors selecting energy-efficient activities; substituting electricity for kerosene for lighting in rural and urban areas; substituting electricity for diesel in railways; increasing LPG use in cooking; substituting gas for coal in electricity generation; and investing in renewable energy resources including large-scale hydro. As the need for curtailing carbon emissions increases, the use of gas for electricity generation becomes more economic as do investments in renewables.

In regard to the costs of CO_2 emissions, the model shows that in the first instance, when efficiency improvements are being implemented, aggregate costs and carbon emissions both decline indicating that at this level the costs of carbon reduction are negative i.e., when trying to reduce CO_2 from 271 million tonnes (MT) of carbon per year to 261 MT per year, the cost of the reduction is negative. However, when carrying out further carbon reductions, to the level of 235 MT of carbon per annum, the unit cost remains positive and roughly equal to Rs. 2 per kilogram of CO_2 reduced. The unit cost rises very steeply thereafter if further reductions in carbon are required.

Although these results are very preliminary, they show the potential of the approach followed here and the advantages of the model being used. Additional results being obtained through the use of this model will be reported in subsequent publications.

ECONOMICS OF REDUCING CO_2 EMISSIONS FROM CHINA

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Relative to the nations of the industrialized world, developing countries emit far lower levels of CO_2 per capita. In coming years, however, as the developing world experiences more rapid rates of economic and population growth, their carbon emissions per capita inevitably will rise. Therefore, developing countries should be encouraged both to adopt more advanced energy technologies in order to improve the efficiency of energy exploration, transportation, generation and end-use and to replace carbon-intensive fuels sources with less carbon-intensive sources (non-fossil fuels and renewable energy). By incorporating methods aimed at curtailing carbon emissions into their energy development strategies, developing nations can reduce the risks posed by higher CO_2 emissions. However, adopting more advanced energy technologies generally entails high costs. These higher prices serve as a particularly large obstacle for developing nations. In order to serve the common interest of protecting the global environment, international funds should be devoted to cover the high costs of reducing developing world CO_2 emissions.

How much will it cost to reduce carbon emissions from developing nations? In a microeconomic analysis, an economic evaluation method can be adopted to calculate the added investment costs for reducing CO_2 emissions. This method assumes two alternative projects which use different technologies with the same discount rates and economic lifetime. The priority of the projects will be determined by their IRR (Interior Recovery Rate).

Now consider an alternative energy problem: substitute technology B, which uses highly carbon-intensive fuel with technology A, which uses less carbon-intensive fuel. Technology A requires a higher investment than technology B. Technology A's contribution to the recovery of investment also remains higher (Contribution revenue - O & M cost full cost). Thus, whether to adopt technology A will be determined by the extra investment cost. The extra investment cost required to adopt new technologies is defined in relation to the cost of existent technologies: if the Capital Recovery Factor (CRF) of a new technology which would save more energy than current technologies and/or would reduce carbon emissions below their current levels is lower than that of the existent technology, the excess investment needed to ensure the same payback time and the same IRR as the existent technology is considered the extra cost for reducing carbon emissions.

The following equation presents this extra investment cost:

$$EIC = \frac{Ka - Ka'}{\text{Reduction of } CO_2 \text{ Emissions}}$$

Ka = The actual investment cost of the new technology
Ka' = The minimum investment cost of the new technology with the same payback capacity as that of the existent technology.

This method for calculating extra investment costs, can be used to evaluate several technologies that rely on less carbon-intensive fuels, including: pressurized fluidized bed boiler power, coal combined-cycle plants and nuclear power. When the discount rate is 10 percent, payback time is 15 years and the extra investment cost for reducing 1 ton of carbon annually equals between US$ 100 and 1750.

The above criterion can also be used to assess the renovation project for energy conservation. The direct economic result of undertaking an energy conservation project is the reduction of fuel costs. An additional benefit is the environmental impact, which can be shown by the extra investment cost for reducing CO_2 emissions. A comparison of the economic result of reducing fuels costs via these methods and of the costs of further exploiting China's coal mines shows that most of China's coal mines have a payback time of 20 years and a discount rate of 5 percent. If the extra investment cost for reducing 1 ton of CO_2 per year equals US$ 100, then it is appropriate to consider an energy conservation renovation project with an investment cost of US$ 600 for reducing energy use by 1 TCE per year. At present, most of China's energy conservation projects have investment costs lower than this value.

Both the high and low emissions scenarios for energy use and carbon emissions in China in the year 2025 assume the same economic growth rates between the present and 2025. However, in the high emissions scenario, where energy use and carbon emissions are higher, the extra investment for reducing these higher emissions will constitute a greater share of the nation's GDP than in the low emissions scenario. Thus, energy saving or fuel substitution measures aimed at reducing CO_2 emissions will free up a greater portion of the nation's GDP.

THE POTENTIAL OF NON-CARBON ENERGY SOURCES IN DEVELOPING COUNTRIES -- THE CASE OF THE PRC

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1 INTRODUCTION

While developing countries presently account for a small share of the world's carbon emissions, in coming years, the quantity of energy-related CO_2 generated by developing nations will surpass the amount produced by industrialized countries. In response to this trend, an increasing amount of attention has been paid to the prospect of reducing emissions in developing countries by exploiting non-carbon energy resources. To date, however, financial constraints have limited the development of non-carbon alternatives; the costs of these sources typically loom far above the costs of conventional forms of energy.[8]

Due to its heavy reliance on coal energy, China makes a disproportionately high contribution to global CO_2. In 1990, China's energy-related activities consumed 8 percent of the world's commercial energy, but accounted for 11 percent of global carbon emissions. While financial constraints will continue to hinder the exploitation of non-carbon alternatives, increasing the roles of hydropower, nuclear energy, solar radiation and wind energy could play a major role in curtailing the growth of carbon emissions in the PRC. This paper evaluates the potential for integrating various non-carbon energy sources in China and provides possible strategies for deploying these sources.

2 LONG-TERM ENERGY DEMAND IN THE PRC

Table 1 shows the results of a forecast for China's energy demand in 2020 and 2050. Although the turn of events following the construction of this forecast may serve to decelerate the future growth rate, the general trend remains unchanged. By extending the time span, China's energy demand equals 4.7 billion tons of coal equivalent (tce) by 2070. The forecast incorporates various technical improvements into the analysis, thereby accounting for the potential for energy conservation in each sector.

The forecast indicates that China's share in global carbon emissions will come to exceed its share in the world population (Table 2).

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[8] A. Manne and R. Riechels, "Global CO_2 Emission Reductions -- The Impacts of Rising Costs," *The Energy Journal*, To be published.

Table 1[9]
The Energy Forecast of the PRC (MTCE)

Fuel	2000	2020	2050		
Total	1500	2400	5200		
Oil	286	358	166		
Natural Gas	53	133	266		
Hydro	100	210	329		
New Energy	0	10	250		
			Case A	Case B	Case C
Coal	1051	1626	3640	3120	2600
Nuclear	10	63	558	1078	1598

Case A: Low nuclear energy; Case B: Medium nuclear energy; and Case C: High nuclear energy.

Table 2[10]
CO_2 Emissions from China (%)

	2000	2025	2050			
			Case O	Case A	Case B	Case C
% of Global Carbon	15.7	16.7	27.3	23.8	20.6	17.4
% of Global Population	19.2	20.9	19.9	19.9	19.9	19.9

Case O: No nuclear energy; Case A: Low nuclear energy; Case B: Medium nuclear energy; and Case C: High nuclear energy

3 THE POTENTIAL OF NON-CARBON ENERGY SOURCES IN CHINA

3.1 HYDROPOWER

China has abundant hydropower resources. The total exploitable capacity amounts to 360 Gwe with an annual output of 1900 Twh. At present, China has exploited only 6 percent of its total capacity, despite the fact that mature hydro-technology is available and that, although capital investment remains high, the power cost is competitive.

Three major drawbacks serve to hinder the development of hydropower in China:

1) China's hydro resources are distributed quite unevenly.[11] More than 70 percent of China's total hydro reserves are concentrated far from the industrialized coastal provinces

[9] Z. Wu *et al*, *The Energy Demand of the PRC up to 2050*, Internal Report, Institute of Nuclear Energy Technology (INET), Beijing, China, 1988.

[10] Z. Wu *et al*, *The Energy Demand of the PRC up to 2050, op cit*, Ref. 9.

[11] Y. Lu, "The Important Role of Nuclear Energy in the Future Energy System of China," *Energy*, Vol. 9, No. 9-10, 1985, pp. 761-771.

in the nation's mountainous southwest regions. In particular, 26 percent of these resources are located in the distant regions of Tibet and the Yunnan Plateau. Thus, the construction of long-distance ultra-high voltage transmission lines necessary to access this capacity will require additional investment. Some of these hydrosources simply cannot be utilized.

2) Hydropower plants require higher specific capital and longer lead times than fossil power plants. In general, hydroplants require 50 percent higher investments than fossil power plants. In China, where both capital and power are short, the combination of these two factors serves to make hydropower less attractive to planners despite its lower operating costs.

3) The direct environmental impacts, such as the inundation of large arable land areas, the relocation of millions of people and the disruption of the ecological environment, introduce a wide range of controversies. These issues have led several major hydropower projects to be shelved for decades. For example, the construction of the Shanxia Dam across the Yangtze River has been delayed for the past decades as the various parties involved battle over environmental issues.

3.2 NUCLEAR ENERGY

The controversy over nuclear energy in China differs from the types of controversies nuclear power elicits in industrialized countries. Even taking into account the radioactive emissions from normally-operating nuclear power plants, nuclear energy is far cleaner than coal. In fact, due to the uranium and thorium contents in most varieties of coal, the amount of radioactivity generated into the atmosphere from coal-fired power plants far surpasses that from nuclear plants. As a result, many environmentalists in China advocate using nuclear energy instead of coal and the public is not hostile to nuclear installations. Consequently, the Chinese government has developed ambitious nuclear programs for providing electricity and supplying district heating to Chinese cities. Nonetheless, several major obstacles continue to hinder the full-fledged substitution of nuclear for fossil fuel energy in China.

1) Nuclear power presently lacks an "absolute" safety guarantee. China requires an "absolute" safety guarantee in the production of nuclear energy. While hundreds of nuclear power and heating stations could be built all over the country, the fate of this choice depends not only on the domestic safety record but also on the exogenous events of the global nuclear community. Events such as the Chernobyl or Three Mile Island disasters call today's nuclear technology into question. If another one of these catastrophes occurs anywhere in the world, nuclear energy based on present technology may fail to meet the safety standards. In this case, China will have to look for other alternatives. Before undertaking such a large-scale nuclear program, it is logical to look for an invulnerable design which can exclude the occurence of such accidents. The focus of current R & D efforts is on the development of an inherently safe reactor, either water use or gas coolant, which would provide the ideal energy choice.

2) Nuclear power plants are highly capital intensive relative to fossil fuel plants. This problem hinders the development of nuclear energy across the world. However, the high costs of nuclear power pose a particularly difficult challenge for China's rapidly developing economy. The specific cost of installed capacity of nuclear power plants exceeds the costs of conventional fossil plants in China by between 50 and 100 percent. As a result, the replacement of nuclear for coal sources would entail a serious financial penalty. A careful analysis indicates that the share of the reactor investment is already less than the turbo-generator and the auxiliary systems. When reactor systems achieve inherent safety, then the adoption of conventional quality equipment for the turbo-generator and auxiliary system may prove acceptable. The mass production of reactor equipment in factories also may help to reduce both the direct cost of field installation and the indirect cost caused by long lead times. Taking all of the above factors into consideration, the development of an "inherently safe and economic reactor" design appears feasible in the future of the Chinese nuclear program.

3) The controversy over waste treatment and disposal and the issue of non-proliferation continue to hinder the development of nuclear energy sources in China. China must face this unsolved issue in current technology if it plans to engage in large-scale nuclear development. Some preliminary work has been done in the reprocessing of the spent fuel and the vitrification of the high level waste. For example, by taking out the long-life actinides from the HLW, the present storage technology may be able to guarantee the safe storage of radioactive wastes for several hundreds of years and to reduce the radioactivity of shorter life isotopes to unharmful levels. However, further R & D must be carried out before the technologies involved in this process are put into commercial operation.

As to the issue of non-proliferation, China is one of the world's nuclear powers and is obliged not to use nuclear weapons "first." While the current world situation suggests that the probability of a nuclear war between the super powers is slight, local conflicts may trigger the acquisition and use of nuclear weapons on a smaller scale. Nonetheless, this issue has no relationship to nuclear energy development. Currently advanced technologies such as isotope separation (e.g. with centrifuges or laser lights) could produce fissile materials at a comparatively small scale without the need for the construction and operation of a commercial nuclear reactor. On the contrary, civil application of nuclear energy provides the best way to consume the dangerous fissionable material. The issue of non-proliferation can only be solved politically and need not entail the utilization of nuclear energy.

China's current nuclear energy program includes both nuclear power and heating reactors. The first prototype PWR is scheduled to be completed at the end of 1990. The French-designed 900 MWe commercial reactor will be on line by 1992. However, the domestic commercial reactor is still in the planning stage and the unit power level is 600 MWe, which is too small relative to the level of current energy consumption. The major limitation is the inability to manufacture the heavy components needed for PWR technology. On the other hand, the PRC has actively pursued the development of nuclear heat. The prototype 5 MWt district heating reactor started operation in November 1989, the commercial 200 MWt heating reactor in Jilin Chemical Company was approved by the SPC in 1990, and the prototype HTGR is in the planning stages. The application of more simple pool-type reactors is also under preparation.

3.3 SOLAR ENERGY

Solar radiation is plentiful in China.[12] Those regions with an annual average radiation level over 120 kcal/m^2 may find it economically-feasible to use solar energy collectors or photovoltaic cells. At present, China produces solar water heaters on a commercial scale. China has also disseminated solar stoves across its desert regions; over 100,000 units have been installed in Gansu province alone.

On a large scale, solar energy simply cannot compete with carbon-based fuels according to present costs and technologies. However, the potential for improved and less expensive solar devices exists. Several sites in Europe and the United States are involved in the large-scale demonstration of solar thermal power stations. This technology hopes to achieve the cost of 11 cents per KWh with current technology at a scale of 100 MWe. Photovoltaic technologies are also developing very fast. The highest efficiency with multi-junctions and with concentrators has reached 30 percent in experiments. At present, the cost equals 12 cents per KWh; in the next decade, the cost should be reduced to 6 cents per KWh. Extrapolating 4-5 decades into the future, there is reason to expect that solar electricity will become competitive in some parts of China and provide a sizable share of power for the national grid at a reasonable cost by 2050.

Another approach to utilizing solar energy in conjunction with environmental improvement is to plant fast growing trees or other energy crops. China has an ambitious afforestation program aimed at increasing its forest coverage from the current level of 12 percent to 18 percent by 2000 and higher in the next century. Such a program may help to solve the energy problem in China's vast rural regions.

3.4 OTHER RENEWABLE ENERGY SOURCES

Other renewable resources are distributed very unevenly across China and, therefore, only hold relevance on a local or regional level. Wind energy capacity exists in the prairies of Inner Mongolia and some of China's islands and the potential for geothermal energy lies in Tibet and several other regions. In the long run, if geothermal resources prove economically exploitable, the potential capacity for geothermal energy in China may be quite substantial.

4 CONCLUSIONS

In order to reduce its emissions of CO_2 from energy-related activities, China must further develop its use of non-carbon energy sources. Thus, China must make great efforts to develop

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[12] B. Wang *et al*, "Solar Energy Resources in China," *Acta Energia Solaris Sinica*, Vol. 1, No. 1, 1980, pp.1-9.

more advanced technologies some of which are not yet readily available on the commercial market. As a first step, China should exploit all of its available hydro resources. However, the further integration of hydropower into China's fuel mix will have only a minimal impact on China's total carbon emissions. The potential for nuclear energy lies in the development and commercialization of inherently safe and economic reactors. Solar energy, with its environmentally-benign characteristics, is still too costly and technologically underdeveloped. Until these new technologies reach maturation, carbon emissions from Chinese energy production and use will continue to rise steadily.

A METHODOLOGY FOR ESTIMATING COSTS OF CARBON REDUCTION FOR BRAZIL

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The cost of CO_2 abatement depends not only on the set of measures proposed to achieve the reduction of CO_2 emissions but also on the particular economic, demographic, political and/or other energy-related conditions within a given country. These "boundary conditions," which vary from country to country, have a major impact on the system of energy production and use in most developing countries.

Boundary conditions can refer to any of a number of circumstances including:

1) A nation or state's particular method of exploiting commercial energy sources;
2) the external control and/or development of energy management, distribution, production and use;
3) an enormous restrained demand;
4) demographic growth which necessitates the rapid expansion of a nation's water, road and sewage systems and health and housing services;
5) a particularly low level of investment capability; and
6) an extreme dependence on the industrialized countries to determine the nature of domestic policies.

In most developing nations, the manner in which these particular conditions are addressed will largely determine the success of efforts to reduce carbon emissions.

The introduction of new technologies entails both direct and indirect costs. In addition to the costs of technology development or transfer, many countries need to develop their infrastructure and fuel supply standards and management and change their appliance and building stocks.

A range of alternatives exist to save energy and reduce CO_2 emissions and a number of methodologies have been created to compare the specific costs of shifting from one technology to another. However, most of the existing methodologies assume constant boundary conditions. A methodology for calculating the costs of CO_2 reduction must be developed which incorporates changes in boundary conditions.

For example, an energy-saving motor requires fine voltage control. However, the condition of the electricity grids in most developing countries does not allow for such fine control. Thus, in order to use energy-saving motors in household appliances, the method of electricity distribution in the low voltage grid must be changed. This effort costs much more than developing a stock of energy-saving appliances or changing the stock of available appliances.

This methodology can only be used when the scenarios constructed identify energy consumption by particular end-uses. Using this information, the methodology can pinpoint the origin of energy and carbon savings.

One major difficulty exists when trying to carry out this kind of cost calculation: to identify the various boundary conditions all the proposals for reducing CO_2 emissions suggested in the scenarios thus far must be changed. Thus, perhaps the application of this more detailed methodology should be incorporated only in the construction of the most important CO_2-reducing propositions (i.e., the five highest measures for curtailing carbon emissions).

The first step of implementing this methodology entails identifying the set of measures proposed to limit carbon generation in a nation and determining the impact of these measures on the country. In order to carry out this procedure, one must recognize that carbon emissions emanate both from the demand and the supply side. For example, power generation emits about 30 percent of total CO_2 emissions in the United States and India while the use of cars generates about 10 percent of all emissions in the United States and Brazil. In order to limit the amount of CO_2 generated, not only should the efficiency of power production be improved, but additionally the level of electricity use should be limited on the demand side. Similarly, the key to reducing the level of CO_2 emissions from private cars may lie in improving the efficiency of fuel use in cars, restricting the use of cars and/or bettering the quality of the fuel consumed by cars and the condition of the roads on which these cars travel.

The second step involves identifying the improvements needed in the boundary conditions of a specific nation in order to achieve the level of CO_2 reduction proposed by a particular scenario. This process includes calculating the costs of both improving the boundary conditions and implementing the CO_2-saving measure.

Only by understanding the energy-related conditions in each particular developing nation will we come to understand the types of measures needed to reduce emissions of CO_2 and only by creating a more accurate and flexible system for estimating the costs of these measures will their implementation become a reality.

REDUCING CO_2 EMISSIONS IN SIERRA LEONE AND GHANA

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With soaring population growth rates and minimal economic growth, the nations of Africa are afflicted with innumerable problems. Why then should Africa's developing countries worry about CO_2 emissions? First, because agricultural activities form the backbone of most African economies; thus, these nations may be particularly vulnerable to the negative impacts of climate change. Second, acting to reduce carbon emissions will bring about more efficient energy use. All of Africa could benefit from the improved use of energy. Finally, the accumulation of CO_2 in the atmosphere is a global problem with individual solutions; in order to reduce international emissions, all countries, including those in Africa, must contribute.

Typical of many African countries, Ghana and Sierra Leone have among the lowest levels of energy demand per capita across the globe. Primary energy demand per capita in these two West African nations equals about one quarter of the world's average and about one twentieth of the United States' average. This work summarizes the results of two long-term energy use and carbon emissions scenarios for Sierra Leone and Ghana.[13] In the high emissions (HE) scenario for 2025, policy changes focused on galvanizing economic growth lead to significant increases in energy use and carbon emissions in Ghana and Sierra Leone between 1985 and 2025. In the low emissions (LE) scenario, the implementation of policies aimed specifically at curtailing CO_2 emissions significantly limits the increase in carbon in both nations by 2025.

Presently these two nations have among the highest rates of population growth and among the slowest rates of economic growth of all the study countries. By 2025, however, economic growth rates pick up. In contrast, population growth rates in Ghana and Sierra Leone drop due to: better family planning activities; improved education, particularly of women; and the increased economic growth.

While Sierra Leone and Ghana's residential sectors consume the largest share of the nations' energy supplies, their transport sectors produce the greatest portion of commercial energy-related carbon. The heavy consumption of biomass for domestic purposes limits the extent of the residential sector's carbon emissions. In contrast, the carbon-intensive nature of transportation leads to significant CO_2 emissions from this sector in both nations.

Shifts occur in all of the five sectors between 1985 and 2025. As a large number of rural residents drift to urban areas, appliance ownership and LPG and kerosene use increase in both nations. Cooking, which currently accounts for 97 percent of Ghana's residential energy use and 82 percent of Sierra Leone's household energy consumption, remains the dominant household

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[13] J. Sathaye and N. Goldman (eds), *CO_2 Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term, Volume IV: Ghana, GCC Countries, Nigeria and Sierra Leone, op cit,* Ref. 3.

energy end use. Although biomass' share in the residential fuel mix drops, biomass sources continue to provide the bulk of the household energy supply. In the transport sector, the vehicle stock -- of both old and new vehicles -- expands by 2025 and public transport improves. Both nations expand their industrial sectors as well. Agro-based industries grow and the mining sector continues to account for a substantial share of industrial energy use. Although energy demands for industry rise significantly, the industrial sector remains a relatively small energy consumer by world standards in 2025. The agriculture sector -- comprised mainly of manual and peasant labor -- and the service sector continue to absorb a minor share of Ghana and Sierra Leone's energy demand in 2025.

In both nations, biomass continues to comprise the majority of the national fuel mix in 2025. The shares of biomass do drop, however, and oil and electricity take on far greater roles (Table 1).

Table 1
Aggregate Energy Use (PJ)

	Ghana			Sierra Leone		
	1987	2025		1985	2025	
		High	Low		High	Low
Total	192	616	474	53	118	100
Oil	16%	27%	27%	25%	45%	46%
Biomass	78%	56%	54%	74%	51%	50%
Electricity	7%	17%	19%	1%	4%	4%

In both Ghana and Sierra Leone, carbon emissions increase more rapidly than energy consumption between 1985 and 2025 as the fuel mixes grow more carbon intensive. Currently, Ghana and Sierra Leone's transport sectors generate the largest amounts of carbon. By 2025, the share of Ghana's transport sector in total carbon emissions drops substantially and the residential sector becomes the premiere carbon-emitting sector. Industry's share of carbon rises from 8 to 18 percent in the HE scenario; the LE scenario reduces industry's share to 10 percent. Service's and agriculture's contributions to carbon emissions fall in both scenarios (Table 2).

Table 2
Carbon Emissions (Million Tons)

	Ghana			Sierra Leone		
	1987	2025		1985	2025	
		High	Low		High	Low
Total	0.64	4.42	2.74	0.32	1.20	0.95
Residential	15%	47%	51%	19%	28%	22%
Industrial	8%	18%	10%	15%	19%	20%
Transportation	59%	23%	27%	65%	52%	58%
Services	7%	5%	5%	1%	*	*
Agriculture	4%	*	*	*	*	*
Losses	6%	6%	6%	*	*	*

* Less than 1 percent

In Sierra Leone, transport continues to produce the nation's largest share of carbon in 2025. Residential activities, which currently account for about one quarter of the nation's carbon, comprise an increasing share in both scenarios. Like in Ghana, in Sierra Leone industry's share in carbon emissions expands over time. The agriculture and service sectors' shares of total emissions remain negligible in both scenarios (Table 2).

Policy measures to reduce carbon emissions in Ghana and Sierra Leone should focus on the residential, transport and industrial sectors. Improving the efficiency of energy use in the residential sector requires strong policies that emphasize the development of emissions standards for LPG and kerosene stoves. In the transport sector, these two nations can attain improved efficiencies by controlling the efficiency levels of the imported vehicle fleet. On the domestic front, the governments need to investigate the potential for setting pollution standards, regulating the composition of the future vehicle fleet and improving the nations' road systems. In the industrial sector, by switching from modern fuels to biomass, emissions can be reduced. Currently the palm produce and forestry industries in these nations have begun using biomass residues to generate electricity. The government should continue to encourage this transition.

To promote carbon reductions in Ghana and Sierra Leone, the focus should not be on climate change. Instead, limiting carbon emissions should be linked to the idea of sustainable economic development in African countries. Only when the focus shifts to regional issues does the reduction of CO_2 emissions take on meaning for the African countries.

IMPORTANCE OF ENERGY EFFICIENCY IN VENEZUELA

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Venezuela's economic development relies heavily on oil. The nation's energy production equals 3.5 million barrels of oil equivalent (boe) per day. Oil comprises 71 percent of the energy Venezuela produces, natural gas 20 percent, hydro 9 percent and coal 1 percent. Of the energy produced, Venezuela exports three quarters and consumes the remainder. Over 99 percent of Venezuela's energy exports are crude oil and oil products.

Venezuela has substantial energy resources. They include: 60 billion barrels of conventional crude oil; 240 billion barrels of extra heavy oil/bitumen; 120 trillion cubic feet of natural gas; 7 billion tons of coal; and 83 megawatts of hydropower. The nation's population of 18 million inhabits an area of 960,000 square kilometers. Industry consumes 58 percent of Venezuela's energy, transportation accounts for 32 percent and the residential and service sectors combined absorb 10 percent.

Economic problems have constrained Venezuela's development in recent years. Saddled with an external debt of $US 32 billion, Venezuela will continue to encounter barriers for years to come. The nation is, however, in the process of restructuring its economy. As part of this process, the Venezuelan government has begun to integrate opportunities for improving the efficiency of its energy use.

As a major oil producer and exporter, Venezuela is conscious of its responsibility to the international community to limit its emissions of energy-related CO_2 into the atmosphere. For this reason, the Venezuelan government is in the process of creating a program to conserve and ration the use of energy. This effort incorporates a number of measures including the substitution of natural gas for liquid fuels for all end uses (including transportation activities), the increased reliance on hydropower in the generation of electricity and the reduction of waste in the production of natural gas to 2 percent of the economically recollectable volume.

POLICIES TO REDUCE CARBON EMISSIONS FROM MEXICO

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The two long-term scenarios carried out for Mexico attempt to paint a picture of carbon emissions and energy use in the year 2025.[14] The scenarios reveal that Mexico's current energy path is not optimal; the energy-intensity indicators show an increasing reliance on petroleum products and electricity over the next 40 years. Thus, Mexico must embark on a program of energy conservation in the near future.

Mexico recently has undertaken several energy conservation efforts. The Mexican government implemented a National Program for Energy Modernization. This program identifies the promotion of energy conservation in Mexico as one of its top priorities between 1990 and 1994. It incorporates a number of actions geared at improving energy conservation, including: establishing pricing policies which pay special attention to electricity tariffs; setting aside budget appropriations for energy-savings programs; carrying out an energy diagnosis in the transportation and industrial sectors; promoting cogeneration and new legislation in this field; setting efficiency standards for equipment; initiating a public education campaign to inform people about energy conservation; promoting the participation of research institutes and consulting firms in the research of the technological aspects of energy-saving measures; and creating agreements with industrial and commerce associations.

In September 1989, a cabinet of Mexican ministry directors -- headed by the Secretary for Energy (SEMIP) and including Finance and Public Credit, Commerce and Industrial Promotion, Transportation and Communications, Urban and Environmental Development, Public Education, Budget and Programming and the Federal District Department -- in collaboration with the state-owned energy enterprises (PEMEX and CFE) established the National Commission for Energy Conservation (CONAE). CONAE serves as the public consulting unit in charge of the public energy conservation programs, as the coordinator of efforts in states and municipalities and as the public advisor on energy conservation matters. Last month the Commission stated the following as its main objectives:

1. To improve Mexico's energy supply;
2. To support industrial modernization;
3. To help consumers choose efficient equipment;
4. To reduce the environmental impacts of energy production and distribution;
5. To promote international technological exchange; and
6. To preserve the role of non-renewable energy resources.

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[14] A. Ketoff, J. Sathaye and N. Goldman, *CO_2 Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term, Volume II: Argentina, Brazil, Mexico and Venezuela, op cit*, Ref. 3.

In several ways, the outlook for CONAE appears positive. Mexico's Budget and Programming Ministry already has integrated an energy-saving appropriation into the 1991 budget. In addition, credit mechanisms have been created to support CONAE's work. However, CONAE still faces a number of obstacles. Notably, CONAE has limited access to the adjustment of pricing policies and insufficient fiscal support.

The private sector has contributed as well. For example, Philips Mexicana, a Mexican company, has a staff working on energy savings. Their Technical Assistance Division has developed three broad programs geared towards conserving the use of electricity for lighting. The programs, directed at energy consumers, include: PANACEA, in the residential sector; HORECA, aimed at hotels, restaurants and coffee shops; and INCOM, targeted at the industrial and commercial sectors. In addition, Philips Mexicana is working with several public entities, including SEMIP, to promote and research new technology implementation. Philips also has supported several demonstration projects, which entailed giving 2000 free lamps to people living in certain Hermosillo and Puebla zones, and has begun carrying out studies about the feasibility of financing compact fluorescent lamps. The major problem encountered by these programs is that people tend to be suspicious of Philips' motives: why would a private company geared towards maximizing its own benefits try to promote a social project? Additionally, consumers often require greater financial assistance than is currently available.

In concordance with CONAE's policies, there is a special program within the electricity company called PAESE, the Electricity Sector Energy Savings Program. PAESE has identified two major goals to be achieved by 1994:

1. To generate, transmit and distribute electricity at lower cost and with lower primary energy consumption; and
2. To optimize electricity use, in the production of goods and services as well as in its final end use.

PAESE has undertaken a number of actions to carry out these objectives. In the same spirit, the petroleum state company (PEMEX) has a program directed at it main operative areas.

The concept of energy conservation is relatively new to Mexico and, for a number of reasons, the implementation of conservation strategies in Mexico may prove difficult: Mexico has had very little experience in energy conservation; the nation has limited financial resources to devote to improving the efficiency of energy use; the coordination between the entities responsible for energy remains quite poor; and the prices of energy-consuming products remain low. This situation is in the process of changing due to the implementation of government policies aimed at opening the nation's economy and thereby encouraging industries to invest in new technologies. Some consulting companies that deal with energy-savings recommendations have oriented their analysis only to the electrical system, however; there continues to be a general lack of knowledge about the heat transfer and combustion processes.

IMPROVING ENERGY EFFICIENCY IN NIGERIA

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I. Background

Despite its huge population of about 100 million people, Nigeria consumes a relatively small share of the world's energy. GDP per capita equalled about US$ 800 in 1985. Agriculture accounts for the largest portion of GDP, at around 40 percent, followed by services with 31 percent, industry with 25 percent and transport with 4 percent. Unlike most other African nations, Nigeria has abundant energy sources. Recent estimates assume that Nigeria has about 16 billion barrels of oil, 30 billion barrels of oil equivalent (boe) of gas and 3 billion boe of coal.

The results of two long-term energy use and carbon emissions scenarios for Nigeria indicate that between 1985 and 2025, Nigeria's energy consumption will rise substantially as both population and economic growth rates soar.[15] While biomass consumption drops markedly over the observed time period, gas and oil consumption witness significant increases. Coal and solar power also account for increasing shares of Nigeria's energy supply in the coming four decades. Hydro's share in energy use remains stable (Table 1).

Table 1
Aggregate Energy Use (PJ)

	1985	2025	
		High	Low
Total	1345	3292	2617
Coal	1%	4%	4%
Oil	28%	50%	44%
Natural Gas	2%	7%	15%
Biomass	69%	29%	26%
Electricity	2%	10%	11%

II. Options for Reducing CO_2 Emissions

A number of options exist for reducing CO_2 emissions in Nigeria:

1. **Increase Natural Gas Utilization.** Nigeria has a large natural gas resource base. At present, however, about 80 percent of all natural gas is flared. By increasing the utilization of these wasted gas resources, Nigeria could expand

[15] J. Sathaye and N. Goldman (eds), *CO_2 Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term, Volume IV: Ghana, GCC Countries, Nigeria and Sierra Leone, op cit*, Ref. 3.

its energy supplies substantially.

2. **Improve Energy Efficiency**. First, many opportunities exist for cutting waste in Nigeria. In the refining and cement industry about 25 percent of the fuel inputs are wasted. Households use fuelwood very inefficiently. The chaotic traffic situation in Nigeria's major cities also leads to substantial fossil fuel wastage. Second, Nigeria can pursue a more energy-efficient development path. Efforts in this realm would include emphasizing mass transit over private automobile modes and encouraging appropriate building designs.

3. **Increase the Use of Renewables**. The potential for increasing the share of solar and mini- and micro-hydro power in Nigeria has yet to be developed.

III. Barriers to Reducing CO_2 Emissions

Various barriers inhibit the success of each of the options. At present, most Nigerians lack the awareness of the great potential that improved energy efficiency can offer. Overall, the Nigerian perception about energy promotes the use of all the indigenous natural gas and oil supplies in the present; Nigerians tend not to worry about their energy future. Nigeria also lacks the skilled indigenous manpower necessary to implement these options. Financial constraints hinder shifts in current energy use patterns. Transporting natural gas, for example, requires the construction of very expensive pipelines. The lack of a suitable institutional infrastructure to deal with energy issues and Nigeria's weak technological base hinder the development of these alternatives. Improvements in energy efficiency and greater natural gas utilization are further limited by the inefficiency of energy pricing, the lack of awareness of the potential for waste reduction and the scarcity of alternatives due to supply constraints.

POTENTIAL BENEFITS OF A LARGE-SCALE EFFICIENT LIGHTING PROGRAM IN MEXICO

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Mexican industries absorb the largest portion of the nation's electricity supply by far. Industry consumed 57 percent of the nation's electricity in 1989. Over the past 15 years, however, electricity use has increased more rapidly in the residential sector than in the industrial or any other Mexican sector. Between 1975 and 1980, household electricity consumption grew by 10.6 percent per annum. These growth rates slowed down in the early- and mid-1980s. However, the 1988-89 increase in household electricity consumption of 11.8 percent surpassed even those of the 1970s. A 40 percent drop in appliance net prices, due to the liberalization of imports since 1987 and an incremental growth in salaries in the middle and upper social strata, has helped facilitate this recent growth.

In 1975, the average Mexican home consumed 80.7 kWh of electricity per month. By 1989, the average Mexican household consumed 117.8 kWh per month. Most of the growth occurred in high-income households.

As a result of the growth, Mexico's residential sector has come to account for an increasing share of the nation's electricity use. In 1975, Mexican households accounted for 17.6 percent of the nation's electricity consumption. By 1989, homes accounted for 21.2 percent. Agriculture and services combined consumed 17 percent of Mexico's electricity in 1989.

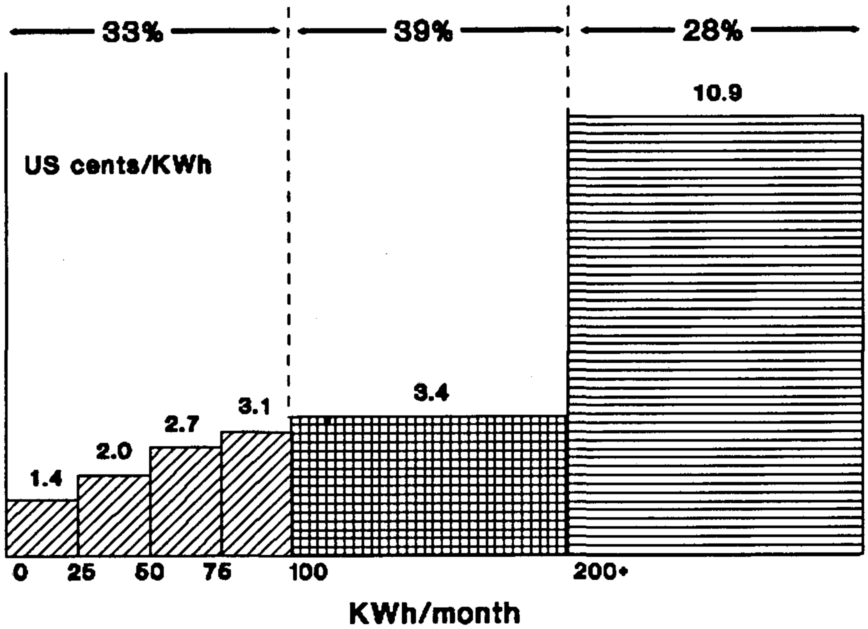
Residential energy prices dropped considerably over the 14-year time span. Residential energy prices averaged about 4.8 cents/kWh in 1975 (Table 1). By 1989, household energy cost only 3.3 cents/kWh. Present pricing policies entail that the more electricity a household consumes the higher the cost for each kWh. Today, prices for electricity remain quite low for households consuming between 0 and 200 kWh per month, showing only minor price increases for increased consumption. Just under three quarters of the Mexican population consumes under 200 kWh of electricity/month. However, 28 percent of Mexican households consume over 200 kWh/month. Prices soar for these high energy users. Each kWh above the 200 kWh/month threshold costs at least three-fold the highest price under 200 kWh/month (Figure 1).

Table 1
Household Electricity Consumption and Prices

Year	Average Household Elec. Consumption (kWh/Month)	Average Electricity Prices (1975 Pesos/ kWh)	(U.S. cent/ kWh)	Average Total Energy Prices (US cent/kWh)
1975	80.7	1.00	4.8	2.9
1980	102.7	0.75	5.1	4.0
1985	108.6	0.59	3.9	3.5
1988	110.3	0.53	3.6	3.8
1989	117.8	0.44	3.3	4.2

Figure 1

Mexican Electricity Pricing



Lighting accounts for between 30 and 37 percent (or 5700-7000 GWh) of household energy consumption. For this reason, Mexico has begun focusing on the potential for reducing energy use for lighting -- and particularly on the substitution of compact fluorescent for incandescent bulbs. Preliminary studies suggest that the replacement of a single 60 watt conventional incandescent bulb for a 15 watt compact fluorescent would allow for the generation of slightly higher light output, would last significantly longer and ultimately, would bring about a savings of about 1.7 US cents per kWh.

The implications for promoting these substitutions in Mexico on a wide-scale appear impressive (Table 2).

Table 2
Impact of Substituting 25 Percent of Actual Installed Conventional Lamps in Mexico with Compact Fluorescents

Conventional Lamps (Watts)	Quantity of C.F. (Mns)	Annual Energy Savings/Lamp[a] (kWh/yr-lamp)	Annual Cost/Lamp[b] (US$/yr)	Total Energy Savings (GWh/yr)	Total Cost C.F. (US$ Mn)	Generation Cost[c] (US$ Mn)
40	1.6	45.3	1.3	72	2.1	7.2
60	4.8	65.7	1.3	315	6.2	31.5
75	2.4	99.3	2.0	238	4.8	23.8
100	6.4	119.7	3.1	766	19.8	76.6
Total	15.2	---	---	1391	32.9	139.1

[a] 4 hours of daily use; [b] Gas turbine; [c] 75 percent of retailing

Table 2 indicates that by replacing one quarter of Mexico's conventional lightbulbs with compact fluorescents, a total energy savings of 1361 GWh can be achieved each year. The table also reveals, however, that the initial costs of undertaking such a large-scale substitution would be substantial.

AN ANALYSIS ON POSSIBLE EFFECTS OF IMPLEMENTING ENERGY POLICIES TO REDUCE CARBON EMISSIONS ON THE INDONESIAN ECONOMY

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1 INTRODUCTION

Growing concern about the accumulation of CO_2 in the atmosphere and its linkages to global warming have led to intensified efforts aimed at finding ways to control and suppress emissions of CO_2 and CO_2 precursor gases.

The concerns about energy-related carbon emissions have led to different types of responses in industrialized and developing countries. In the industrialized countries, efforts primarily have focused on reducing energy consumption per capita and promoting the use of fuels which are less damaging to the environment. In the developing world, most nations will continue to experience increases in energy consumption per capita in coming decades, due to their presently low consumption levels. In these nations, a different path of development must be pursued which focuses on reducing excessive energy use and avoiding environmentally-damaging energy use and energy-related technologies.

This paper presents an analysis of the possible effects of policies geared at improving energy efficiency and promoting the use of less carbon-intensive fuels in Indonesia. The analysis begins with a description of the salient features of Indonesia's economic structure, energy use patterns and demography to provide a background for understanding the nature of the problem. The paper then goes on to provide two base case scenarios for Indonesian energy use in the year 2020. The first scenario (the export scenario) describes the behavior of the system in response to a continuation of the export policy paradigm currently being pursued. The second scenario (the export + technology scenario) augments the export policy with measures aimed at relieving the strong dependence on externally-acquired capital goods by enhancing domestic technology capabilities. In the process, this scenario develops the linkages between agriculture and industry.

The modeling process also involved imposing an additional set of environmentally-motivated policies onto each of the base case scenarios to investigate the impact on efforts to reduce carbon emissions. The policy scenarios incorporate the following actions:

1. Energy prices are deregulated, as opposed to the regulated prices that apply to the base scenarios;
2. Disincentive measures are applied towards the use of more carbon-intensive fuels; and
3. Mechanisms for retrofit of capital for energy intensity adjustments are allowed to take place, while in the base case scenario such mechanisms are not accommodated.

The system's responses are compared to observe the effects of the different policy paradigms on: GDP, population growth rates, energy consumption patterns, energy price changes, energy intensity, the fuel mix and consequent levels of CO_2 emissions.

2 AN OVERVIEW OF THE ECONOMIC SETTING

Over the past 20 years, Indonesia's oil and gas export earnings have largely influenced the growth pattern of the national economy. Oil and gas have not only dominated the energy supply, but also have played a determining role in generating foreign exchange and government revenues.

Mainly as a result of higher oil prices on the international market, Indonesia experienced relatively high economic growth in the 1970s. However, due to the considerable drop in oil prices later that decade, economic growth rates fell to around 2-3 percent between 1981 and 1985. Beginning in 1983, the government undertook a series of economic reforms directed at developing the export of commodities from the agricultural, forestry and manufacturing sectors. As a result, revenues from non-oil and non-gas exports rose steadily. In 1987, revenues from non-oil and non-gas commodities surpassed those from oil and gas commodities.

Indonesia's economy depends heavily on export earnings. Purchases of capital goods and other major industrial inputs comprise about 80 percent of Indonesia's imports. While revenues from the export of non-oil and non-gas commodities has exceeded those from exports of oil and gas, the expenses for imports of non-oil and non-gas products remain higher than the revenues of these commodities. Foreign exchange revenues from export are an absolute necessity for acquiring the necessary flow of technology in the form of capital goods, other commodities for industrial inputs and technical services.

The structure of Indonesia's industry and the technological base to support industrial development are basically very weak. Recently the government has begun to consider the incorporating the enhancement of Indonesia's technological capability into the development process. In addition, the Indonesian government has begun to pursue the development of stronger linkages between the agricultural and industrial sectors. This last approach also may help to increase the personal incomes of the majority of the population, who earn their incomes through agricultural activities. In turn, such a development may serve to strengthen the domestic market.

3 AN OVERVIEW OF THE ENERGY SETTING

Besides having a dominant role in Indonesia's economic development, oil also dominates the supply and consumption of energy in Indonesia. For the past four or five years, however, the use of coal has accelerated. The production levels for both domestic supply and exports have also increased rapidly. Relative to the size of the domestic energy supply, however, the amount of coal being produced today remains quite small.

Table 1 provides an overview of Indonesia's energy resources. In view of the known level of Indonesia's resources and reserves, the scenarios imply that within 15 to 20 years the nation will be forced to become a net importer of oil in order to satisfy its heightened demand for petroleum products. Natural gas and coal then may become the nation's dominant energy resources. With the increasing environmental actions, the rate of domestic natural gas consumption and exports is be expected to remain high. This trend may serve to hasten the depletion of the natural gas resources.

Table 1
Energy Resources of Indonesia

Resource	Amount
Oil	48.4×10^9 barrels
Natural Gas	216.8×10^{12} SCF
Coal	28.3×10^9 tons
Hydro	75000 MW
Geothermal	10000 MW
Uranium	Indicated
Peat	200×10^9 tons
Wind	Prospective
Biomass	85×10^6 hectares of forest and agro- and silviculture wastes

If the above transitions do occur, then coal will become the major domestic energy source in Indonesia within the next three to four decades. The share of new and renewable energy resources will also grow, but the amount of energy that can be delivered by renewables will be far from adequate. Unless better technological schemes are undertaken to utilize coal, the effect will be contrary to efforts to reduce CO_2 emissions.

4 CURRENT ACTIVITIES TO REDUCE CO_2 EMISSIONS

No clear and concrete policy dealing specifically with CO_2 emissions has taken shape in Indonesia. Various targeted policies which indirectly contribute to reducing emissions, have been implemented, however, although most of these were created for other, non-environmental purposes. These include:

1. In forestry, mainly due to international pressures, various activities are underway including: reforestation programs, the designation of forest areas as protected forest and the enforcement of selective cutting procedures in forest exploitation;

2. Efforts to reduce the flaring of gases from oil and gas fields, oil refineries and major natural gas-consuming chemical industries are taking place. The current level of flared gas from oil and gas field equals 7 percent of the total gas production;

3. In power generation, there is a set ceiling in the use of coal for installations located in Java. Furthermore, new plans for power generation are based on the use of natural

gas in combined cycle systems;

4. Conservation measures, a long-standing component of the general energy policy in Indonesia, are also gaining momentum, namely in energy-intensive basic industries such as steel, cement, fertilizer, ceramics and certain non-ferrous metals.

In addition to the previously outlined conservation measures, a number of externally-initiated projects and studies are also underway such as the USAID-sponsored project for setting up standards for building energy conservation measures and the World Bank-sponsored project on financing schemes for small-scale energy users (jointly funded by the governments of the Netherlands and the United States). The Department of Mines and Energy is also preparing for the implementation of a more effective nationwide energy conservation campaign.

5 SCENARIO DESCRIPTION AND RESULTS

With reference to the past development trends described above, a systems dynamics model of the economy, energy and demography of the country was built. Four scenarios were developed based on this analysis.

In conducting the simulation experiments, the following common assumptions were used:

1. US$ inflation rate after 1983 averages 3 percent;
2. The exchange rate of the US$ with respect to "rupiah" (Indonesian currency) increases by 5 percent per year;
3. The "rupiah" inflation rate average 8 percent per annum;
4. Government expenditures after 1984 equal 15 percent of GDP;
5. The industrial technology index of the industrialized countries increases at a rate of 15 percent per year after 1984; and
6. The agricultural technology index of the industrialized countries increases at a rate of 1 percent per year.

The results of the scenarios indicate that through the implementation of pricing policies, Indonesia can curtail the growth of future CO_2 emissions without hurting the nation's general economic performance. The imposition of energy policies onto the base case scenarios results in only a slight depression in the GDP growth rate over the next three decades. In addition, the policy scenarios achieve lower energy intensities (energy use per unit of GDP) than do the base case scenarios. Due to the deregulation of energy prices and the taxation on fossil fuels, energy prices in the two policy scenarios surpass those in the base case scenarios. As a result, the nature of the fuel mix in the policy scenarios is less carbon intensive, relying more heavily on geothermal and hydro energy than do the base case scenarios. The two policy scenarios have a considerable impact on lowering fossil fuel-related carbon emissions beyond the base case levels.

CARBON EMISSIONS FROM THE PERSIAN GULF COUNTRIES

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The wealth of indigenous oil resources has largely determined the economic and energy use patterns in the member countries of the Gulf Cooperation Council (GCC). Sizable profits accrued from the inflation of world oil prices spurred tremendous economic growth across the Gulf during the 1970s. The GCC nations channeled this oil wealth into the rapid development of infrastructure and the creation of super-welfare states. Today, these highly affluent societies enjoy benefits ranging from free medical care, schooling and housing to subsidized electricity and gasoline supplies.

The combination of great personal prosperity, abundant petroleum resources and highly subsidized energy prices has led to excessive energy use in the Gulf nations. These countries consume among the highest amounts of energy per capita in the world. Correspondingly, these nations generate among the highest levels of energy-related carbon per capita.

The following are some of the major results on energy use and carbon emissions in the GCC region for the year 2025.[16] In the high emissions (HE) scenario, the GCC governments promulgate policies between 1985 and 2025 focused primarily on promoting greater economic growth, irrespective of the potential environmental hazards. In the low emissions (LE) scenario, the GCC governments take direct measures to reduce the amount of carbon generated from energy use.

Table 1
Delivered Energy and Carbon Emissions

	Energy Demand (EJ)			Carbon Emissions (Million Tons)		
	1985	2025		1985	2025	
		High	Low		High	Low
Total	2.2	15.4	13	62	402	328
Residential	11%	11%	11%	21%	18%	19%
Industry	38%	39%	43%	29%	29%	31%
Transport	38%	31%	28%	26%	23%	22%
Agriculture	4%	11%	11%	5%	13%	13%
Services	9%	8%	7%	13%	11%	10%
Losses	---	---	---	6%	6%	6%

In 1985, the total population of the GCC equalled about 16.3 million. The population size increases four-fold over the next four decades. This region possesses 40 percent of the world's oil reserves and 15 percent of global natural gas reserves. Oil and gas production dominate the

16 J. Sathaye and N. Goldman (eds), *CO_2 Emissions from Developing Countries: Better Understanding the Role of Energy in the Long Term, Volume IV: Ghana, GCC Countries, Nigeria and Sierra Leone, op cit*, Ref. 3.

GCC economies. The mining industry also accounts for the largest portion of the nation's energy use at present and continues to in 2025 (Table 1).

By 2025, GCC energy use increases substantially. Oil consumption accounted for just under three quarters of the energy used in the GCC in 1985. By 2025, oil's share drops to 63 percent in the HE scenario and 60 percent in the LE scenario. In both instances, the shares of natural gas and electricity use expand.

Carbon emissions rise from 62 million tons to 402 million tons in the high emissions scenario and to 328 million tons in the low emissions scenario. Thus, while the LE scenario achieves significant reductions in CO_2 emissions below the HE level, in both scenarios the increases from 1985 and 2025 are dramatic (Table 1).

Historically, several factors have led to over-consumption of energy in the GCC region. By tackling the following issues, the GCC countries can reduce future energy demands and, thus, reduce their carbon emissions:

1. The absence of emissions standards and the failure to enforce existing standards. The GCC countries import cars, appliances and building materials from every corner of the world with no consideration for energy efficiency. Building codes in the GCC are obsolete. While most of the nations take city planning into account, few incorporate energy efficiency into this process.

2. The under-utilization of power plants. By improving maintenance, the efficiency of power generation could be increased.

3. The lack of incentives. The GCC nations over-subsidize energy prices, thereby promoting over-consumption. The governments of both Saudi Arabia and Kuwait tried to increase electricity prices in the past, but these efforts failed due to public pressure. In both of these cases, the governments approached the pricing issue poorly. The motivation for increased energy prices in the past stemmed from the need for greater revenues. In the future, these measures should represent efforts to reduce waste.

4. The lack of public awareness. The members of the GCC population lack an awareness of energy and environmental issues. The dearth of incentives to save energy and the absence of standards contribute to this ignorance.

A decade ago, the Iran-Iraq war posed a major threat to the GCC nations. At present, the Iraqi invasion of Kuwait represents the GCC's greatest challenge. This crisis certainly will leave a firm imprint on the regional economies and will alter the development paths in the GCC. While the GCC states are likely to sustain their welfare measures and their present levels of affluence, the Iraqi invasion of Kuwait may result in more emphasis on productivity and incentives to achieve such productivity across the Gulf region. Such a change would have a positive impact on reducing both energy consumption and CO_2 emissions in the GCC. Only upon the resolution of this conflict, however, will the full impact on energy demand and CO_2 be understood.

POTENTIAL FOR TECHNOLOGY TRANSFER

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Developing countries need energy to raise productivity and to improve their living standards. Yet supplying energy to achieve these goals, with the current patterns of production and use, raises serious problems -- financial, institutional and environmental. The magnitude of these problems underlines the need for more efficient and sophisticated production, conversion, delivery and use of energy in developing countries.

The consumption of commercial energy -- coal, oil, gas and electricity -- in the developing countries could triple by 2020. The absolute amount of "traditional" or biomass fuels consumed will rise considerably as well. While energy consumption per capita in the developing world will continue to lie far below consumption per capita in industrialized countries in coming years, the share of the developing countries in world commercial energy consumption will rise from 23 to 40 percent over the next three decades. Among the factors contributing to this rapid increase are: population growth, rising living standards and growing and changing consumer demands.

At the Office of Technology Assessment (OTA) we are currently evaluating ways of better providing energy services for development, including incorporating better technologies (more efficient consumer appliances, industrial processes and transport systems, as well as new and improved energy supply systems) and improving the institutional and policy mechanisms that determine their rate of adoption. Based on this analysis, OTA will examine the role of the U.S. government in promoting the transfer of improved energy technologies to developing countries.

The technology transfer process involves many actors. These include: government departments, international organizations, trade and industry, private voluntary organizations, research establishments and universities. These institutions work through a number of channels, such as financing, technical assistance, debt negotiation, technical exports and research and development. The matrix provided in Table 1 tries to identify which institutions are involved in the different activities.

Many opportunities exist for improving the efficiency of energy production and use in developing countries. Raising these efficiencies could moderate the expansion of energy services while still providing the energy services needed for development. However, the importance of factors other than technology also must be recognized in securing energy efficiency improvements. Rational decisions made in a complex maze of regulatory and economic incentives and disincentives often lead to "inefficient" results. A close examination of the technology transfer process may help to eliminate some of the barriers that currently hinder the integration of more efficient and environmentally-sound energy production and use in the developing world.

Table 1[17]
Channels of Influence

SELECTED ACTORS	CHANNELS									
	Financing			Tech.	Training/	R&D	Licens-	Debt.	Advice,	Int'l
	Bil.	Multi.	Priv.	Exports	Tech Asst.		ing,etc.	Neg.	Studies	Coop.
Gov't Dept.										
AID	X				X				X	X
DOE						X	X		X	
EPA									X	
Commerce				X				X		
Treasury								X		
State										X
Int'l Orgs.										
World Bank		X			X				X	X
UNEP					X				X	X
IDB		X			X				X	X
Trade/Industry										
G.E.			X	X		X	X			
Spire Corp.				X	X	X	X			
PGE			X	X						
US Counc. on Ren. En.				X						
Ex-Im Bank				X						
Enron			X				X			
OPIC			X							
PVO's, etc.										
VITA			X		X				X	
Conserv. Int'l					X			X	X	
Foundations			X		X				X	
Research, Univ.										
NAS-BOSTID							X		X	
U. of Penn.					X					
National Labs									X	

17 This matrix is based upon our preliminary perception of the activity of each agency and will be amended as our study progresses.

BARRIERS TO REDUCING CARBON EMISSIONS IN EASTERN EUROPE AND THE SOVIET UNION

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The Soviet Union and Eastern Europe accounted for 27 percent of global carbon emissions in 1986.

While the recent opening of the formerly "planned" economies offers a number of opportunities to improve the efficiency of energy use in these regions and reduce their energy-related carbon emissions, various barriers hinder changes in Eastern European energy use:

1. Lack of Incentives. People living in these regions often still lack the economic incentives to improve energy efficiency; this faltering incentive largely stems from the long-time subsidization of energy prices. To surmount this obstacle, energy sources should be subject to market pricing. This change in policy would require market pricing of Soviet oil and gas and Polish and Czech coal.[18]

2. Insufficient Infrastructure. These nations lack much of the equipment necessary to improve efficiency. Most of the formerly planned economies do not have updated technologies, such as meters, materials and motors. In terms of services, this region generally lacks the banking, communication, maintenance and consulting services necessary to improve efficiencies. Overcoming this barrier will require investment from the private sector, the World Bank, joint ventures or other funding sources. New private companies may have the incentives necessary to improve the efficiency of energy use.

3. Scarce Human Resources. The Soviet Union and the rest of Eastern Europe have numerous problems competing for priority. Issues such as macroeconomic reform and inflation control often take the limelight pushing energy efficiency into the background. The solution to these problems will require incorporating energy efficiency into future plans for macroeconomic reform, environmental protection and inflation control. On-the-job training can educate more people to work towards improved efficiency without sacrificing immediate action. Western "assistance" may fail to actually help the Soviets and Eastern European nations improve energy efficiency because aid organizations often offer tied aid and show biases towards the electric sector.

4. Heavy Reliance on Low Quality Fuels. The formerly planned Eastern European economies draw the bulk of their energy from low quality, carbon-intensive fuels. Because of the plethora of these cheap indigenous, but inefficient, resources, successfully

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[18] These countries have taken steps toward market pricing since the workshop.

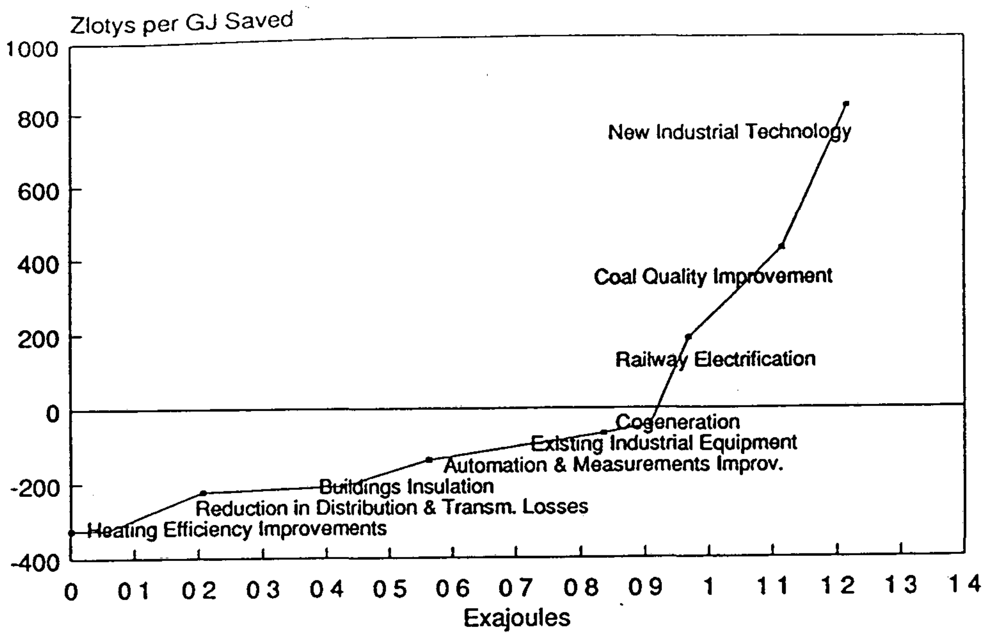
promoting more expensive, less accessible energy sources proves difficult. The Polish fuel mix exemplifies the carbon-intensive nature of energy use in Eastern Europe. Poland consumed 5.8 exajoules of energy in 1988. Coal provided 75 percent of this energy, oil 18 percent and natural gas 7 percent.

Energy intensity (MJ/$ 1980 of purchasing power parity) in the Eastern European countries far surpasses the estimated energy intensity in the United States and Western Europe. However, substantial potential exists for improving the efficiency of energy use in these regions as displayed in Figures 1 and 2 for Poland and the Soviet Union.

Battelle, Pacific Northwest Laboratories has recently established energy efficiency centers in Warsaw and Prague. These two centers share the twin goals of galvanizing economic development while simultaneously improving environmental protection. They mean to achieve this purpose by promoting efficient energy use through: policy analysis and support; model efficiency standards; joint venture promotion; loan package development and least-cost utility planning. The centers are staffed by Polish and Czech professionals. Not only do U.S. experts also come for extended visits to work at the centers, but in addition, the Eastern Europeans come on exchanges to the United States. After three years of this process, these centers should be self-sustaining.

Figure 1

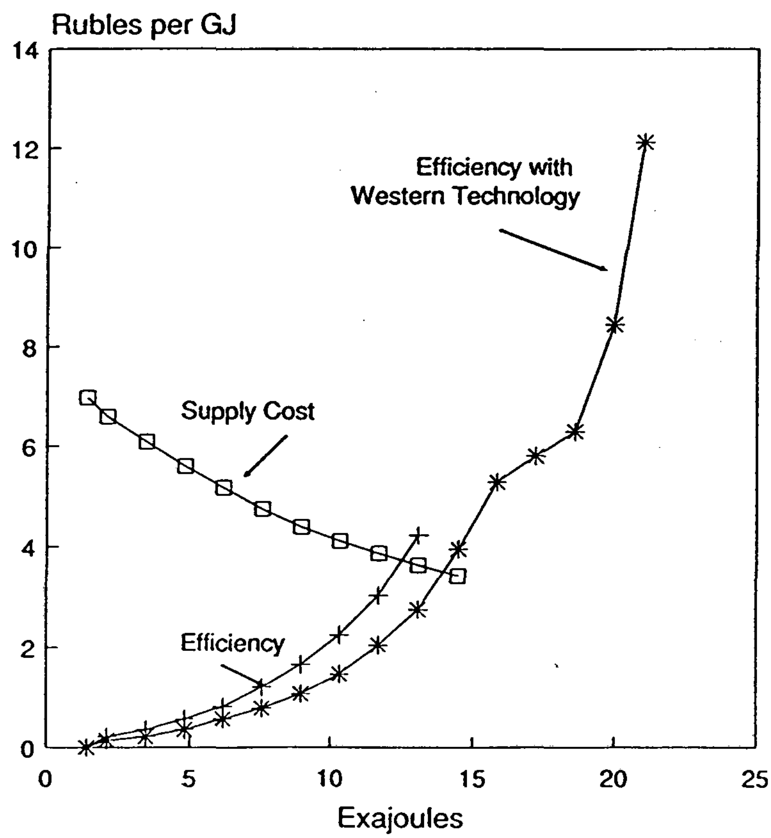
Polish Energy Efficiency Supply Curve



SOURCE: Stanislaw Sitnicki et al

Figure 2

Soviet Efficiency Potential by 2010
Shadow Supply Cost vs. Efficiency Cost



SOURCE: Energy Research Institute of
the USSR Academy of Sciences