Energy Efficiency, Developing Nations, and Eastern Europe

A Report to the U.S. Working Group on Global Energy Efficiency

Mark D. Levine, Ashok Gadgil, Steven Meyers, Jayant Sathaye, Jack Stafurik, and Tom Wilbanks
ERRATUM, p.3: in the sentence beginning, "As shown in Figure iii," in major finding number 9, two different findings are mistakenly combined. The full distinction should read, "As shown in Figure iii, this represents a reduction of about 70 quads per year in the developing nations and Eastern Europe. When this is combined with efficiency gains in the OECD countries, it yields a reduction of 150 quads per year, equivalent to more than half of current world energy consumption!"

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ENERGY EFFICIENCY, DEVELOPING NATIONS, AND EASTERN EUROPE

A Report to the U.S. Working Group
On Global Energy Efficiency

June 1991

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EXECUTIVE SUMMARY

Energy literally fuels the global economy, securing humans a steady flow of goods and services. Without energy, prosperity would cease, economic development would come to a grinding halt, and the very survival of humanity would be threatened. Energy helps grow and refrigerate our food, pumps our water, removes our wastes, mines our metals, manufactures and transports our goods, gives us incredible mobility worldwide, warms and cools us against the elements, and is an inextricable part of national security.

But these manifold services come at a price. Energy is expensive, consumes enormous sums of capital, and is one of the major causes of damage to health and the environment. The 1973 Arab oil embargo and subsequent oil disruptions raised serious national security concerns, since nearly two-thirds of the world's remaining oil supplies are in the Middle East.

These issues of cost, environmental damage, and energy insecurity are especially troubling for the developing countries and Eastern European nations. Both groups of nations are debt-strapped and face an acute scarcity of capital. In developing countries the per capita level of energy consumption remains five to ten times lower than that in the OECD countries. Yet, energy growth rates are seven times higher than in OECD countries, while air and water pollution already wildly exceed World Health Organization standards in many cities. In Eastern Europe, per capita energy consumption is comparable to that of OECD countries but energy efficiency in that region is very low.

In an effort to minimize these soaring costs and risks, countries, companies, communities, and citizens have sought ways to supply energy services that are more efficient, lower in cost, and safer. The results over the past two decades have been nothing short of staggering and bode well for industrialized and developing countries alike.

Scientific advancements and technological innovations have produced a steady flow of more efficient and less polluting commercial products and services. These range from highly efficient gas turbines and pollution-trapping equipment on the supply side, to a several-fold increase in the energy efficiency of end-use devices like lights, appliances, buildings, windows, vehicles, motors and power electronic devices, and office and manufacturing equipment.

These end-use efficiency improvements have reaped enormous savings. For example, in the U.S. the equivalent of more than 14 million barrels of oil per day were displaced through energy conservation investments (equal to half of OPEC's output), saving Americans a phenomenal $150 billion per year. These gains also reduced smog, acid rain, and greenhouse gas pollutants—carbon dioxide (CO₂), sulphur oxides (SO₂), nitrogen oxides (NOₓ), carbon monoxide (CO), and particulates—well below what they otherwise would have been in the absence of these efficiency gains.

The resource pool of cost-effective, energy-saving options continues to grow, and the technical innovations show no sign of slowing. This is profoundly good news, because it offers a sound means of satisfying a substantial fraction of the rapid growth in demand for energy services expected in the coming decades.

As this study shows, taking advantage of technologically available and economically attractive energy-conserving improvements in the coming decades will yield massive capital savings and achieve dramatic environmental gains (effectively cost-free), compared to foregoing these energy-saving opportunities.

Under conventional energy scenarios, to accommodate the doubling of the world's population and a quadrupling of gross world product, energy consumption is estimated to double to roughly 600 quads (quadrillion BTU's)
of primary energy per year by 2025. The bulk of this energy growth will occur in the developing countries.

The capital requirements for the entire energy sector in the developing countries and Eastern Europe are projected to be nearly $70 billion per year through the year 2000. This increases steeply to about $145 billion per year in the first quarter of the next century. Serious questions of how to overcome capital scarcity loom large, given the fact that current World Bank lending for the energy sector is less than $4 billion per year, and commercial bank lending for developing country energy projects has steadily declined over the past decade.

In sharp contrast, according to this study, investment in energy efficiency improvements would achieve impressive capital savings. Developing country capital requirements would drop by half, cumulatively saving more than two trillion dollars over the next 40 years.

Equally important is preventing the release of millions of tons of environmental pollutants. Under the conventional scenario, the greenhouse gas, CO₂, will more than double by 2025, and NOₓ, SO₂, and particulate pollutants will rise by 50 percent. In addition to air and water pollution and solid wastes caused by the projected fossil fuel use, 130 percent growth in hydroelectric power would occur in developing countries rich with tropical forest areas, displacing indigenous communities and threatening some of the most biologically diverse habitats of endemic plant and animal species.

However, compared with the conventional scenario, the efficiency scenario presented in this report would cut the growth of global CO₂ by half, NOₓ emissions by nearly a fifth, and reduce some of the land requirements for hydropower. Again, these environmental gains would occur along with enormous capital savings.

While in no way exhausting the full range of energy-saving options, the energy efficiency scenario put forward in this report clearly offers substantial benefits for individuals and society the world over. However, a number of financial constraints, institutional barriers, and market imperfections and distortions currently impede the attainment of these savings. Experience in the United States and other OECD countries indicates that none of these problems need prove intractable.

The report describes a number of insights gained from efforts to promote energy efficiency that have been pursued in developing countries in recent years, and details some of the ways we can move towards a more efficient energy future. Securing this capital-minimizing, pollution-preventing energy future will require a commitment on the part of both public and private decision-makers. This report should prove useful in initiating needed, innovative policies. In particular, this report should begin a dialogue about the ways in which the United States can enter into a partnership with developing nations to increase efficiency of energy production and use worldwide. Fledgling efforts to increase energy efficiency in the developing world need strong support from the United States and other industrialized nations if they are to blossom and ultimately play a major role in supporting sustainable economic and social development paths.

The major findings of this report are:

1. The rate of growth in energy consumption in the developing countries over the past two decades has been more than seven times that in the OECD countries (5.3 percent per year compared to 0.7 percent per year). (See Figures i and ii.)

2. Despite the rapid energy growth in developing countries, per capita consumption still remains a small fraction of that of OECD countries. Electricity use per capita is 10 times lower than in Western Europe and 20 times lower than in the United States.
3. At current levels of energy efficiency, increases in demand for power in developing nations will require $1.7 to $4 trillion over the next two decades, or 1.5 to 4 times current investment levels.

4. Energy inefficiency is a major problem in developing countries. On average, savings of 20 to 25 percent in energy use are available today with a payback period of two years or less.

5. Many power plants in developing countries consume 20 to 40 percent more fuel per kilowatt-hour (kWh) of electricity, and suffer transmission and distribution losses 50 to 100 percent higher, than in OECD countries.

6. Many industrial processes in developing nations require far more energy per unit of output than do processes that yield similar products in the industrialized world. For example, producing steel and ammonia fertilizer requires twice as much energy per unit output; pulp and paper production often requires three times as much.

7. Transportation in developing countries often consumes 40 percent of all oil used in those countries and is a large contributor to severe air pollution.

8. A number of countries have achieved some considerable successes in initial efforts to spur energy efficiency. For example, China has reduced the growth of energy use to half that of GDP growth, in large part by devoting investment funds to energy efficiency projects. Tunisia has also reduced growth in energy demand per unit GDP growth by 50 percent, as a result of a strong government commitment to energy efficiency.

9. A vigorous effort to increase reliance on cost-effective efficiency investments in developing countries could achieve dramatic savings. Compared to a "reference scenario" (what will likely occur in the absence of such vigorous effort) an "efficiency scenario" could achieve a 25% reduction in consumption in developing countries. As shown in Figure iii, this represents a reduction of about 150 quads per year, equivalent to more than half of current world energy consumption! Capital requirements for the energy sector would drop 50 percent for developing countries and Eastern Europe, resulting in more than two trillion dollars in cumulative capital savings by 2025. Global CO2 emissions from fossil fuels drop 25 percent, as show in Figure iv. This could potentially reduce eventual global warming by 1 degree C or more.

10. The United States and other industrialized countries can play a major role in helping to spur energy efficiency in developing countries and Eastern Europe. Four activities will be most valuable: (1) setting up training and information programs; (2) making access to capital for energy efficiency investments much easier to obtain; (3) initiating major programs in energy efficiency and other activities to increase awareness of the role of efficiency; and (4) increasing access of developing countries to improved energy technologies. A much larger effort than presently underway is essential if significant strides to increase energy efficiency are to be made in developing countries and Eastern Europe.
4 • Energy Efficiency, Developing Nations, and Eastern Europe

**Figure i.** Average growth rates of primary energy consumption (1973 to 1988)

- Former DCs: 9.7%
- Middle East: 5.7%
- China: 6.7%
- Asia: 5.5%
- Africa: 5.5%
- Latin America: 4.2%
- USSR: 3.4%
- E Europe: 2.3%
- Other OECD: 1.1%
- US: 0.6%

* DCs: Developing countries

**Source:** Reference 2

**Figure ii.** World primary energy consumption

- Quads


- Former DCs
- Asia
- China
- Latin America
- Mideast & Africa
- USSR & EE Europe
- Other OECD
- US

**Source:** Reference 2

**Figure ii.** World primary energy consumption
Figure iii. Projected primary energy consumption by region (developing countries and Eastern Europe)

Figure iv. Projected CO₂ emissions from fossil fuels
CHAPTER I

INTRODUCTION

Among governments, organizations, scientists, and citizens around the world, a consensus is emerging that strategies must be found to reconcile social and economic goals with those of environmental protection. Because of its intimate role throughout the economy, energy is a key aspect of any economic development strategy. But energy is also the primary cause of a number of local, regional, and global environmental problems. Is there a way to provide the energy needed for economic development without threatening the human habitat? A number of observers of the world energy scene believe we can. Of particular note is the thesis, propounded by Goldemberg, Johansson, Reddy, and Williams, that energy strategies that focus on energy services as distinct from energy supply can go a long way toward preserving economic and environmental values.

This report is concerned specifically with the role that energy efficiency could play in the formulation of energy strategies for the developing world and Eastern Europe. More and more observers believe that present energy and economic paths are not sustainable and in time will worsen current environmental and economic problems. It is not clear, however, that the developing world is in a position to make substantial progress in energy efficiency without considerable assistance and support from industrialized countries. If this is the case, as we believe, serious actions need to be taken by the industrialized countries to support emerging efforts in developing countries.

Although the benefits of energy efficiency are substantial, both donors (including bilateral agencies of industrialized countries, the United Nations, and multilateral development banks) and the developing world have been reluctant to embrace this new way of meeting energy demand. To address key issues involved in understanding why greater attention is not given to improved energy efficiency in developing countries, and to seek concrete ways to overcome the barriers, a series of meetings in the United States among a group of distinguished energy development specialists from government, industry, non-governmental organizations, and academia has taken place every two to four months since 1989. This group has come to be known as the U.S. Working Group for Global Energy Efficiency. (See Appendix A for member names.) This report to the U.S. Working Group is intended to establish a common framework and understanding of the issues and the actions required to move energy efficiency into a more appropriate place among development strategies.

The report first treats the historical record of energy growth in developing countries and Eastern Europe (in Chapter II). Chapter III describes in some detail the problems of inefficiency in energy production and use in these regions. An analysis of two scenarios—business-as-usual (which nevertheless assumes that energy efficiency does increase substantially) and an efficiency scenario—is presented in Chapter IV. Chapter V provides indications of ways that energy efficiency in developing countries and Eastern Europe can be pursued by describing some successful experiences of initial efforts. Chapter VI outlines briefly the next steps that are needed to move to concrete actions.

* All references may be found at the end of this report.

** It is also apparent that many industrialized countries could do much to increase the efficiency of energy production and use in their countries. This leadership by industrialized countries in improving energy efficiency at home is also of great importance.
Most of the developing world currently faces a growing need for energy services to support the economic and social development of their rising populations. At present, per capita energy consumption in the developing world remains much lower than in the developed world. On a per capita basis, developing countries in 1987 consumed an average of 18 million Btu in commercial fuels and an additional 8 million Btu in biofuels, compared with more than 130 million Btu in Western Europe and 305 million Btu in the United States.

Total primary commercial energy consumption in 1988 was 74 quads in the developing countries and 20 quads in Eastern Europe, compared to 77 quads in the U.S. and 82 quads in the rest of the OECD countries. Among the developing nations, China accounted for 33 percent of total consumption, Latin America for 22 percent, Asia (excluding China) for 26 percent, Africa for 11 percent, and the Middle East for 8 percent.*

The rate of growth in energy consumption in developing countries for the last two decades, however, has been far higher than in OECD countries (Figure 1). As a result, the developing nations’ share in world commercial energy consumption grew from 14 percent in 1973 to 23 percent in 1988 (Figure 2). Energy growth in these countries during this period averaged 5.4 percent per year, compared to 0.9 percent per year in the OECD countries.

This rapid increase in primary energy consumption is due to a number of factors, including: (1) faster economic growth than in the OECD countries, particularly in the 1970s; (2) migration from rural areas, where energy needs are met primarily with biomass, to urban areas, where commercial fuels predominate; (3) penetration of energy-intensive technologies (e.g., increasing use of fertilizers, personal vehicles, and electric appliances); (4) limited capability and resources to improve energy efficiency; (5) development of energy-intensive industries; and (6) population growth.

The developing nations and Eastern Europe experienced significantly higher energy growth rates from 1973 to 1979 than in the 1980s (Table 1). The difference was due primarily to slower economic growth in the later period. In 1988 and 1989, however, growth for the developing countries as a whole averaged 5.6 percent, above the 1979-87 average of 4.1 percent.2

*The source of energy data in this chapter is reference 2, the International Energy Agency, World Energy Statistics and Balances 1971-1987 and 1985-1988, Paris, 1989, 1990. Primary energy consumption includes losses in production and supply of electricity and other energy products, and includes non-energy uses of energy products (e.g., feedstocks for petrochemical production). Consumption does not include biomass, use of which is not well documented. To calculate the primary energy equivalent of inputs of nuclear and hydro energy to electricity production, the IEA uses a theoretical generation efficiency of 38.5 percent. We have not included as developing countries a number of countries with relatively high per capita GNP that have often been classified as part of the developing world. These countries, which we call “former developing countries,” are Hong Kong, Singapore, Taiwan, South Korea, Israel, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates. We have included South Africa and Turkey, since their per capita GNP places them within the rank of developing countries. Middle East developing countries as defined in this report do not include the high-income oil-exporters, but do include Turkey. OECD is the Organization for Economic Cooperation and Development and includes Canada, the United States, Western Europe, Japan, Australia, and New Zealand.
Figure 1. Average growth rates of primary commercial energy consumption (1973 to 1988)

*DCs: Developing countries

Figure 2. World primary energy consumption

Source: Reference 2
Table 1. Average annual growth in primary energy consumption (percent)

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Source: based on data in reference 2

ENERGY CONSUMPTION AND GDP

Overall, commercial energy consumption in the developing countries grew about 20 percent more than gross domestic product (GDP) between 1973 and 1988, although this relationship has varied between regions and over time (Figure 3).* In Asia (excluding China), energy consumption has grown slightly faster than GDP, especially since 1984. While the buildings and agricultural sectors became more energy-intensive and the private transportation sector expanded, these upward pressures on energy consumption were partly balanced by structural changes to a less energy-intensive product mix in industry. In China, which experienced even more rapid GDP growth, increases in energy consumption slowed markedly after 1979, mostly due to improvements in the historically inefficient industrial sector and to major programs to allocate capital to energy-efficiency investments.4

In Latin America, energy consumption has grown somewhat faster than GDP, especially during the recession of the early 1980s. In Africa, energy consumption has risen much faster than GDP, which has increased only slightly since 1980. Underutilization of industrial capacity may have lowered efficiency in Latin America, while growth in the use of commercial fuels for residential purposes, such as cooking, has contributed to increased energy use in Africa.

*Throughout the text we use the expressions "commercial energy consumption" and "energy consumption" interchangeably. The expressions exclude traditional (biomass) fuels. If biomass is included, this is noted explicitly.
Figure 3. Indices of primary commercial energy and GDP

Source: Energy data from reference 2; GDP data from Chevron Corporation and Asian Development Bank.
SECTORAL ENERGY CONSUMPTION

For the developing nations as a group, industry accounted for 50 percent of final energy consumption in 1987, transportation for 22 percent, and buildings and agriculture for 29 percent (Table 2). The share for industry ranged from a high of 59 percent in China to a low of 30 percent in the Middle East. Transportation is nearly as important as industry in Latin America. Its relative importance is low only in China, where private motorized transportation is used much less than elsewhere. Energy consumption in buildings and agriculture ranged in share from 40 percent in Eastern Europe, which has much more need for space heating, to 18 percent in the rest of Asia.

While industry is the major energy-consuming sector in the developing countries, energy use in buildings and agriculture has grown faster (5.8 percent per year from 1973 through 1986) than industrial energy use (4.9 percent). Growth in transportation energy use averaged 4.1 percent per year. Energy demand growth in buildings and agriculture was fastest in China and Africa, while it was about the same as growth in industry in Latin America and Asia (Figure 4). Transport was the fastest growing sector only in the Middle East. Growth in buildings energy use throughout the developing world has been primarily due to increase in appliance ownership, switching from biomass to oil-based fuels for cooking, and construction of modern commercial buildings. In Eastern Europe, buildings and agriculture were also the fastest growing energy end-use sectors.

Table 2. Sectoral shares in final energy consumption in 1987 (percent)

<table>
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<th>Region</th>
<th>Industry</th>
<th>Transportation</th>
<th>Buildings &amp; Agriculture</th>
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<td>Middle East</td>
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<td>34</td>
<td>36</td>
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<tr>
<td>Total Developing Countries</td>
<td>50</td>
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<td>Eastern Europe</td>
<td>50</td>
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Source: based on data in reference 2
BIOMASS CONSUMPTION

The role of the residential sector in total energy use is considerably larger if one includes biomass fuels. The majority of households in the developing countries continue to rely on such fuels for their basic energy needs, but the magnitude of biomass energy consumption is uncertain. One recent review of the statistics estimated that total use of various biomass fuels in 1986 amounted to about 25 quads, a quantity equivalent to 38 percent of total commercial energy consumption in the developing nations. Although data on historical trends in biomass consumption are uncertain, it appears that per-capita biomass consumption in urban areas has declined. Per capita consumption in rural areas may also have declined over the past decade due to increasing resource scarcity and increased availability of commercial fuels. Population increase may have balanced the decline in per capita use, leaving total biomass consumption little changed or perhaps slightly increased.

ELECTRICITY

Electricity use merits special attention because growth rates and attendant capital requirements have been especially dramatic in the developing countries. Despite the growth of the power sector, developing countries still use only 500 kWh (kilowatt-hours) of electricity per capita per year, compared with 5,000 kWh for Western Europe and 10,000 kWh for the United States. Growth in electricity consumption has been higher (7.8 percent per year between 1973 and 1987) than the increase in overall final energy consumption, which averaged 5.1 percent. Experience indicates that increases in electricity consumption can be well above the economic growth rate. This is because rising incomes lead
to demands for amenities associated with electricity services (e.g., comfort, convenience, and increased labor productivity) which grow even faster. Growth in electricity consumption between 1973 and 1987 was somewhat faster in Asia (8.0 percent per year) and China (8.2 percent) than in Latin America (7.4 percent) and Africa (6.6 percent). Electricity consumption in Eastern Europe grew more slowly, at an average rate of 4.2 percent per year, during this same period.

One consequence of the rapid expansion in the electric power sector has been the demand for massive capital outlays needed for financing new capacity. At current levels of efficiency, new power supply to meet electricity demand growing at 5 to 7.5 percent annually would require $1.7 to $4 trillion in developing countries worldwide over the next 20 years, or an average of $85 to $200 billion per year. This is 1.5 to 4 times current investment levels.*

The stark implications of an electricity-consumption growth which is substantially in excess of economic growth are readily illustrated by a simple projection. If the capital needs for electricity generation were to continue to increase 50 percent faster than GDP over the next three decades, with an annual GDP growth rate of 4 percent, the fraction of investment devoted to power would increase from a current 30 percent (for many countries) to more than 50 percent in thirty years' time. Such levels of capital investment could not be sustained, for they would crowd out essential investment in other socially and economically important activities. Even over the short term, attempts to achieve this kind of growth in power supply are likely to raise irreconcilable conflicts with other development goals. Equally severe problems apply to Eastern Europe.

Even if sufficient capital resources were available to meet power sector demand, the environmental consequences of this expansion in electric capacity in the developing world would be sobering. Environmental and related issues of continued growth in electricity, as well as other energy forms, are discussed in Chapter IV.

*Because these historical trends in electricity growth cannot be sustained, the reference case described in Chapter IV assumes considerable electricity end-use efficiency improvements. However, even with the 3.5 percent annual growth in electricity demand, the capital requirements over the forty years of the reference case are much higher than current levels.
CHAPTER III

PROSPECTS FOR IMPROVING ENERGY EFFICIENCY IN DEVELOPING COUNTRIES

Many studies have shown that developing countries use energy inefficiently and that they can improve efficiency significantly through relatively low-cost measures. This chapter summarizes current knowledge about energy inefficiency and discusses prospects for improving efficiency through cost-effective conservation measures.

ELECTRIC POWER

Electric generation efficiency is a serious problem in the developing world, particularly for older plants. New plants are generally state-of-the-art, but as they age deterioration of both efficiency and availability is accelerated by a lack of proper maintenance and spare parts, insufficiently trained personnel, and low fuel quality.

Many thermal power plants in developing countries use over 13,000 Btu of fuel per kWh of output, compared with 9,000–11,000 Btu per kWh for efficient plants. In addition, these plants tend to produce well below design capacity, thus requiring investment in additional generating capacity.

Many sources of inefficiency can be corrected. A study of steam-generating plants in Karachi, Pakistan, indicated that overall efficiency could be improved by 11 percent and capacity increased by 16 percent through a variety of measures with paybacks ranging from 2 months to 2 years. Such measures include boiler and turbine improvements, installation of instrumentation and controls, improved water treatment, repairs and replacements of pumps and heaters, and personnel training.

Transmission and distribution (T&D) losses in developing countries are often very high. In many countries they are over 20 percent, as compared to a range of 5 to 10 percent in the developed world. A World Bank study of 130 developing countries estimated that average T&D system losses were 17 percent; 64 countries had losses over 15 percent. Technical causes include inadequate maintenance and capacity, long line lengths to serve rural villages and agricultural pumping, low voltages in distribution networks, and substations located far from load centers.

Methods for reducing technical T&D losses are straightforward and do not require any advanced technologies. One major cause of high losses is low power factor in primary distribution lines. Installation of capacitors can easily remedy this problem. A World Bank study in Sudan, for example, indicates that installation of static capacitors at a cost of $1 million would produce generating capacity savings of over $12 million. Improving utility operating and maintenance procedures can also reduce losses at low cost.

A further source of energy inefficiency is the unreliable performance of power plants. Energy is wasted when a plant is down for unscheduled repairs because the power must be supplied by another, usually older and less efficient plant, or by expensive diesel-powered generators.

*Non-technical causes such as theft, bribery of meter readers, and inadequate billing procedures may represent half of the T&D losses in some developing countries. Generally these do not affect the overall engineering efficiency of the power system, but can seriously affect the prices, reliability, and financial viability of the electric utilities.
In addition to inefficient generation, distribution, and transmission of electricity, inefficient use by consumers causes significant energy losses. Extensive end-use efficiency programs implemented by utilities in the United States and Europe have had substantial impacts. Few such utility programs exist in developing countries. An exception is Brazil, which has seen active involvement of utilities in end-use efficiency programs. The government of Thailand has recently indicated its intent to begin utility programs. Costa Rica has shown interest in developing utility end-use efficiency programs, after initial positive experience with load management projects.

INDUSTRY

Industry is the largest and most diverse energy-consuming sector in the developing world. Meaningful comparisons of industrial energy consumption among different nations are difficult to develop because output product characteristics, raw materials, and other factors can lead to major differences in energy requirements. Typically, large plants in heavy industries in developing countries are not much less efficient than average plants in many industrialized countries, but one needs to adjust for differences in raw materials and products. For example, the average U.S. integrated, or ore-based, steel mill uses 15 percent less energy per tonne of rolled mill products than the average for larger, or key, plants in China, after adjusting for the production of cast iron in China. However, if one does not account for cast iron production and for the much greater use of scrap in the U.S., and if one includes the smaller antiquated mills in the Chinese total, then it appears that the Chinese industry is more than twice as energy-intensive as that of the U.S. In heavy industries the energy inefficiencies are largely associated with the process technology adopted, which depends on the age of the plants. In addition, energy inefficiencies result from inadequate maintenance and operating procedures. A rough estimate of the long-term conservation potential for major sectors of heavy industry can be made by juxtaposing the specific energy consumption of the most efficient plants to typical performances of plants in developing countries. With proper design and operation, many industrial plants in developing countries could reduce their energy consumption by 30 percent or more. Considerably greater savings could be achieved in many new industrial plants if advanced industrial processes were employed and properly maintained.

Table 3. Specific energy consumption in selected industries (kilograms of oil equivalent per tonne product)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Model Plant</th>
<th>U.S. Average</th>
<th>Developing Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>550</td>
<td>775</td>
<td>900-1015</td>
</tr>
<tr>
<td>Pulp and paper</td>
<td>690</td>
<td>990</td>
<td>up to 2300</td>
</tr>
<tr>
<td>Cement</td>
<td>105</td>
<td>145</td>
<td>160-210</td>
</tr>
</tbody>
</table>

* Based on technology currently in use.
  * Mid-1980s.
  * Resource, or primary, energy per tonne of rolled mill product at an integrated mill. Developing country range is for key plants and all plants in China (Reference 10).
  * Resource energy per tonne of paper, including energy from process by-products. The pulp and paper mix is that of the U.S. The model plant and U.S. average are from Reference 13. The developing country upper limit is from Reference 11.
In addition to the potential for major savings at new facilities, existing plants can significantly improve their energy efficiency through a variety of actions, many of which require little capital investment. For example, audits of 285 plants in Thailand showed that 11 percent of their energy use could be saved through measures having simple paybacks of 3 months to 3 years. A multi-sector industry study in Indonesia showed 11 percent energy-savings potential with no capital investment. In Egypt, audits of 9 industrial plants showed energy-savings potential of 23 percent with a one-year payback on the necessary capital investment. An audit program for industrial boilers in Pakistan showed that overall energy savings of 12 percent or more were available from low-cost and no-cost measures.

AGRICULTURE

As farming practices in the developing world become more modernized and energy intensive, energy demand for pumps, machinery (tractors, harvesters), chemical applications (fertilizers, pesticides), and post-harvest treatments (drying, curing) is likely to continue to grow. Since many of these energy-intensive practices lead to enhanced productivity, they may well be justified. However, unnecessary energy demands may also result. Three representative cases are cited below.

In Pakistan, agriculture accounts for 18 percent of total national electricity demand (as much as 25 percent during peak periods). Most of this electricity is used in the operation of tubewell pumps to irrigate field crops. Average efficiency for tubewell pumps is 70 percent below what is technically achievable. A 20 percent efficiency improvement in the existing system can be achieved through cost-effective retrofits.

In Venezuela, as in many other developing nations with large, centralized grain-processing operations, the high-volume, high-temperature dryers used in these facilities are much less energy efficient than lower temperature dryers used in local cooperatives. In addition, an average of 20 percent of the total national rice and corn harvest is lost to fermentation during excessive waits in the receiving lines in centralized processing centers.

In India, the dominant and most energy-intensive fertilizer in use is nitrogenous urea. Currently, significant amounts of nitrogen do not reach the crop roots due to leaching and denitrification. An Indian research organization has developed a form of urea that provides better delivery of nitrogen to the crop roots. Using this, an Indian farmer can use 35 percent less fertilizer in rice cultivation.

TRANSPORTATION

The transportation sector often accounts for more than 40 percent of petroleum consumption. Because 60 to 80 percent of the transport fuel consumed in many developing countries is used by road vehicles, long-term energy savings are possible by influencing the patterns of vehicle use through transport and land-use management, transport pricing, education, infrastructure investments, and technology improvements. The use of such strategies is rare today and difficult to implement, given traditional growth patterns for cities.

The markets for motor vehicles are growing at a very rapid pace in many developing countries. Car ownership increased nearly 10 percent per year in the 1970s and 5 percent per year throughout the 1980s. Between 1984 and 1988, motor vehicle fleets grew annually by 30 percent in the Republic of Korea, 26 percent in Kenya, and by roughly 10 percent in Brazil, Pakistan, and Thailand.

Fuel efficiency standards for imported and domestic automobiles, trucks, and buses offer major opportunities for energy savings in developing nations with rapidly expanding motor vehicle fleets. Several already have a differential tariff fee based on engine displacement to discourage the import of energy-guzzling cars. Improved vehicle maintenance
through fleet management and mandatory periodic inspection can provide modest energy savings, as can improved driver training.

Transport system energy efficiency is fundamentally affected by land-use patterns that can be influenced by transport policies and investments. By encouraging clustered growth in multiple centers that are compatible with pedestrians and bicycles, and by connecting these centers with public transport on its own reserved rights-of-way, growing cities can reduce dependence on energy-inefficient automobile transportation. For such strategies to be successful, investments in motorized road transport and alternative modes must be carefully balanced.

Curitiba, Brazil, is an example of a city whose use of land-use planning and promotion of mass and non-motorized transit has provided significant energy savings. Curitiba has developed a bus system comprised of five arterials radiating from the city center, with most of the space on them dedicated to express buses that travel to stations where a system of local feeder buses connects to the main bus lines. In addition to providing incentives to use the bus system, the government requires high-density commercial and residential development to be along the express bus lines. This system has resulted in a per capita automobile fuel usage in Curitiba significantly less than that of other, similarly-sized cities in Brazil, even though its automobile ownership rates are among the highest in the country.

While difficult to implement, these types of changes in land-use planning and urban transport are also possible for very large cities in developing countries. A recent analysis estimated that transport petroleum use could be reduced in Jakarta, Indonesia, by 10 percent over a 25-year period by promoting multiple employment centers rather than continued monocentric concentration. For Mexico City, it was estimated that increased public transport investment could yield roughly 15 percent less transport energy use in the year 2000 than projected current policies.

Transportation system management and pricing changes can provide significant energy savings, often in short time frames. For example, a comprehensive traffic management project in Thailand produced savings of approximately 25 percent with a projected return of 100 percent per year. Area pricing, as in Singapore, offers great promise for energy savings, especially if implemented with major improvements in public transport. Although the area pricing system in Singapore was primarily designed to reduce congestion in the central business district of the city, it served to reduce transportation energy use considerably.

Aircraft are second to motor vehicles in transport fuel use and their energy consumption is growing rapidly. However, the efficiency of fuel use in new generation aircraft is also increasing rapidly. New aircraft now get about 50 seat miles per gallon (SMPG), or twice that of aircraft produced in 1970. Technology improvements are anticipated to raise this to 65 to 80 SMPG in the 1990s. Rates of 100 to 150 SMPG appear to be feasible in the near future.

In freight transport, shifting to more efficient transport modes can reduce energy intensity significantly. Investments in railroads or waterways for commercial shipping can lead to reductions in energy use per ton-mile by 60 to 80 percent. In Brazil, the energy intensity of freight transport has declined since the 1970s due to the increased use of ship and railway, conversion of the truck fleet to diesel, and a shift from light and medium trucks to less fuel-intensive heavy trucks. Accomplishing such modal shifts requires, at a minimum, a government commitment to less energy-intensive transport modes, careful analysis of the best opportunities to construct attractive and efficient alternative transport systems, and allocation of capital to appropriate infrastructure.

BUILDINGS

Buildings constitute a significant and rapidly growing energy-consuming sector in the developing world, accounting for 28 percent of total commercial energy use and 38 percent of
electricity use. As countries modernize, the expected level of comfort (i.e., floor area per person, amount of air-conditioning, lighting level, electric appliances, etc.) also increases, often causing energy (especially electricity) consumption in the buildings sector to increase more rapidly than in other sectors. During the 1980s electricity consumption in buildings in developing nations increased by over 11 percent per year, compared to 4 to 9 percent per year in other sectors.

The current low efficiency of energy use in buildings in these countries presents a significant opportunity for energy conservation. In many developing countries the system-wide peak electricity demand occurs in the early evening, coinciding with the peak use in buildings (especially homes). Thus, energy conservation in the buildings sector will significantly reduce the load during peak hours when electricity is most expensive to generate, and will mitigate the problem of load shedding that often occurs during peak hours because demand exceeds supply.

Common inefficiencies and sources of wasted energy in buildings include: (1) lack of insulation in roofs and walls; (2) use of electric resistance heating; (3) use of inefficient lighting, including inappropriate use of incandescent bulbs and inefficient fluorescent bulbs and light fixtures; (4) poor quality fan motors, appliances, and heating, ventilating, and air-conditioning (HVAC) systems; (5) constant volume, manually controlled, single-zone HVAC systems; (6) absence of adequate control systems; and (7) low overall construction quality and high infiltration rates.

The potential for energy savings varies among countries, depending on the climate and the energy intensity of particular building types. In hot climates, significant energy efficiency opportunities in air-conditioned buildings can be achieved from reflective (white) coating on roofs, solar shading of windows, shade trees, and daylighting. In cold climates, insulation and infiltration reduction are important improvements. In all climates, efficiency improvements in heating and cooling equipment through maintenance and reduction of excessive lighting loads can lead to further savings. Even in unconditioned buildings, improvements in lighting and fan motors are usually cost-effective.

In Thailand, detailed computer simulations of offices, hotels, and retail buildings have shown that a combination of increased shading, proper daylighting design, lighting power reduction, reflective coating on roofs, and improved chiller efficiency reduces energy consumption by 45 to 50 percent, with a simple payback of about 2 years, depending on building type. Studies of commercial buildings in Malaysia and Singapore show similar energy savings.

A study of residential and small office buildings in Pakistan estimated that reducing infiltration can save 15 percent of electricity consumption; raising air conditioner efficiency, 20 percent; adding minimal insulation of roofs, 15 percent; and adding reflective coating on roofs, 12 percent. A combination of the above measures results in a savings ranging from 29 percent in Karachi (where buildings are air-conditioned but not heated), to 40 percent in Peshawar (where buildings are both heated and air-conditioned).

A study of lighting in India and Brazil found that replacement of incandescent lamps with compact fluorescents will reduce consumption per fixture by 75 percent, with a simple societal payback of one to two years for typical usage in residential buildings and an even shorter payback with the higher usage in commercial buildings. The study concludes that it is more cost-effective for utilities in India and Brazil to subsidize the cost of compact fluorescent lamps for residential consumers than to continue to subsidize wasteful use of electricity for incandescent lamps.

Electric appliances are another area where considerable energy savings can be achieved. The problem of rapidly proliferating inefficient appliances is common throughout the developing
Energy Efficiency, Developing Nations, and Eastern Europe

Studies in Indonesia and Egypt found that the appliances produced locally are significantly less efficient than world standards. Efficiencies for new appliances could increase 20 to 30 percent in the near-term and much more in the longer term, if policies are put into place to eliminate production and sale of inefficient appliances.

DOMESTIC BIOMASS CONSUMPTION

Domestic energy use in the rural areas of many developing countries is dominated by biomass fuels for cooking. In nations with a low level of industrialization, cooking may represent the largest single use of energy. Even in relatively industrialized India, the consumption of biomass energy roughly equals the annual consumption of commercial energy sources. Cooking is typically done with traditional stoves which have efficiencies of only 6 to 12 percent. Much higher efficiencies have been demonstrated in laboratories with well-engineered stoves. By improving both the efficiency of combustion (less fuel ends up as charcoal or in smoke), and of heat transfer (more heat goes into the pot, and less escapes as hot gas), stoves can achieve laboratory efficiencies ranging from 18 to 35 percent. Costs of improved stoves range from $2 for mud stoves to about $10 for metal stoves.

Improved cookstove efficiencies offer other benefits as well. Household members have more time to pursue economic activities (rather than gathering fuel wood). Exposure (particularly of women) to indoor air pollution in the form of irritating and toxic smoke is significantly reduced. Deforestation from fuelwood gathering is also reduced. Unfortunately, implementation of programs to introduce improved cookstoves in rural areas have met considerable difficulties. Programs targeted to urban or semi-urban populations, on the other hand, have been more successful, likely because biofuels are purchased and stoves can be produced by local artisans.

CONCLUSIONS

Savings in energy use of 20 to 25 percent with a payback period of two years or less appear possible in the near-term. Detailed assessments of individual countries indicate that the savings could be substantially greater. The estimate of 20 to 25 percent savings reflects opportunities that are visible and attainable, as well as highly cost-effective. Over the long term, as investments are made in new capital equipment (industrial facilities, automobiles, appliances, buildings, power generation and distribution), larger energy savings are possible, on the order of 30 to 60 percent when compared with current equipment.

Potential savings in electricity supply and use are particularly large. Improvements of 15 percent in power plant efficiency, reductions in T&D losses by 6 percent, and increases in end-use efficiency by 25 percent could cumulatively reduce electricity generation requirements by 40 percent. Under these circumstances, unsustainable growth in generation capacity, 1.5 times that of GDP growth in a typical case, can be reduced to a more nearly sustainable 90 percent of GDP growth. Significant reductions in oil consumption are also possible, in part because of widespread inefficiency in the transportation sector. Substantial efficiency gains in the use of other fuels can be achieved as well.
CHAPTER IV

ENERGY SCENARIOS AND IMPACTS

TWO SCENARIOS OF WORLD ENERGY DEMAND IN 2025

To illustrate the potential impact of a long-term, global effort to improve the efficiency of energy supply and use, we constructed two scenarios of energy demand in the year 2025 for each of nine regions. The analysis built on work conducted for the U.S. Environmental Protection Agency as part of its report to Congress on global climate change. The assumed growth in population and in GDP for each of the regions—which was used in both scenarios—is shown in Table 4. The GDP growth rates for most regions were taken from forecasts to 2010 developed for the U.S. Department of Energy. The growth rates between 2010 and 2025 were assumed to be slightly lower than the 1985-2010 rates. These assumptions on economic and population growth as well as the scenarios described in this chapter are intended to be illustrative and not predictive of the future.

The Reference Scenario represents a plausible estimate of future levels of GDP and energy efficiency. This scenario assumes a number of structural changes in the end-use sectors for each region. It also envisions a technological evolution in which energy efficiency improves significantly as economies develop and energy-using capital stock changes, and some efforts to improve energy efficiency are undertaken in all sectors. The price of oil is assumed to be $35 per barrel (1988 dollars) by 2025.

The Efficiency Scenario assumes that substantial further efforts are undertaken—with large-scale assistance—to improve the efficiency of energy use and supply. It does not envision significant changes in behavior or industrial development that could also contribute to lower energy use, though it does assume that governments invest more heavily in mass transportation to reduce energy use and local air pollution. Because this scenario results in lower energy demand, the price of oil increases to only $29 per barrel.

For each region, Reference and Efficiency Scenarios were constructed for five end-use sectors: industry, agriculture, transportation, residential, and services. The method and level of disaggregation varied for each sector, depending in part on the data available in the base year. In each sector, energy demand was broken into fuels (oil, natural gas, coal), electricity, and, where appropriate, biomass. Indicators of energy intensity—energy use per unit of output or activity—were developed for each of these fuels. For the developing countries and Eastern Europe, the future levels of intensities are based on historical experience in the OECD countries, estimates of the future pace of technological change, and estimates of the uptake of new technologies in the developing regions.

To derive sectoral energy consumption, energy intensities were multiplied by the levels of output or activity in 2025. Primary energy consumption is obtained from sectoral energy demand. Reduction in transmission and distribution losses, and increased generating efficiency, are assumed for both scenarios, but the degree of change is greater in the Efficiency Scenario.

Primary Energy Use

Figure 5 shows the growth in world primary commercial energy use between 1985 and 2025 for the two scenarios. Consumption doubles from 287 quads in 1985 to 600 quads in 2025 in the 2025 Reference Scenario. In the Efficiency

*Additional information on methodology and comparisons with other scenario results is contained in Appendix B.
Table 4. GDP and population assumptions

<table>
<thead>
<tr>
<th>Region</th>
<th>GDP 1985 (billion $)</th>
<th>GDP 2025 (billion $)</th>
<th>Growth Rate (%/year)</th>
<th>POPULATION 1985 (million)</th>
<th>POPULATION 2025 (million)</th>
<th>Growth Rate (%/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD</td>
<td>9656</td>
<td>23,310</td>
<td>2.2%</td>
<td>813</td>
<td>938</td>
<td>0.4%</td>
</tr>
<tr>
<td>USSR</td>
<td>1167</td>
<td>3626</td>
<td>2.9%</td>
<td>289</td>
<td>369</td>
<td>0.6%</td>
</tr>
<tr>
<td>E. Europe</td>
<td>510</td>
<td>1463</td>
<td>2.7%</td>
<td>113</td>
<td>123</td>
<td>0.2%</td>
</tr>
<tr>
<td>China</td>
<td>282</td>
<td>1385</td>
<td>4.1%</td>
<td>1045</td>
<td>1420</td>
<td>0.8%</td>
</tr>
<tr>
<td>S&amp;E Asia</td>
<td>413</td>
<td>2150</td>
<td>4.2%</td>
<td>1349</td>
<td>2412</td>
<td>1.4%</td>
</tr>
<tr>
<td>Latin America</td>
<td>678</td>
<td>2146</td>
<td>2.9%</td>
<td>402</td>
<td>829</td>
<td>1.8%</td>
</tr>
<tr>
<td>Africa</td>
<td>415</td>
<td>1158</td>
<td>2.6%</td>
<td>570</td>
<td>1680</td>
<td>2.7%</td>
</tr>
<tr>
<td>Middle East</td>
<td>302</td>
<td>1600</td>
<td>4.3%</td>
<td>144</td>
<td>356</td>
<td>2.3%</td>
</tr>
<tr>
<td>Former DCs*</td>
<td>403</td>
<td>1583</td>
<td>3.5%</td>
<td>89</td>
<td>132</td>
<td>1.0%</td>
</tr>
</tbody>
</table>

*Former developing countries

Figure 5. World primary energy consumption by regions
Scenario, consumption is reduced by 25 percent to 450 quads in 2025. Energy consumption in the developing nations and Eastern Europe increases from 26 percent of the world total in 1985 to 39 percent in 2025 in the Reference Scenario and 37 percent in the Efficiency Scenario. From 50 percent of OECD consumption in 1985, it becomes comparable to OECD use in 2025.

For the developing nations and Eastern Europe, the Efficiency Scenario shows a 29 percent reduction in primary commercial energy consumption in 2025 relative to the Reference Scenario (Figure 6). This amounts to a savings of 67 quads. The Efficiency Scenario results in considerably slower growth in primary energy use in all of the developing regions and Eastern Europe (Table 5). For all of the regions together, the annual growth in primary energy use is 2.9 percent in the Reference Scenario and 2.0 percent in the Efficiency Scenario. In both cases, GDP growth averages 3.4 percent. In fact, it is very likely that GDP growth would be higher in the Efficiency Scenario, since capital that is not needed for the energy sector could be invested elsewhere in the economy.

When considering the reduction in energy demand growth in the Efficiency Scenario, it is important to remember that the Reference Scenario is not at all a low-efficiency case. In fact, primary energy use grows more slowly than GDP in all regions except Africa and the Middle East in the Reference Scenario. This is due in part to rising energy prices during the 1985-2025 period. It also reflects the expected turnover of the energy-using capital stock in the developing countries and Eastern Europe, and their increasing absorption of technologies like those used in today's industrialized countries. Also significant is the shift of economies toward lighter industry and services that will occur as these nations develop.

While there is considerable improvement in efficiency in the Reference Scenario, growth in energy use could be reduced still further if strong policies that place a high priority on improving energy efficiency were implemented.

Table 5. Growth of primary energy use between 1985 and 2025 (percent per year)

<table>
<thead>
<tr>
<th>Region</th>
<th>Reference Scenario</th>
<th>Efficiency Scenario</th>
<th>GDP Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latin America</td>
<td>2.5</td>
<td>1.9</td>
<td>2.9</td>
</tr>
<tr>
<td>S&amp;E Asia</td>
<td>3.6</td>
<td>2.6</td>
<td>4.2</td>
</tr>
<tr>
<td>China</td>
<td>3.1</td>
<td>2.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Africa</td>
<td>2.9</td>
<td>2.1</td>
<td>2.6</td>
</tr>
<tr>
<td>Middle East</td>
<td>4.3</td>
<td>3.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>1.3</td>
<td>-0.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Developing Countries &amp; Eastern Europe</td>
<td>2.9</td>
<td>2.0</td>
<td>3.4</td>
</tr>
</tbody>
</table>
The estimated efficiency gain varies among regions. The percentage reduction in primary energy use in 2025 in the Efficiency Scenario relative to the Reference Scenario is 45 percent in Eastern Europe, 33 percent in S&E Asia, 30 percent in China, 26 percent in Africa, and 22 percent in Latin America (Figure 7).

Table 6 gives the percentage change in the ratio of primary energy consumption to GDP in 2025 relative to 1985. The greatest reduction in this ratio occurs in Eastern Europe and China, for both the Reference and Efficiency Scenarios. These two regions are somewhat similar in that the current capital stock is very inefficient and economic growth will bring a great improvement through stock turnover. Achieving economic competitiveness will require great improvement in efficiency. Part of the projected decline in energy intensity in Eastern Europe is also due to considerable reduction in the share of heavy industry, which is assumed to occur as the economies are integrated into the world market economy. To some extent, a similar shift may occur in China, but less so because its size and natural resource base can sustain more heavy industry than Eastern Europe. Thus, the improvement in the Reference Scenario in China is more the result of efforts to improve efficiency, whereas in Eastern Europe structural change plays a greater role.

The energy savings achieved in the Efficiency Scenario depend in part on the energy intensities assumed in the Reference Scenario. The changes in energy intensities in the Reference Scenario (relative to 1985) are based to some extent on the experience of the past 15 years. China has substantially reduced energy intensity. The energy-to-GDP ratio has increased somewhat in S&E Asia and Latin America, and grown substantially in Africa. Therefore,
Figure 7. Primary energy consumption (1985 and 2005) by region for developing countries and Eastern Europe (with savings in percent)

Table 6. Change in the ratio of primary energy consumption to GDP (percent change relative to 1985)

<table>
<thead>
<tr>
<th>Region</th>
<th>Reference Scenario</th>
<th>Efficiency Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latin America</td>
<td>-14</td>
<td>-33</td>
</tr>
<tr>
<td>S&amp;SE Asia</td>
<td>-20</td>
<td>-47</td>
</tr>
<tr>
<td>China</td>
<td>-30</td>
<td>-51</td>
</tr>
<tr>
<td>Africa</td>
<td>+12</td>
<td>-17</td>
</tr>
<tr>
<td>Middle East</td>
<td>+2</td>
<td>-12</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>-41</td>
<td>-68</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>-23</td>
<td>-46</td>
</tr>
<tr>
<td>&amp; Eastern Europe</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
in the Reference Scenario, energy intensity declines more in S&E Asia than in Latin America. As China, relatively high economic growth brings considerable stock turnover and more rapid change to a lighter industrial mix. The percentage decline in overall energy intensity in the Efficiency Scenario is about the same in Latin America as in S&E Asia.

The only region with significant increase in overall energy intensity in the Reference Scenario is Africa. As in Latin America, this is partly due to slower economic growth and the resulting slower turnover of the capital stock. Another factor is that the level of energy-using capital stock is relatively low in Africa today. Therefore, economic growth will push upward on energy intensity more than in other regions, as people switch from biomass, which is in widespread use today, to commercial fuels, and acquire appliances and personal vehicles.

Change in Sectoral Energy Demand

The discussion above is in terms of primary energy consumption, which is determined by energy demand in the end-use sectors, and conversion and distribution efficiency. Final fuel consumption in the Efficiency Scenario is 23 percent less than in the Reference Scenario, while consumption of electricity is 35 percent less (Table 7). This difference reflects the greater potential for cost-effective efficiency improvement in electric end-uses.

For the developing nations and Eastern Europe together, 49 percent of total savings in fuel use are in industry, 31 percent are in transportation, and 20 percent are in the residential and service sectors. For electricity, 53 percent of savings are in industry and 47 percent are in the residential and commercial sectors. Along with these savings in final energy use, there is also a reduction of 25 quads in power sector losses as a result of lower electricity consumption, improved electricity generation, and reduced transmission and distribution losses. The high energy and capital requirements of generating electricity make savings in end-use electricity especially important.

The percentage reduction in energy use in the Efficiency Scenario varies among end-use sectors. Fuel savings amount to 22 percent in industry, 28 percent in transportation, and 21 percent in the residential and commercial sector. The reduction in electricity use is 31 percent in industry and 40 percent in the residential and commercial sector.

Change in Sectoral Energy Intensities

The degree of efficiency improvement in each sector varies among regions. In part, this is because the regions begin with different efficiencies in 1985, and also have different patterns of change in the Reference Scenario. The relative change in fuel and electricity intensity (consumption per unit of value-added) from 1985 to 2025 in the two scenarios is shown for industry in Table 8. The Efficiency Scenario shows the greatest decline in fuel intensity relative to 1985 in China and Latin America, mainly because the 1985 value is relatively high. Asia has the greatest reduction in electricity intensity, generally brought about through significantly more efficient motors, pumps, and compressors. Both fuel and electricity intensity are affected by the shift in product structure that is assumed to occur between 1985 and 2025.

In transportation, the scenarios consider fuel intensity separately for the different transport modes. The fuel intensity for automobiles declines considerably in most regions in the Reference Scenario, and then declines further (to 45 to 65 percent of the 1985 level) in the Efficiency Scenario. The largest percentage reduction is in Latin America, which had relatively inefficient cars in 1985. The reduction in freight energy intensity is somewhat less than that for passenger energy intensity.
Table 7. Scenario results: developing countries & Eastern Europe final energy consumption (Quads)

<table>
<thead>
<tr>
<th></th>
<th>1985</th>
<th>2025 Reference Scenario</th>
<th>2025 Efficiency Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINAL ENERGY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuels</td>
<td>28.2</td>
<td>74.1</td>
<td>57.9</td>
</tr>
<tr>
<td>Electricity</td>
<td>4.5</td>
<td>15.5</td>
<td>10.6</td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuels</td>
<td>12.8</td>
<td>36.7</td>
<td>26.4</td>
</tr>
<tr>
<td>Electricity</td>
<td>0</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Buildings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuels</td>
<td>10.9</td>
<td>30.2</td>
<td>23.8</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.7</td>
<td>10.7</td>
<td>6.4</td>
</tr>
<tr>
<td>Total Secondary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuels</td>
<td>51.9</td>
<td>141.1</td>
<td>108.2</td>
</tr>
<tr>
<td>Electricity</td>
<td>6.2</td>
<td>26.4</td>
<td>17.3</td>
</tr>
<tr>
<td>POWER LOSSES</td>
<td>17.3</td>
<td>64.9</td>
<td>39.7</td>
</tr>
<tr>
<td>PRIMARY ENERGY</td>
<td>75.4</td>
<td>232.4</td>
<td>165.1</td>
</tr>
</tbody>
</table>

Table 8. Index of energy intensity in industry (energy per unit of value-added), 1985 = 100

<table>
<thead>
<tr>
<th></th>
<th>1985</th>
<th>2025 Reference Scenario</th>
<th>2025 Efficiency Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Intensity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>100</td>
<td>68</td>
<td>45</td>
</tr>
<tr>
<td>S&amp;E Asia</td>
<td>100</td>
<td>71</td>
<td>61</td>
</tr>
<tr>
<td>China</td>
<td>100</td>
<td>63</td>
<td>46</td>
</tr>
<tr>
<td>Africa</td>
<td>100</td>
<td>87</td>
<td>70</td>
</tr>
<tr>
<td>Middle East</td>
<td>100</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>Electricity Intensity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>100</td>
<td>95</td>
<td>70</td>
</tr>
<tr>
<td>S&amp;E Asia</td>
<td>100</td>
<td>95</td>
<td>50</td>
</tr>
<tr>
<td>China</td>
<td>100</td>
<td>93</td>
<td>61</td>
</tr>
<tr>
<td>Africa</td>
<td>100</td>
<td>100</td>
<td>85</td>
</tr>
<tr>
<td>Middle East</td>
<td>100</td>
<td>110</td>
<td>95</td>
</tr>
</tbody>
</table>
In the residential sector, there is relatively small reduction in fuel intensity of the end-uses, and overall fuel use increases due to switching from biomass. Electricity use per person increases substantially, though part of the increase is a result of the increased number of homes with electricity. Overall electricity intensity, expressed in terms of use per person with electricity, also increases significantly between 1985 and 2025 in the Reference Scenario, due to increased appliance saturation and size, and a switch from kerosene to electricity for lighting. The increase is greatest in China because appliance saturation was very low in 1985. The improvement in the Efficiency Scenario reflects more efficient appliances and lighting. In Asia, for example, the average annual consumption for refrigerators declines from 600 kWh in 1985 to 334 kWh in the 2025 Reference Scenario and to 265 kWh in the Efficiency Scenario. For lighting, average annual use per electrified household grows from 200 kWh in 1985 to 270 kWh in the 2025 Reference Scenario (due to higher lighting levels), but falls to 160 kWh in the Efficiency Scenario because much more efficient lighting systems are employed.

In the services sector, modernization increases saturation of electric end-uses. Greater use of air conditioning is an important factor pushing intensity upward, but turnover of the building stock and penetration of more efficient lighting and space conditioning technologies leads to a decline in overall electricity intensity in 2025 in the Reference Scenario. Further improvement is achieved in the Efficiency Scenario, which assumes construction of more energy-efficient buildings and installation of more efficient equipment.

### Biomass Energy Use

Biomass is widely used today as a fuel for cooking in the developing regions. It is also used in smaller amounts in certain industries. In Brazil it is used to make ethanol for transportation. Total use of biomass increases between 1985 and 2025 in the Reference Scenario in Asia and Africa due to population growth, but decreases in other regions. On a per capita basis, its use declines in every region between 1985 and 2025 as biomass is replaced with modern fuels. Further declines occur in the Efficiency Scenario as the efficiency of biomass use improves and more of it is replaced by modern fuels. The share of biomass in total primary energy consumption declines from 22 percent in 1985 to 7 percent in both 2025 scenarios. No account is taken of possible increased industrial use of crop residues and other forms of biomass, which could result in larger reduction in use of fossil fuels.

### IMPLICATIONS FOR THE POWER SECTOR

The combination of lower electricity consumption, improved electricity generation, and reduced transmission and distribution losses in the Efficiency Scenario results in a reduction in electricity-generation requirements in the developing countries and Eastern Europe. As a result, the electricity-generating capacity needed declines from 1956 GW (gigawatts) in the 2025 Reference Scenario to 1240 GW in the Efficiency Scenario (Figure 8). The growth rate for electricity generation changes from 3.5 percent per year to 2.3 percent per year. This 700 GW reduction is greater than the total installed capacity that exists today in the developing nations.
ENVIRONMENTAL IMPLICATIONS

Reference Scenario

The environmental implications of the Reference Scenario are sobering, especially since this particular vision of a future already includes substantial energy efficiency improvement. Using the same analytical model used in the EPA’s study of policy options for stabilizing global climate, global CO₂ emissions increase from about 6,000 teragrams per year in 1985 to about 12,400 teragrams per year in 2025. This amounts to more than twice the current rate of emissions—at a time when some parties are arguing that the current rate actually needs to drop to avoid global warming. The single most important contributor is fossil fuel emissions, which increase from 5,200 to 10,600 teragrams per year. Around 56 percent of the increase comes from developing countries and Eastern Europe. Other greenhouse gases, such as methane and nitrous oxide, also increase significantly.

The atmospheric concentration of greenhouse gases, expressed as parts per million of CO₂ or the equivalent, grows from 370 in 1985 to 550 in 2025, an increase of about 50%—in spite of impressive accomplishments over the years in efficiency improvement. Extrapolating the trends past 2025 leads to a significant further increase in atmospheric concentrations in decades ahead, pointing toward at least a doubling (from current levels) of greenhouse gas concentrations later in the 21st century. This doubling is likely to result in a 2 to 6 degree C rise in the global average temperature.

Other environmental impacts of the Reference Scenario are also worth attention. For instance,
NO\textsubscript{x} emissions are projected to grow from 51 teragrams per year in 1985 to 75 teragrams per year in 2025. Fossil fuels are the major contributor, accounting for 24 and 46 teragrams per year, respectively. This increase suggests similar growth in air emissions (SO\textsubscript{2} and particulate matter), which can cause urban air pollution locally, and acid precipitation regionally. An increase by 50 percent in air pollution levels in many cities in the developing world and Eastern Europe would be unacceptable. Air quality in Mexico City, for example, failed to meet international standards 312 days during 1989 alone. China and Eastern Europe also face serious problems at current emission levels.

Environmental impacts extend beyond air emissions. The Reference Scenario projects an increase of more than 130 percent in electricity supply from hydroelectric power between 1985 and 2025. Most of the growth occurs in developing countries, especially in Latin America, China, and S&E Asia, where large-scale hydropower developments are meeting opposition for environmental and social reasons.

In summary, the 2025 Reference Scenario represents a future in which global carbon dioxide emissions would more than double from the 1985 level, and regional and local environmental conditions would worsen.

**Efficiency Scenario**

The Efficiency Scenario presents a more positive and more sustainable picture of the future. Global carbon dioxide emissions in 2025 drop 25 percent from the 12,400 teragrams per year predicted in the Reference Scenario to 9,200. CO\textsubscript{2} emissions from fossil fuels drop 28 percent from 10,600 teragrams per year to 7,600. (Figure 9). Nearly two-thirds of this reduction results from efficiency improvements in developing countries and Eastern Europe. The atmospheric concentration of greenhouse gases in 2025 is reduced from 546 to 519 parts per million of CO\textsubscript{2} or the equivalent, a decrease of about 5 percent. If the conventional assumptions about relationships between greenhouse gas concentrations and global warming temperatures are correct (i.e., a doubled concentration results in 2 to 6 degrees F in global warming), an efficiency improvement policy initiative might by itself reduce eventual global warming by one degree F or more.

Local and regional environmental impacts would decrease. For instance, total NO\textsubscript{x} emissions in 2025 drop by 18 percent compared with the Reference case (see Figure 10). Hydroelectric power development by 2025 decreases by less than 6 percent, for example, and only in Latin America, but total electricity supply from coal is reduced by nearly 38 percent, which means lower SO\textsubscript{2} emissions. Transportation energy use per capita drops by 20 to 25 percent in developing countries and by 37 percent in Eastern Europe, meaning lower levels of urban air pollution.

In summary, a global energy efficiency initiative could make a significant contribution to environmental management worldwide. It has the potential to halve the increase in greenhouse gas emissions from an already fairly efficient world and to bring about a measurable reduction in the eventual equilibrium global average temperature. It would have a wide variety of other beneficial environmental impacts as well.

**CAPITAL REQUIREMENTS**

Capital requirements to meet the growing needs of developing countries for energy services are a major problem for the development process.
Figure 9. Projected CO₂ emissions from fossil fuels

Figure 10. Projected NOₓ emissions from fossil fuels
Table 9. Capital requirements for the energy sector (billions of 1990 dollars)

<table>
<thead>
<tr>
<th>Region/Country</th>
<th>Reference Scenario</th>
<th>Efficiency Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1985-2000</td>
<td>2001-2025</td>
</tr>
<tr>
<td></td>
<td>1985-2000</td>
<td>2001-2025</td>
</tr>
<tr>
<td>OECD</td>
<td>724</td>
<td>1303</td>
</tr>
<tr>
<td>Soviet Union</td>
<td>358</td>
<td>744</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>44</td>
<td>176</td>
</tr>
<tr>
<td>China</td>
<td>268</td>
<td>900</td>
</tr>
<tr>
<td>Middle East</td>
<td>86</td>
<td>423</td>
</tr>
<tr>
<td>Africa</td>
<td>90</td>
<td>327</td>
</tr>
<tr>
<td>Latin America</td>
<td>185</td>
<td>496</td>
</tr>
<tr>
<td>S&amp;E Asia</td>
<td>201</td>
<td>914</td>
</tr>
<tr>
<td>Other</td>
<td>150</td>
<td>398</td>
</tr>
<tr>
<td>Developing &amp; E. Europe</td>
<td>1024</td>
<td>3633</td>
</tr>
<tr>
<td>Average per year</td>
<td>68</td>
<td>145</td>
</tr>
<tr>
<td>World Total</td>
<td>2106</td>
<td>5679</td>
</tr>
<tr>
<td>Average per year</td>
<td>140</td>
<td>227</td>
</tr>
</tbody>
</table>

Table 9 presents estimates of the capital resources needed to supply energy in the two scenarios.*

In the Reference Scenario, developing country and Eastern Europe requirements during the 1985-2000 period are nearly $70 billion per year for the entire energy sector and about $45 billion per year for the electric power subsector. They increase steeply to $145 billion/year and $105 billion per year respectively in the first quarter of the next century, rising from less than half of the annual global investment requirement to 64 percent. These figures are somewhat smaller than those given in other recent reports. For instance, the World Bank reports that 70 developing countries plan power sector investments of about $750 billion during the decade of the 1990s—a rate of $75 billion per year.** Many observers believe, however, that these plans are unrealistically optimistic, in the sense that the needed capital will not be available. "Capital requirements" here refer to capital for economic growth realized, not

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*Estimated by combining energy outputs with an incremental capital-output ratio (ICOR) reflecting regional efficiency in converting investment capital into energy output and conservative assumptions about fixed prices for energy. If prices are assumed to be higher, the estimates of capital requirements will be higher. ICOR is the macro-economic equivalent of an investment/benefit ratio, measuring the increase in output associated with an additional increment of investment. For the Reference Scenario, ICOR was assumed to be 4:1 for industrialized countries, 6:1 for the Soviet Union and Eastern Europe, and 8:1 for developing countries in the 1985-2000 period, and 4:1, 5:1, and 7:1, respectively, for the 2001-2025 period.
economic growth desired. If more energy services can be provided, the development process will benefit, but the capital estimates will rise accordingly, unless the increase in energy services comes from improved efficiency.

The estimates for the developing world in the 2000-2025 period are daunting. Increasing overall energy sector investment from an average of $68 billion per year to an average of $145 billion/year appears far beyond the realm of possibility. Increasing annual power subsector investments by a factor of two seems equally unlikely. The current investment level of about $50 billion per year is already jeopardized due to overall national indebtedness and poor performance of electric utilities in many of these countries. The picture presented in the Reference Scenario suggests two fundamental issues for development assistance: (1) a high probability that expansion of the energy sector in general and the power sector in particular will be severely inhibited by capital scarcity, which will sharply slow development; and (2) a high probability that borrowing and lending for the energy sector will increasingly compete with needs of other sectors.

The impact of an energy efficiency improvement initiative, however, could be quite dramatic. The estimates of capital requirements for the Efficiency Scenario consider reduction in energy production requirements as well as improvements in the incremental capital-output ratio as a reflection of higher levels of institutional efficiency. The 50 percent reduction in capital requirements for the energy sector of developing countries and Eastern Europe amounts to a savings of $450 billion (1990 dollars) in the 1985-2000 period and $1,890 billion in the 2001-2025 period. The savings amount to about $60 billion per year for electric utility investments in the latter period. Taking into account capital requirements for the efficiency improvements themselves, which might amount to 10 to 20 percent of the gross savings, the net savings are striking.

These estimates indicate that for many countries an energy efficiency initiative could mean the difference between availability and scarcity of capital resources for non-energy sectors of the economy, and between possible versus impossible levels of capital resource requirements for the energy sector itself.

\(^1\) ICOR was assumed to improve from 6:1 to 5:1 in 1985-2000 and from 5:1 to 4:1 in 2001-2025 for the Soviet Union and Eastern Europe, and from 8:1 to 7:1 in 1985-2000 and from 7:1 to 6:1 in 2001-2025 for the developing countries.

\(^2\) The lack of any capital requirements in Eastern Europe in the Efficiency Scenario results from the absolute decline in primary energy consumption envisioned in the scenario. In reality, of course, there will be capital requirements for new facilities to replace many of those operating today. These are not accounted for in this analysis.
EXPERIENCES IN SEVERAL COUNTRIES

Over the past 10 years, energy conservation programs have been implemented in a number of developing countries, both with and without assistance from international donor organizations. In this chapter, we briefly review selected programs in Brazil, China, Pakistan, Hungary, Tunisia, and the Philippines. These examples were chosen to represent some of the more successful national conservation efforts in the developing world.

Brazil

A national electricity conservation program (PROCEL) began in Brazil at the end of 1985. In its first four years, PROCEL primarily engaged in technology R&D, demonstrations, education and promotion, and direct installation of conservation measures. As of early 1990, PROCEL had undertaken over 150 projects with a total budget of around $20 million. Collaborating organizations such as utilities and research institutes contributed a similar amount.

PROCEL has helped to advance the development and commercialization of a number of energy-efficient technologies, including improved refrigerators, energy-efficient lamps, reflectors for fluorescent fixtures, and building control systems.

One of PROCEL's larger projects has been the replacement of incandescent street lights with mercury vapor and high-pressure sodium lamps. Over 280,000 lamps were replaced during 1986-89, with most of the cost paid by PROCEL. PROCEL spent over half its budget during 1986-89 on education, promotion, and information dissemination. Activities included equipment testing and labeling, auditing of industries and commercial buildings, manuals, fairs, and seminars.

Although it is difficult to determine which conservation measures were installed due to PROCEL's efforts, program officials estimated direct savings of 1.1 TWh per year as of 1989. Total savings, including information programs and other activities, have been estimated as high as 2.5 TWh per year. The lower figure would mean that PROCEL enabled utilities to defer investing about $0.6 billion in new power plants, transmission lines, and distribution facilities.41

PROCEL is by now well established and could be doing more if the funds were available. Indeed, it appears likely that funding will significantly expand (in part from a World Bank loan). Increase in program activities, as well as new policies, will be needed to attain the official electricity savings goals, which are equivalent to over 10% of projected electricity demand in 2000 and about 14% of projected demand in 2010.

Programs that finance conservation measures installed by businesses and industries have met with less success. This is attributed to limited promotion, poor program organization, inconsistent energy pricing policies, and economic instability.42 Because of these problems, one financing program was revamped in early 1990. Also, a new comprehensive energy conservation program was created by the President of Brazil in 1990. This program, directed by a ministerial-level executive committee, began by proposing minimum efficiency goals for important end-use technologies such as automobiles, refrigerators, and motors.
China

During the period of the sixth Five-Year Plan (1981 to 1985), the Chinese government implemented a massive program to achieve energy conservation in industry. Investments totaling around 10 billion yuan were made for retrofit of existing equipment and installation of new energy-saving equipment by the central government as well as by local administrations and enterprises.* The magnitude of the program is illustrated by the fact that the amount made available for conservation in 1981 and 1982 was more than 10 percent of the total investment in energy supply in those years. While some of the projects contributed to increased production capacity as well as energy conservation, the size of the Chinese investment is nonetheless impressive.

Loans for conservation projects were available at an interest rate almost one-third lower than the standard rate. The criterion applied for projects required that the cost of saving a unit of coal, oil, or electricity per year be less than the marginal cost of new coal supply capacity (or its equivalent, including transportation). Projects implemented included cogeneration systems, recovery of waste heat and gases, renovation of industrial boilers and furnaces, upgrading of small fertilizer plants and cement kilns, and continuous casting technology for steel processing.

The 10 billion yuan investment resulted in estimated energy savings equivalent to 6.3 percent of total industrial energy consumption in 1985. The average cost for savings was 370 yuan per annual ton, slightly below the cost of new coal supply.

China’s energy conservation efforts were not limited to investment projects. Regulations and guidelines concerning energy use were promulgated, engineers were trained in energy conservation, and energy conservation centers were established and equipped throughout the country to provide technology consultation, equipment testing, and feasibility studies. In addition, the government raised the price of most coal, oil products, and natural gas several times during the past decade. At current prices, however, all of the major fuels in China still receive substantial subsidies. Since the end of the Sixth Five-Year Plan, the federal government has continued to provide funds for energy efficiency projects and has strongly encouraged local administrations and industries to match these investments.

Pakistan

Since 1986 the government has been implementing a National Energy Conservation Program, with technical assistance from the U.S. Agency for International Development. The program includes audits, feasibility studies, technology demonstration projects, training, and information/promotion. It focuses primarily on retrofits in industry and buildings, although some activities are being carried out in transport and agriculture. The National Energy Conservation Centre (ENERCON) was established in 1986 as the energy conservation agency. No financial incentives are offered for energy conservation investments, but an Energy Conservation Loan Fund has been included in the current Five-Year Plan, and there is discussion with the World Bank to include a $35 million line of credit in the next Energy Sector Loan to help finance energy conservation projects. In the power sector, the national utility has undertaken a major effort to reduce T&D losses and has assessed the energy conservation potential of thermal power plant rehabilitation.

*It is difficult to express the investment in U.S. dollars, as the official exchange rate rose from 1.7 to 2.9 yuan per dollar during the period (and to 4.7 yuan per dollar in 1989). Further, since these rates are administered rather than determined by the market, use of them may distort the real comparative value of the two currencies.
The initial phase of ENERCON’s program focused on developing capabilities and increasing awareness. Over 3,000 Pakistani engineers, businessmen, and policymakers have attended energy management courses and workshops put on by ENERCON. These training courses were complemented by a comprehensive information and outreach program that provided technical and financial information, such as a bimonthly newsletter, technical fact sheets, an equipment cost directory, national and international technical symposia, a National Energy Conservation Award program, and related press releases, articles, and advertisements.

Implementation of energy conservation measures is just beginning. Through energy audits, annual savings of $10.5 million has been identified to date and an estimated savings of $4 million has been achieved. A study found that of a sampling of 265 energy conservation projects identified in audits of 40 companies, 55 percent had been implemented. Through an Industrial Boiler/Furnace Tune-Up Program, average efficiency improvements of 10 percent per combustor have been estimated. The Boiler/Furnace Tune-Up Program and related combustion analyzer demonstration program saved an estimated 3 percent of Pakistan’s total natural gas consumption. In the transport sector, the preliminary results of a free tune-up demonstration program for automobiles show average fuel savings of 11 percent for the 260 participating vehicles. Finally, the preliminary results of a tubewell retrofit program show an average efficiency improvement of 60 percent in 14 tubewells retrofitted so far.

An important finding from the experience in Pakistan is that it is possible to create generic packages of conservation measures, particularly for industrial retrofits, that can be spread widely through the country after thorough testing and demonstration. Such approaches to energy efficiency in existing facilities may be applicable to other countries as well.

**Hungary**

Since 1983, Hungary has received three World Bank loans for energy conservation. The funds have been used for loans to help industrial enterprises finance the implementation of energy audit recommendations. Some of these loans have also gone to companies that manufacture efficiency products, such as high-efficiency windows and foam insulation for freezers. The effort is co-managed by the National Bank of Hungary (NBH), which handles procedural details, and the Energy Supervision Institute (ESI), which handles the technical aspects of the program. A network of commercial banks is responsible for loan intake, processing, and disbursal, and the ESI reviews the technical viability of each proposed project. Post-installation evaluations of all the projects are conducted by the district offices of the ESI. If a company does not meet the savings originally estimated by the company itself, its loan becomes due immediately. These sanctions are controversial in Hungary, but are only applied where the actual savings are radically different from the expected savings. About 2 to 3 percent of all loans have had these sanctions applied.

Until 1989, the Hungarian government offered small subsidies in the form of concessional-rate loans as incentives for companies to participate in the program. The loans, offered in 1983, 1986, and 1989, totaled $95.6 million. While the subsidy has been discontinued, there has been no concomitant downturn in loan applications, according to NBH staff. One of the reasons for the success of the program is that it provided access to otherwise scarce foreign exchange, allowing companies to purchase foreign equipment. Another is that the Hungarian government actively supports and promotes energy conservation investments because it is concerned about the cost of expensive imported fuels.
Tunisia

Tunisia's interest in energy conservation can be traced in large part to the government's concern over growing domestic oil consumption, which has constrained the availability of Tunisian-produced oil for export. In 1985, the government created an independent conservation agency called Agence de Maitrise de l'Energie (AME), and gave it sufficient legislative and administrative authority to put the country on a path to higher energy efficiency. Since that time, AME has led an ongoing public outreach and marketing effort on conservation. In 1986, an energy audit program was initiated, mandating audits for the 200 largest industrial, ground transport, and commercial sector companies, representing 80 percent of Tunisia's total commercial energy consumption. AME reviews each audit and reimburses the companies for half of the audit cost. Companies are required to sign a contract with AME on implementing the audit recommendations. AME provides implementation assistance, including paying half of the cost of prefeasibility studies and recommended training programs. Companies also receive permission, for tax purposes, to accelerate the depreciation on the conservation hardware investments and are eligible for low-interest loans for the conservation investments. Also, any company that wants to import equipment for improving its energy efficiency can get an import tariff reduction for that equipment. These incentive programs are financed in part through a 1/2 cent per litre sales tax on fuel oil and gasoline.45

Even if the companies implement the audit recommendations, they still must have new audits every three years. The follow-up audits identify new cost-effective conservation measures and also provide information on the performance of the conservation measures. Small and medium-sized companies may also participate in the conservation program.

AME is currently working with the National Institute for Standards to establish energy efficiency standards for refrigerators, air-conditioners, heaters, boilers, and other appliances. It is also trying to increase domestic manufacturing of energy-efficient products, especially in lighting, refrigerators, industrial boilers, and burners. It is working with local manufacturers of these products to inform them of high-efficiency technologies and overseas companies with whom they might form joint manufacturing ventures.

Since 1986, when AME began work, Tunisia's ratio of growth in energy consumption to growth in GDP dropped from 1.3 in 1985 to 0.8 in 1989. AME staff consider this to be a partial indicator of their success. In the highly energy-intensive cement industry, energy consumption decreased by 40 percent between 1980 and 1989, in large part because of AME's auditing, training, and implementation work with the industry.

Philippines

In the Philippines, the government began to actively promote energy conservation soon after the 1973 oil price rise. A National Energy Conservation Program was legislated in 1975. In 1978 the government established the Bureau for Energy Utilization (BEU), under the Ministry of Energy, to develop and implement the program. Measures to promote conservation have included prohibitions on the import or manufacture of large cars and requirements that large energy users monitor and report their energy consumption, appoint energy managers, and submit energy management plans and energy audits to the BEU. The BEU has provided technical assistance, including free energy audits. Financial incentives for energy conservation have included loans, import duty and tax exemptions, and tax allowances.

The Philippines' energy conservation program achieved some impressive results through the mid-1980s. The BEU estimates that between 1977 and 1982, its programs saved up to 15 percent of energy consumption in 205 participat
ing industrial and commercial enterprises.46 However, most savings were achieved through low cost measures and it has been estimated that additional savings of 10 to 40 percent can still be achieved.

Since 1987, the government—in partnership with the private sector and with assistance from AID—has been implementing the Technology Transfer for Energy Management (TTEM) program, which focuses on the industry and commercial buildings sectors. The TTEM program includes a loan program for the demonstration of technologies, technical assistance, training, and information dissemination. Implementation of this program has been slow; loans totaling about $2 million had been issued through 1990.

LESSONS LEARNED

It is clear that well-designed energy conservation programs can be effective in the developing countries. Experience to date in the implementation of such programs holds valuable lessons about the appropriateness and effectiveness of various strategies. Significant energy savings can be captured quickly and cost-effectively using proven technologies, but success is not easily achieved. Some specific lessons and guidelines are summarized below.

Government Commitment

A common feature of successful energy conservation programs in developing countries is government commitment. Empowering the implementing agency with the legislative, administrative, and long-term funding authority needed to design and implement effective conservation programs is important. Energy users must understand that energy efficiency is an important national priority and that words will be followed by deeds. Not only must the government endorse energy efficiency at the highest levels, it must also set an example of good conservation practices by improving the efficiency of its own buildings and enterprises. (In some countries, over 80 percent of the industrial energy use is in state-owned facilities). Most of the successful examples of conservation programs described above could not have taken place without this high level of government commitment. Countries without similar government support have had difficulty in achieving successes.

Commitment to energy conservation must exist on the donor side also. A program without continuity of support, both in terms of funding and intangible factors, will not succeed. At the same time, support should not be blind. Major donors must monitor performance to ensure that funds are being effectively used to meet stated objectives.

Human Resource Development

Energy efficiency and conservation programs have complex organizational and technical requirements. Whether the program involves the development of energy policies or implementation of programs, a high level of technical and managerial skill is needed. It is presently very difficult for any country, even one with a strong commitment to energy conservation, to arrange for training staff to design and carry out energy efficiency policies and programs.

The successful programs discussed above have been accomplished essentially through self-training or as a part of an energy conservation project funded by a donor (as in Pakistan). More extensive training, for specific projects, will help spread energy efficiency programs and policies among developing countries.
Access to Information and Technologies

An adequate set of current, up-to-date material from which to learn about the engineering, economic, and managerial aspects of energy conservation is lacking. This paucity of information is often cited as a major deterrent to continued advances in those countries which have mounted significant conservation programs. For example, there is virtually no information about technologies for daylighting in commercial buildings in developing countries in Southeast Asia, in spite of the fact that daylighting is technically and economically very well-suited to the region.

Similarly, the Chinese have noted that their energy efficiency efforts will in time flounder unless they have access to advanced technology. To date, most of their successes have been achieved through enhanced energy management efforts or replacement of old, outmoded, and very inefficient technology with improved but still not modern technology.

Capital for Energy Efficiency

Energy efficiency improvements usually require capital. The net effect of well-conceived efficiency investments is to reduce capital requirements for energy. However, energy supply projects continue to receive virtually all of the public funding for energy. For energy efficiency to become a dominant aspect of energy policy, the lack of balance between investments in projects to increase energy supply and those intended to reduce demand must be redressed.

The funds could come from policies to attract private capital, as in Tunisia; from large-scale public investments, as in China; or from concessionary loans, as in Hungary. If funds for energy development from international lending agencies were allocated to energy supply and efficiency projects on a common basis of merit, capital for energy efficiency investments would increase significantly. For efficiency to spread widely, a greatly increasing share of energy investment in efficiency projects will be required. Examples of current activities that are designed to link electricity efficiency projects to capital funds include the Program to Accelerate Commercial Energy Research (PACER) in India and the Multiagency Working Group on Power Sector Innovation (MAGPI).*

Energy Pricing

Energy pricing based on long-term marginal costs is a very important element of efficient resource allocation. Rationalization of energy prices is often very difficult to achieve, however, and will usually take many years to implement because of a host of real-world economic, political, and social constraints. While pricing reform is generally important to the success of energy policies and to implementation of energy efficiency programs, it should not be a precondition to implementation of assistance programs, since this could result in major delays and thus significant energy waste. In addition, pricing alone is insufficient to achieve major gains in energy efficiency, since technical assistance, training, and access to capital will often be required if the prices are to have the desired conservation effects.

*MAGPI is an innovative approach to foster collaboration on electricity issues of developing countries among donor agencies (KfW and GTZ from Germany, FINNIDA from Finland, ODA of Britain, the U.S. Agency for International Development, and the United Nations Department for Technical Cooperation for Development) and the World Bank.
Conclusion

The examples described in this chapter demonstrate the diversity of programs and policies that can spur energy efficiency. The lesson is that there are many different ways to achieve success, and countries will develop the types of programs that best fit their situations. At the same time, knowledge gained from programs in one country can and should be transferred to others.

To date, efforts to promote energy conservation in many developing countries have stopped at paper studies or energy audits of individual facilities. There is a need for an overall strategy for inducing, persuading, mandating, financing, or otherwise managing the implementation of the study and audit recommendations. Program evaluation is also important. The effectiveness of efficiency investments should be analyzed with respect to energy savings achieved and the cost per unit of energy saved, so that mistakes are not perpetuated and so that the cost of conservation can be compared to cost of providing additional energy supply. The existence of a national energy conservation agency can help ensure that efforts are comprehensive. The autonomous or semi-autonomous national energy conservation center may be an effective institutional model, although activities to date are not so far along for the strengths and weaknesses of such a center to be evaluated in depth. Experience in both industrialized and developing countries suggests that financial incentives are usually required to stimulate energy conservation technologies, at least in the early stages of a program when efficient technologies are still perceived as being risky. Several industrialized countries and some developing countries have also learned that energy performance standards and mandatory energy efficiency requirements and regulations can be very effective. For example, the development and implementation of energy standards for commercial buildings, underway with donor support in Indonesia, Malaysia, the Philippines, Singapore, and Thailand, can produce substantial cost-effective energy savings.
Before addressing the issue of what is to be done, it is useful to revisit what we have learned in the report. Chapter II shows the rapid growth of commercial energy use in the developing world and Eastern Europe during the past fifteen or so years. This growth is large both in comparison with that of the industrialized countries and with respect to the capability of many developing countries to pay for it.

Chapter III demonstrates that an important part of the problem is the inefficiency with which energy is produced and used. One can infer from the information in Chapter III that efficiency improvements could increase energy services 20 to 25 percent over the next ten years and 40 percent over the next twenty or so years. Another way of looking at this is that energy demand growth might be cut almost in half over the foreseeable future in developing countries, if as much emphasis were given to improving efficiency as to increasing supply during that time period.

Chapter IV confirms this inference, making clear that energy efficiency gains for developing countries can substantially reduce (1) energy growth rates while providing increasing energy services; (2) overall capital requirements for energy services, thus freeing capital for other social purposes; and (3) local and global environmental impacts. In short, a major thrust to increase energy efficiency can be a spur to sustainable economic development for developing countries, as well as a benefit to the global environment.

Chapter V provides some examples of successful conservation programs in developing countries.

Indeed, one or more of the countries have mounted programs of such a magnitude that they have altered growth of commercial energy in much the manner suggested in the efficiency scenario of Chapter IV.* Chapter V also summarizes some lessons learned from these initial efforts to promote energy efficiency in developing countries. In particular, this chapter makes clear that major advances in energy efficiency require a clear government commitment to efficiency, the development of human resources to design and carry out programs and policies, access to information and technologies to assure that the countries can take advantage of the best approaches to improve efficiency, and capital for energy efficiency. If these conditions can be met in significant measure for a variety of developing countries, then it is reasonable to expect that a diversity of policy reforms and efficiency programs will come to bloom.

What can be done to encourage the types of programs described in Chapter V and to overcome common barriers? Clearly, a first step depends on priorities in the developing world. This report makes the case that increasing energy efficiency is very beneficial to developing countries. Yet, leaders of developing countries have a host of competing needs with which to contend. It is not obvious that energy efficiency is more important than, say, improved health care, better shelter, or improved diets. As a result, the economic planner in a developing

*China is noteworthy in this regard. However, even for China, where significant resources have been allocated to energy efficiency, the continued effectiveness of the program is not assured. Long-term success requires a continuing commitment of the government, new policies and programs, higher levels of training, and access to modern technology. This latter can entail both imports and indigenous manufacture of energy-efficient equipment.
country may well relegate energy efficiency to the second tier of issues, those that can be dealt with after the most pressing problems are addressed. It is important to recognize, however, that energy efficiency, by freeing large amounts of capital, can make it possible to more effectively address these pressing social problems. Citizens, organizations, and governments in industrialized countries can help legitimize the view of the value of energy efficiency in several ways. The first is to "practice what we preach."

If energy efficiency is beneficial for developing countries, then it should be equally valuable for the rest of the world. Unfortunately, the commitment of many of the OECD countries to improving energy efficiency has waned during the past few years, particularly as oil prices have fallen. A renewed commitment is in order, for a variety of reasons.

Second, it is appropriate and desirable for industrialized countries to mount active programs to support increasing energy efficiency in the developing world. Such efforts would be beneficial to industrialized countries themselves: economically, by reducing long-term pressures on world energy (and especially oil) supplies and creating markets for efficiency-improving technologies; environmentally, by achieving reductions in greenhouse gas emissions in a highly cost-effective manner; and socially and politically, by helping developing countries improve the economic and social well-being of their populations.

The efforts by industrialized countries need to be focused on at least four types of activities:

1. **Financing**

   By changing policy, industrialized countries and multinational banks can make financing at least as available for energy-efficiency as for energy-supply investments. For developing countries with limited experience in energy efficiency programs, the loan funds need to be supplemented with grants that permit the planning and organization to carry out such programs.*

2. **Training**

   The key issue in helping developing countries establish sustainable programs is a skilled group of professionals. Training in all aspects of energy efficiency is essential, and is not now available from any source at the level required. There is a particular lack of training in energy conservation planning, such as data gathering, modeling, and policy analysis, in addition to needs for technical and engineering training.

3. **Increased Awareness and Implementation of Programs**

   Raising energy efficiency to the top of the international agenda will require a considerable effort to educate high-level decisionmakers as well as ordinary citizens. Public education campaigns should be a priority. Energy efficiency should be on the agenda of all high-level trade and aid negotiations. At a technical level, easily accessible information networks and data bases are needed. Special support should be given to "model efficiency programs" that can serve as examples for other countries. The implementation of well-designed programs to promote energy efficiency can ensure that both capital and training for energy efficiency are put to good use.

4. **Technology Transfer**

   Improving energy efficiency will require greater access by developing countries to energy-saving

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*In particular, institutions in developing countries need to be strengthened to accomplish such activities as packaging efficiency projects together to create a set of projects large enough to qualify for loans from multinational banks.
energy-saving technologies available in the industrialized countries. The U.S. and other OECD countries should undertake to stimulate the transfer of such technologies through trade negotiations and other means. Developing nations should be encouraged to reduce tariffs and other barriers to the import of efficient technologies. Technical assistance should be offered to help those nations develop indigenous capabilities to design and manufacture efficient technologies.

We believe that the next steps in the United States and OECD nations involve: (1) engaging in dialogue with leaders of developing countries on the issues raised in this report; (2) defining in considerable detail the four activities described above; and (3) raising policy issues at high levels in the United States and OECD to initiate these new efforts.
APPENDIX A

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How the Scenarios Were Developed

The scenarios of world energy demand and supply described in Chapter IV were developed in two basic steps. In the first step, energy demand in the year 2025 was estimated for the five end-use sectors for each of the nine regions into which the world was divided.

The demand scenarios were developed by three research groups: Lawrence Berkeley Laboratory (developing countries), Battelle Memorial Institute (Eastern Europe), and World Resource Institute (industrialized countries). While the exact method differed in each case, the basic approach employed by each group involved estimating future levels of activities and equipment stocks and their energy intensities in each sector. Activities were divided into those using fossil fuels, electricity, and, in the case of the developing countries, biomass. Intensities were estimated separately for each energy type (fossil fuels were not disaggregated at this stage). Values for the base year (1985) were derived from various studies and the scenario authors' estimates, while values for 2025 were estimated. The result of the energy demand scenarios was total final demand for each energy type in 2025 in each region.

The second step involved incorporation of the estimated energy demands into a model that derived primary energy use in each region. This model was based on the IEA/ORAU Long Term Global Energy-CO₂ Model (the Edmonds and Reilly model), modified by ICF, Inc. for use in the U.S. Environmental Protection Agency's Atmospheric Stabilization Framework set of linked models. This model uses inputs on fossil fuel resources and non-fossil energy supply to estimate fuel selection and choice of electricity-generation technologies. The primary energy supply of each fuel estimated by this model is then used to calculate emissions of the various greenhouse gases.

The remainder of this appendix describes in somewhat greater detail the method employed to derive energy demand scenarios for the developing countries. (A more detailed discussion may be found in Reference 37.)

Developing Country Energy Demand Scenarios

Estimating energy demand in the year 2025 required envisioning how today's developing countries might evolve between the present and the year 2025. Given the enormous amount of change that has occurred in these regions in the past 35 years and is expected in the future, attempting to look ahead 35 years is obviously very difficult. In constructing the scenarios described in this report, the authors used a combination of extrapolation from the past and judicious use of analogies from today's industrialized countries. Effort was taken to choose plausible values for the 2025 estimates and to ensure that the scenario outcomes were consistent among sectors.

The method used for the industrial, agricultural, and commercial sectors was much simpler than that used for the residential and transportation sectors. In each of the former sectors, a single indicator of activity-value-added (VA) in U.S.
dollars was used, and energy intensities (energy per unit of VA) were estimated for fuels and electricity. The levels of activity were estimated based on the assumed GDP growth and assumptions about macroeconomic structural change (e.g., agriculture declines as a share of GDP). Estimation of intensities considered changes in processes and capital stocks, and, in the case of industry, structural change within the sector.

The residential sector was divided into five end-uses (cooking, water heating, space heating, lighting, and other electric appliances). For Asia and Latin American, future levels of equipment ownership were estimated for different household income groups in part by reference to current ownership levels in countries at similar per capita income as projected for the developing country groups in 2025. Africa was divided into high-income Republic of South Africa, middle-income North Africa, and low-income "rest of Africa," while China and the Middle East were not disaggregated into income groups. Future energy intensities were estimated based on judgments regarding technology trends and their penetration in each region.

The transportation sector was divided into air and land transport, and land transport was further divided into vehicle types (cars, trucks, and buses). Future vehicle ownership levels were estimated in a manner similar to that employed in the residential sector, although in this case annual average distance travelled was also estimated for each vehicle type. Estimates of vehicle fuel intensity were based on judgments as to technology trends in each region.

Comparison of These Scenarios With Other Projections

Many groups construct projections or scenarios of long-range future energy use in various regions of the world. One often cited projection of world energy consumption by region is that prepared for each World Energy Conference (WEC).48 The most recent WEC projections, prepared for the 1989 conference, give primary energy consumption under "Moderate" and "Limited" economic growth conditions.47 Between 1985 and 2020, primary energy consumption in the developing countries in the WEC Moderate case grows at about the same rate as in the Reference Scenario in this study. The assumed economic growth rates are somewhat higher in the WEC projection (a world average of 3 percent per year) than in our scenarios (2.5 percent). Thus, similar to our Reference Scenario, the WEC study projects considerable reduction in energy intensity. Primary energy consumption in the developing countries in the WEC Low case, which assumes world average economic growth of 2 percent per year, grows at about the same rate as in our Efficiency Scenario, but in this case the slower growth is due to lower economic growth, not to accelerated efficiency improvements.

Another recent projection of note is the so-called "Country Study Base Case" prepared for the Energy and Industry Subgroup (EIS) of the Intergovernmental Panel on Climate Change (IPCC). The Country Study Base Case, prepared by a U.S./Japan Expert Group, integrated numerous individual country studies, prepared by country experts or official organizations, into a consistent base case of world energy use and consequent emissions of greenhouse gases.49

Primary energy use in the developing countries in this projection grows much faster than in our Reference Scenario between 2000 and 2025, and is about one-third higher in 2025. It appears that the assumed economic growth rates in the developing country studies were higher than those used in our scenarios. The assumed growth rate in the Chinese country study, for example, was 5.6 percent per year, whereas in our scenarios it was 4.1 percent per year. While
the EIS suggested that country-specific estimates be consistent with a moderate rate of growth for the global economy, it was agreed that individual countries would provide their own estimates of economic growth. What is very uncertain in the Country Study Base Case is whether the capital and environmental costs of such high rates of energy growth could be managed. One important finding of our own scenario work was that substantial reduction in energy intensity will be required in the developing countries in order to sustain even the relatively moderate rates of economic growth that we assumed. By reducing capital and foreign exchange requirements for energy supply, our Efficiency Scenario would likely enable developing countries to grow at a somewhat higher rate.
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