Potential for Energy Efficiency: Developing Nations

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Glossary

economic potential The energy savings achieved if all new investment and retrofit were based on the most energy-efficient technologies that were cost-effective at that time.

energy intensity The amount of energy required to produce a unit of economic output.

market potential The energy saving that is expected to be realized given the existing energy prices, consumer preferences, and energy policies.

suppressed demand When the demand for energy services is low due to income, access, and infrastructure constraints, not because of consumer preferences.

technical potential The achievable energy savings that result from introducing the most energy-efficient commercial or near-commercial technology at a given time, without taking into account the costs or the life of the equipment to be replaced.

welfare potential The economic potential for energy savings when external costs and economic opportunity costs are included.

This article presents the potential for improvements in energy efficiency in developing countries. It begins by discussing the relevant development context as well as additional barriers that energy-efficiency programs face in poor countries. Then, regional overviews of the potential for energy efficiency within key sectors are presented.

1. INTRODUCTION: THE CONTEXT FOR ENERGY EFFICIENCY

1.1 The Development Context in the South: Poverty and Suppressed Demand for Energy Services

The context for end-use energy efficiency improvements in developing nations is their current energy poverty and the large share of the world's population that uses almost no commercial energy. Per capita consumption of primary energy in Africa, for example, is only 13% of the average in Organization for Economic Cooperation and Development (OECD) countries, whereas for all developing countries it is less than one-fourth (Fig. 1). The gap is even greater for electricity consumption (Fig. 2).

It is common in many poor countries for families not to be able to afford enough energy to heat their

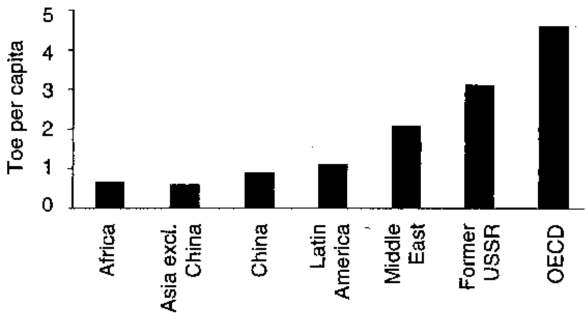

FIGURE 1 Total primary energy consumption per capita. Toe, tons of oil equivalent.

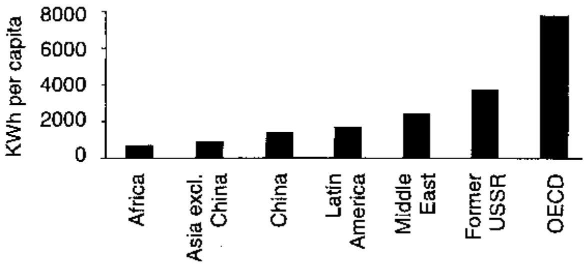

FIGURE 2 Electricity consumption per capita.

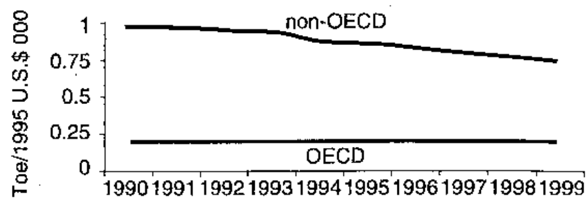

FIGURE 3 Energy intensity (energy use per unit GDP) in the developing and industrialized world.

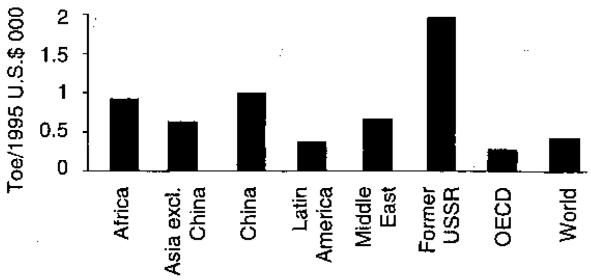

FIGURE 4 Energy intensity by region (energy use per unit GDP).

homes comfortably and cook sufficient food, let alone benefit from high-quality lighting or television. This energy poverty implies massive unmet (or suppressed) demand for energy services in these countries, with demand constrained by lack of energy infrastructure as well as income. In many African countries, for example, less than 10% of the population has access to electricity, and it is common for more than 80% of residential energy demand to be met by fuel wood.

Given these low levels of energy consumption, how do we know that there is a potential for improving end-use energy efficiency? First, it must be remembered that although developing countries' share of fossil fuel consumption is small, rapid population and economic growth will result in a substantial increase in this share in the early 21st century. From 14% of world primary energy demand in 1971, developing countries will account for 40% by 2010 if present trends continue. Even with aggressive policies to promote energy efficiency, their energy demand is likely to increase 5- to 10-fold during the next 30–40 years, resulting in a 3-fold increase in world energy demand.

Second, one measure of the potential for energy efficiency improvements in developing nations is their much higher energy intensity [energy use per unit of gross domestic product (GDP)] compared to that of industrialized countries. As Fig. 3 shows, based on International Energy Agency data, energy use per dollar of GDP in the developing world is almost three times that of the OECD countries. If we consider the difference in purchasing power of developing currencies, this picture changes, with developing countries being only approximately 30% more energy intensive. For products that are traded, particularly those exported by developing countries, purchasing power parity does not really matter. In other words, if India is exporting steel and using two or three times as much energy to make a dollar's worth of steel, that is a very high cost and a competitive disadvantage. Of course, it also represents an opportunity to increase energy efficiency in a cost-effective manner. Even within the developing world, however, there are vast differences in energy intensity, as shown in Fig. 4.

1.2 Additional Barriers to Energy Efficiency in Developing Nations

Although barriers to the uptake of energy efficiency have been generally described elsewhere, they take a different form in many developing countries, and some are unique to developing countries. Before discussing different regions, however, it is useful to highlight some of the more significant barriers in developing countries.

1.2.1 Affordability and Financing

Investment in energy efficiency improvements is often constrained by the limited and irregular cash flow in poor households and difficulties in accessing additional finance; they frequently have to rely on hire purchase agreements or "loan sharks." Poor households sometimes invest in fuels and appliances that, ironically, are inefficient in both energy and economic terms. Poverty dictates overlooking long-term factors such as the life cycle costs, efficiency, and safety of an appliance.

For fuel purchases as well, households are often constrained by income flows, with a decision on purchase depending on the availability of money at a particular time. When there is little, kerosene and coal stoves are used because one can buy these in small amounts. Householders know that buying fuels this way is expensive, but not enough money is available to buy in bulk.

Even within industry, a shortage of capital or high interest rates are significant barriers to normal equipment upgrades, not to mention the purchase of more expensive energy-efficient equipment. This means that the rate of capital stock turnover is lower than for similar industries in industrialized countries.

1.2.2 Information

Information and awareness programs need to take into account the wide range of stakeholders involved in the delivery of energy efficiency services. For example, poor consumers may have low levels of literacy or need materials in local languages. Other stakeholders include local government, utilities, manufacturers, developers, builders, and nongovernmental organizations—all with different informational requirements. Often, awareness programs tend to provide broad conceptual information when the target audience requires more sophisticated information. Where people are already aware of broad notions of energy efficiency, for example, information may be needed on practical implementation, such as how to build an energy-efficient house or install a ceiling, where to access financing, how to mobilize capital to finance energy efficiency for the poor, and how to facilitate community participation.

1.2.3 Physical Access to or Availability of Fuels

In certain circumstances, low-income households are unable to secure the best mix of fuels because certain fuels are not readily available. For example, although kerosene networks are good in many countries, with both fuels and appliances being readily available, many poor household do not have electricity connections. Although a few developing countries have started to develop residential bottled gas networks, this is the exception rather than the rule. The coverage of distribution networks is often weak and inhibited by poor transport infrastructure and a lack of access to transport.

1.2.4 Split Incentives: Construction, Ownership, and Use

In the delivery of housing, those making the initial capital investment in constructing a house are generally separate from those who will live in it and pay the operating costs. It is not common, therefore, to find developers investing in energy efficiency. The consequence is that the low-efficiency house has high operating costs. This is a major problem in developing countries with large public housing programs because the government priority is to deliver as many houses as quickly as possible; for both government and contractors, the tendency is to cut corners and minimize initial cost. It is also a problem in industrialized countries.

1.2.5 Lack of Tenure and Urban/Rural Commitment

In many urban informal settlements, appliance ownership is constrained by space and tenure problems. Lack of space, for example, means that in informal electrified settlements and backyard shacks, more households own two-plate electric stoves than stoves with ovens. More important, the tenure problems in informal unplanned settlements and shacks play a direct role in purchasing electrical appliances or other expensive investments in efficiency. Migrant workers continue to play a large role in many countries' urban communities. They are committed to their rural households and view urban life as temporary and thus tend to save or remit money for the maintenance of the rural households, which obviously implies an even lesser willingness or ability to pay a higher cost for efficient appliances.

1.2.6 Multiple Fuel Use and Household Needs

Multiple fuel use means that households use more than one fuel for the same end use. It is common to use gas, kerosene, coal, and/or electric stoves for cooking. Gas might be used for specific tasks (such as cooking special quick foods) and kerosene appliances used for foods that take a longer time to cook. Therefore, although gas may be a more energy-efficient cooking fuel than kerosene or electricity (and healthier than kerosene), households may not completely stop using kerosene after they buy a gas stove. For example, they may use kerosene for cooking certain foods or if they run out of gas and do not have enough cash to buy an entire gas canister since kerosene can be purchased in small quantities. Also, in some contexts one appliance serves more than one purpose, as in the case in which a kerosene or coal stove is used for cooking and space heating.

1.2.7 The Symbolic Value of Appliances

Not surprisingly, poor consumers do not simply consider the economics of appliance choices when making decisions: Symbolic value can be as important as functional value. For example, many formal households tend to replace their nonelectrical appliances with modern and sophisticated appliances immediately after electrification, not simply because electricity is cleaner and a more convenient fuel. There is a general perception that nonelectrical appliances are not appropriate for formal households. Having electric appliances attracts respect and envy, as symbols of modernity and comfort, and many people will go far to acquire them: The bigger the appliance, the better. Therefore, consumers may not be attracted to smaller, more efficient appliances unless other features enhanced the sense of "modernity."

1.2.8 Technical and Managerial Skills

Compared to industrialized countries, the industrial and commercial sectors in developing countries have lower levels of skill in both the technoeconomic dimension of energy efficiency and the managerial skill to develop and administer programs. There may be many qualified analysts and professionals, but resources are spread too thinly across huge economies and social needs. This is particularly a problem for small to medium firms.

2. TYPES OF POTENTIAL FOR INCREASED END-USE ENERGY EFFICIENCY

As a background to describing the potential for increasing end-use energy efficiency, it is important to understand the different types of energy efficiency potential. The most important categories are technical, ecnomic, and market (Fig. 5):

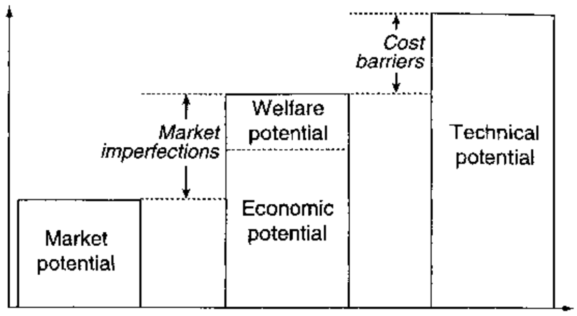

FIGURE 5 Types of potentials for energy savings.

- Technical potential is the achievable energy savings that result from introducing the most energy-efficient commercial or near-commercial technology at a given time, without taking into account the costs or the life of the equipment to be replaced. Realizing the full technical potential means scrapping existing appliances and equipment, although sometimes a phased technical potential is described, meaning that all new equipment is replaced with the most energy-efficient technology.
- Economic potential is the energy savings achieved if all new investment and retrofit were based on the most energy-efficient technologies that were cost-effective at that time. Cost-effectiveness at a minimum must include the energy and operating savings on the benefits side and the additional capital, any additional maintenance or control costs, and future replacement costs on the cost side. There are several perspectives on cost-effectiveness. For an individual firm or household, we would only consider the costs and benefits mentioned previously. In a macroeconomic perspective, however, we would need to consider the costs of implementing the energy efficiency programs. We would also include the benefits that could accrue to the broader economy, such as changes in technology costs over time through learning and economies of scale, or other spillover effects and nonenergy productivity gains. Finally, if we consider the societal perspective, we should include the avoided external costs of the energy saved by end-use efficiency measures. This would increase the economic potential since the benefits (avoided costs) increase. This is called the welfare potential of energy savings.
- Market potential is the energy saving that we expect to realize given the existing energy prices, technology, consumer preferences, and energy policies. This definition must take into account the social obstacles to energy efficiency and other market imperfections (i.e., no internalizing external costs) that block the realization of the full economic potential. In addition, market potential may consider whether energy users choose to use their energy

savings to buy more of what is essentially a less expensive service. This is called the take back or rebound effect.

These definitions also help us understand that the role of energy policy in promoting end-use energy efficiency is to both remove the market barriers that keep market potential below economic potential and address cost issues(e.g., through targeted research and development) that can bring the economic potential closer to the phase-in technical potential. Later, when we discuss the potential for energy-efficient improvements, we refer to economic potential unless otherwise noted.

3. *ECONOMIC POTENTIAL FOR ENERGY EFFICIENCY BY MAJOR DEVELOPING REGIONS*

3.1 India

3.1.1 Trends in Energy Intensity and Consumption per Capita

India, the world's second most populous nation, has seen its population explode from 300 million in 1947 to approximately 1 billion today. Energy consumption has grown rapidly through the process of development. Aggregate consumption has increased approximately 50% during the past decade. The share of commercial energy consumption increased from 26% in 1950–1951 to approximately 60% in 1994–1995. With an elasticity of commercial energy demand (i.e., the percentage change in energy demand for a 1% change in income) of approximately 0.92, and with the objective of rapid economic growth of 6% per annum, a high growth in commercial energy demand is expected. India is the second largest commercial energy consumer within non-OECD East Asia (after China), comprising 19% of the region's total primary energy consumption.

The current low per capita energy consumption (3% of that of the United States and 9% of that of Korea) is an indicator of huge potential for growth in energy demand. Despite an annual approximate 5% growth rate in electricity generation, unmet demand for electricity continues. Although 75% of India's population lives in rural areas, only 29% of rural households have electricity supply and there is no power supply network in many rural areas. In addition to geographical constraints, sparse distribution of dwellings, low ability to pay, and low load make extending the distribution network either impossible or uneconomic for many remote villages. Noncommercial energy still meets 40% of the total energy consumption, which shows the extent of demand that awaits to be met by commercial and more efficient forms of energy.

Energy demand in India has always been greater than supply. Thus, in view of shortages and restrictions, the past trends in consumption of commercial energy do not really represent the growth of energy demand but reflect the growth of its availability. Energy consumption by fuel is dominated by coal (54%) and oil (31%). There is wide scope for enhancing end-use energy efficiency. In addition to replacing outdated technologies and removing market barriers such as pricing distortions, overall economic potential would increase by simply changing the scale of production of many production activities. Such potential exists in all of the energy-using sectors.

Sectoral demand for energy arises mainly from lighting and cooking demand in the residential sector, irrigation and other operations in the agricultural sector, transport of passengers and freight in the transport sector, and fuel requirements in the industrial sector. Fig. 6 shows the use of energy by sector, whereas Fig. 7 shows the trends in energy intensities of these sectors. Decomposition analysis of the energy intensity trends shows that in India increasing economic activity is the main driving force for rising energy consumption, not increasing energy

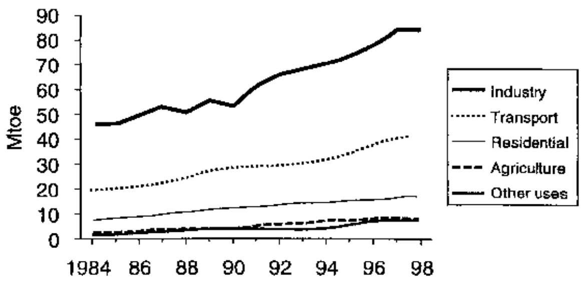

FIGURE 6 Trends in consumption of commercial energy in India, 1984–1998.

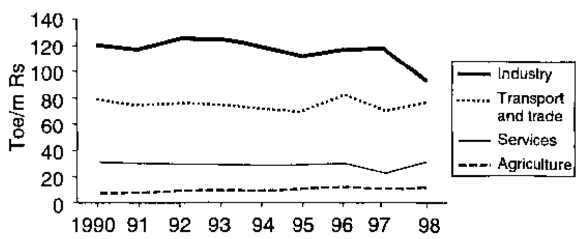

FIGURE 7 Sectoral energy intensities in India (energy/real GDP).

intensity. Since it is difficult to restrict energy demand due to increased output or activity directly at the early stage of development, improved energy efficiency is essential.

A number of efforts to improve energy efficiency, especially through exploration of technical potential, have resulted in a declining trend in energy intensity. The Eighth Plan (1992–1997) included a National Energy Efficiency Program that has the potential to save 5,000 MW in the electricity sector and 6 million tons of oil in the petroleum sector over the 5 years. India established an energy efficiency center as a major agency to implement programs and an energy conservation fund to finance them. On the other hand, electricity prices are far below marginal costs throughout most of the country, as are prices for natural gas and coal. This is a substantial barrier to energy efficiency investments and essentially subsidizes energy sources with environmental and health costs from pollution. One of the major challenges in a country with such high unmet demand is how to correct prices and provide incentives for investment in energy efficiency while protecting the social needs of the poor. A subsidy program for efficient vehicles or appliances without a move toward cost-reflective prices, for example, could substantially increase overall energy demand, as consumers buy more of a much needed service, and not reduce environmental impacts from the sector.

3.1.2 Industrial Sector Potential

In general, Indian industry is highly energy-intensive and its energy efficiency is far below that of industrialized countries. For example, in nitrogenous fertilizer manufacturing, older manufacturing units generally require 8.4–10.5 tons of oil equivalent (toe) per ton of ammonia produced, whereas the standard achieved in a plant in Bristol, England, is only 4.6 toe. An improvement in energy efficiency also includes energy conservation undertaken by a producer or a consumer that reduces losses of energy. In the electricity sector, it has been estimated that older power plants in many developing countries consume 18–44% more fuel per kilowatt hour of electricity produced than plants in industrial countries. Since India has vast reserves of coal, this is the primary fuel in the industrial sector. India has always relied heavily on coal for generating electricity with a low average conversion efficiency of 23%. There is potential for at least a 10% improvement in the conversion efficiency of existing plants. Greater energy efficiency can be implemented through technological enhancements, more research and development, improved energy management, and better operational practices.

A World Bank-sponsored study (1995) of energy demand in five major Asian countries (China, India, Indonesia, Korea, and Thailand) concluded that the industrial sector has the largest potential for energy conservation. This sector accounts for the largest share of final energy consumption in India and is dominated by energy-intensive industries. Higher energy intensities are ascribed to (i) slow capital stock turnover and utilization of out-of-date processes, (ii) poor energy management, and (iii) lack of incentives for firms to invest in energy efficiency due to low energy prices. In addition, scale is a major issue in many industries. In nearly all states in India for the cement and paper sector, and in a few states for aluminum, increasing the scale of production could reduce inefficiency in energy use.

We can also consider a recycling strategy in which secondary materials are fed into the original process, thereby lowering per unit energy consumption. Examples include the substitution of waste paper for paper pulp and using recycled glass and plastics. To improve overall industrial energy efficiency and reduce pollution, there is greater potential from adopting available clean technologies at the beginning of industrial operation rather than "end-of-pipe" solutions, which can actually increase overall energy use.

Technical energy efficiency improvement potential is shown by comparing specific energy consumption (i.e., energy consumption per unit of output) in industrial subsectors. For example, the energy efficiency of ammonia plants can be increased by revamping and modernization. A typical energy efficiency revamp of a plant would reduce the energy consumption for individual plants installed before 1980 by 0.8–2.2 Mtoe and for plants installed between 1980 and 1990 by approximately 0.6–0.7 Mtoe, depending on the feedstock used. The age of the technology, the scale of the plant, and management practices have a major impact on energy efficiency of the overall process. Energy savings potentials are highest for naphtha and fuel oil/low-sulfur heavy stock-based plants built before 1980. With current installed capacity of 5.09 Mt production, energy savings in pre-1980 ammonia plants alone would account for 6.02 Mtoe per year.

In the iron and steel sector, there is a large potential for efficiency improvement. Worldwide, specific primary energy consumption is decreasing with rising scrap-based electric arc furnace production. In India, however, due to a scarcity of scrap metal, this may not be a good option. Still, efficiency improvement may be achieved indirectly by improving power-generation efficiency that feeds iron and steel plants through modernization and captive combined heat and power generation. In addition, technology conversion (e.g., to induction furnaces) and retrofitting, recycling, and waste heat recovery promise major savings. Although most measures are cost-effective and provide net benefits within a short time, only a few have been or are currently being implemented in the iron and steel sector. Lack of dissemination of information on energy-efficient technology as well as specific information on saving and benefits of saving potential contribute to the low uptake of energy efficiency improvements.

For the cement industry, there is not much scope for improvement in dry processes, but there is more in semidry and wet processes. Besides the technical potential when compared to world best-practice technology, efficiency improvements can be achieved through increased use of additives such as fly-ash and blast furnace slag in manufacturing cement. Structural change toward more production of portland slag cement reduces energy consumption, and using a higher share of blast furnace slag compared to clinker leads to lower energy intensity as well. In India, 20% of final energy could be saved by this twofold structural change, which would decrease the clinker-to-cement ratio by 20%. It has also been estimated that better maintenance and monitoring of plant activity can minimize downtime of machinery and plant, thus avoiding excess energy needed for restarting the process.

In the aluminum sector, the potential for energy efficiency improvement varies across companies. For example, whereas the National Aluminum Corporation could achieve 17%, the Hindusthan Aluminum Corporation could achieve 40%. Energy savings potential in smelting range from approximately 16 to 30%. Better monitoring and control can conserve an additional 2 or 3%. Potential from retrofitting ranges from 10 to 15%, and the costs of this retrofitting and modernization are 25–35% lower than the cost of building an entirely new plant. Table I summarizes the industrial sector potentials for energy efficiency improvements by comparing Indian specific energy consumption to worldwide best practice. Worldwide best practice reflects the best available technology adjusted for India-specific structural factors. For paper, best practice reflects the average energy consumption abroad.

Research on the responsiveness of the Indian industry to changes in energy prices indicates that price-based policies could be effective in improving energy efficiency. Pricing policy in the fertilizer sector, for example, has shown that energy price increases would push less productive and inefficient plants (mostly smaller ones) out of the market or force them to immediately improve productivity and efficiency. It has been estimated that with all other economic variables constant, India industry could achieve worldwide best practice in specific energy consumption by 2005 or 2010 with an average annual nominal energy price increase of approximately 6 or 4%, respectively, measured as an increase in the fuel price index relative to other input prices.

3.1.3 Residential and Commercial Sector Potential

In the residential and commercial sector, the demand for energy is mainly for lighting, cooking, space cooling, and, to some extent in higher altitudes, space heating. The residential sector in India accounts for 40–50% of the total energy consumption. For cooking, 77% of households in India use traditional fuels such as firewood, animal dung, and agricultural residues, 0.3% use electricity, 4% use coal or charcoal, 8% use liquefied petroleum gas (LPG), 7% use kerosene, and 0.5% use biogas. Experience

TABLE I

Specific Energy Consumption in Indian Industry and Worldwide Best Practice, 1993

		India			India
Sector	Units	Average energy consumption	Best practice (marginal plant)	Worldwide best practice	Savings potential (%)
Aluminum	GJ/ton aluminum	86–100	87	65.2–81.9	5–35
Cement	GJ/ton cement	4.00	~2.93	3.06	24
Fertilizer	GJ/ton ammonia	39.2	36.4	28	29
Iron and steel	GJ/ton crude steel	35.4	31.4	17.1	52
Pulp and paper	GJ/ton paper	51.6–80.0	NA	32.0–40.9	~43

tells us that in the ladder of fuel-use transition, households usually move from traditional fuels to kerosene/coal (depending on availability), LPG, and electricity; the use of traditional fuel is indeed an indicator of unmet demand for more efficient fuels.

In India, urban and rural energy problems differ. In urban areas, introducing energy-efficient lamps, better space-cooling devices, and solar passive building structures can enhance efficiency in electricity and fuel use enormously. In the absence of any major demand-side management through policies or appliance standards, however, there is hardly any incentive for the households or commercial sector to enhance efficiency in use. Adopting energy-efficient appliances could provide up to 50% savings in electricity consumption in these end uses. This is particularly important in India, where demand for electricity is expected to grow by 7% per year and the gap between peak demand and peak supply today is more than 11,000 MW.

In rural areas, where almost 75% of the Indian population lives, biomass (primarily firewood) accounts for more than 90% of energy needs. It may not be possible to replace this entirely with more modern energy forms and developing modern biomass technologies will be a key element for addressing the needs of rural areas. One of the important constraints in the wider utilization of renewable energy is the high initial capital cost. India has potential for renewable energy generation, particularly wind and hydropower, and programs in these areas, aided by Global Environment Facility (GEF) funding, are under way. At the same time, India presents a unique opportunity for the large-scale commercial exploitation of biomass gasification technology to meet the needs of the agricultural and rural residential and small-industries sector. The gasifier power could solve the problems of technical and economic inefficiencies to a large extent, thereby reducing the social cost of power supply. Currently, commercial activity in most rural areas depends on power supply from the privately owned, decentralized, diesel power-generating sets, whereas residential lighting is typically met with stand-alone kerosene lamps. Use of kerosene for lighting is particularly inefficient, with only 1% of the energy in the kerosene producing useful light. The Ministry of Non-Conventional Energy Sources aims to replace low-efficiency kerosene lamps in rural areas with efficient renewable lighting technologies.

3.1.4 Transport Sector Potential

Transport shows a constantly rising trend in fuel demand. Decomposition analysis shows that it is the rising demand for overall transportation service that is driving up fuel demand. With relatively low substitution possibilities and high income elasticity for privately owned vehicles, it is expected that fuel demand in the transport sector will increase along with vehicle ownership for years to come. In recent years, fuel switching has been attempted by introducing compressed natural gas in public transport in metropolitan cities. Fossil fuel-based transportation may also be reduced through development of the rail network. Pricing reform is playing an important role in reducing inefficient use of energy. In terms of technical interventions, studies have shown that inefficient use of fossil fuels often results from poor design of public buses, which are not using best-practice technologies. Efficiency in transportation fuel can also be increased remarkably by improving the urban road conditions and reducing traffic congestion.

3.1.5 Agricultural Sector Potential

In the agriculture sector, power use for irrigation holds significant potential for improving energy efficiency. Currently, diesel generator-based water pumps with efficiencies of less than 33% are used to draw underground water; an adequate electricity supply would allow a shift to more efficient electric pumps. Where electricity is now available for agriculture, it is heavily subsidized and charges are not linked to consumption, leading to inefficient use. Correction of prices would lead to increased efficiency through better water and irrigation management. Just an important, more efficient use of water for irrigation would decrease agricultural energy demand for the same agricultural output.

Table II summarizes the potential for energy efficiency improvements in India based on a wide range of studies.

3.2 China and Southeast Asia

3.2.1 Trends in Energy Intensity and Consumption per Capita

China has demonstrated significant improvements in energy efficiency since the 1980s. Energy use per unit GDP declined from 2.18 toe per thousand U.S. dollars in 1980 to only 0.73 in 2000, as shown in Fig. 8. During this period, commercial energy consumption increased 2.3 times, whereas the GDP increased more than six times. However, commercial energy intensity in China is double that of OECD countries and triple if noncommercial energy is included (Fig. 4). Many factors affect energy intensity, including economic

TABLE II

Summary of Energy Efficiency Potentials for India

Sector	Technological options/area	Economic potential (% of current use)
Industry	Fertilizer	29
	Cement	20–24
	Electrical	17
	Thermal	27
	Pulp and paper	20–40
	Textiles	23
	Iron and steel	15–50
	Aluminum	5–35
	Refineries	8–10
	Brick-making	15–40
	Foundries	30–50
	Industrial cogeneration	3500 MW (sugar)
Residential	Lighting	10–70
	Refrigerator	25
	Air-conditioning	10
Agriculture	Pump sets	25–55
Transport	Two- and three-wheelers	25
	Cars	7.5–10
	Trains (diesel)	5–10
	Trains (electric)	5–10

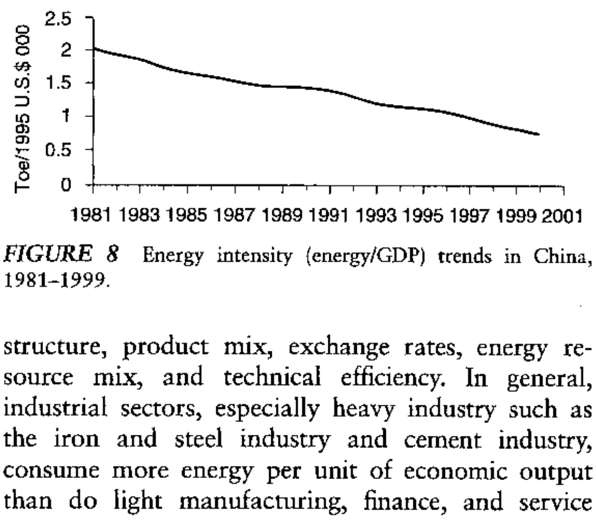

FIGURE 8 Energy intensity (energy/GDP) trends in China, 1981–1999.

structure, product mix, exchange rates, energy resource mix, and technical efficiency. In general, industrial sectors, especially heavy industry such as the iron and steel industry and cement industry, consume more energy per unit of economic output than do light manufacturing, finance, and service sectors. In China, for example, the relative energy consumption per unit of value added in primary (e.g., resource extraction and beneficiation), secondary (e.g., manufacturing and construction), and tertiary (e.g., finance and services) sectors was 12, 68, and 20, respectively, in 1999.

Changes in economic structure have contributed significantly to China's energy intensity improvement. Fig. 9 shows that economic structure has

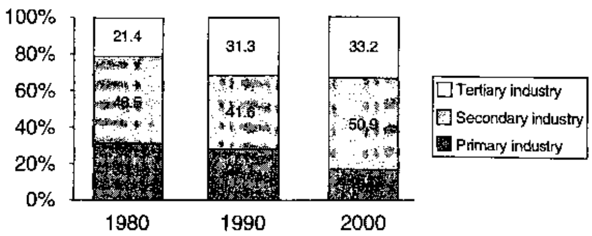

FIGURE 9 Composition of GDP in China, 1980–2000.

changed in China, with a decline in primary industry replaced by rapid growth in the tertiary sector. This trend is expected to continue, and the share of tertiary activities in the total economy will increase. Even within the secondary sector, subsectors with higher value-added and lower energy intensity, such as computer manufacturing and telecommunications equipment production, are developing faster than the traditional heavier manufacturing industries.

China is one of the few countries where coal is the dominant resource for energy use, which is part of reason for China's high energy intensity. For example, even using the latest technology, the highest energy efficiency for combined heat and power generation based on coal as a resource is 60%. Natural gas, on the other hand, can obtain conversion efficiencies of more than 80%. China is currently promoting clean energy production and importing cleaner technologies, which will result in energy efficiency improvements. In Southeast Asian countries, energy intensity is much lower than that of China. Because of the financial crises in the mid-1990s, however, the primary energy consumption per GDP increased, as shown in Fig. 10.

To provide a regulatory framework for energy efficiency interventions, many Southeast Asian countries and China have enacted a range of energy efficiency laws, with differences based on culture, political ideology, and existing institutional structures. Although the scope varies, common provisions include mandatory auditing for industries, mandatory energy building codes, developing performance standards for energy-using equipment, information dissemination, and capacity building. In most cases, implementing the legislation is carried out by existing energy agencies involved in energy efficiency promotion. In Thailand, an energy conservation fund to finance activities and programs for energy efficiency promotion has been set up, whereas for other countries the law specifies budget allocations for energy efficiency programs. For countries without specific legislation, energy efficiency activities are limited to programs that do not require specific

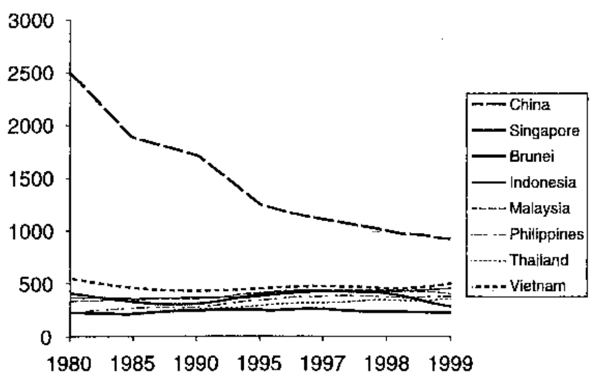

FIGURE 10 Primary energy consumption per unit of GDP.

regulation, such as publicity campaigns, demonstration projects, and programs that can be funded by external grants and loans, government budgets, or payments by consumers and end users. Some energy efficiency programs, such as mandatory appliance standards, appliance labeling, and building energy codes in the Philippines, Malaysia, and Singapore, are implemented through regulation but without reference to any specific law. A wide variety of policy instruments are used in promoting energy efficiency and accelerating the diffusion of energy-efficient technologies. These include appliances standards and building energy codes, appliance labeling, and financial incentives.

Since opening up to the outside world, the Chinese government has paid significant attention to energy conservation projects, including energy policy objectives to "carry out conservation and development of resources simultaneously but giving priority to conservation." To address energy shortages, environmental protection, and sustainable development, the Energy Conservation Law was passed in 1997, providing broad guidance for energy efficiency improvement in all sectors. Since then, governments at national, provincial, and local levels and industrial associations have issued a number of energy efficiency policies and adopted measures for the law's implementation.

3.2.2 Industrial Sector Potential

China's industrial sector is extremely energy intensive and accounted for 76% of the country's total energy used in 1997. It is estimated that the overall final energy use efficiency in the industrial sector was 46% in China, 20% lower than that of OECD countries. The largest energy-consuming industries are chemicals, ferrous metals, and building materials. The energy use per unit of product output provides a better comparison than energy use per unit of production value added. Because of outdated production technologies and processes, slow capital stock turnover, small-scale operation, and poor management and training of staff, most industrial enterprises in China consume more energy to produce a unit of product than applies in developed countries. Even within China, the product energy intensities are quite different in various enterprises. Table III compares energy intensity for selected products between developed countries and China.

There are several technologies available for energy efficiency improvement in industrial sectors. For example, in the cement industry, wet to dry process conversion, on-site cogeneration of heat and power, and coal ash utilization can significantly decrease energy consumption. Based on the available research, it is reasonable that energy efficiency in industry could be increased by 15–20% in China, with a similar situation in Southeast Asia (Table IV).

3.2.3 Residential and Commercial Sector Potential

In 1999, the Chinese residential sector consumed 78 Mtoe commercial energy, accounting for 14% of total final consumption of commercial energy. Including biomass, total residential final consumption was 289 Mtoe. The commercial sector accounts for a further 3% of commercial final consumption. Most residential energy consumption is for space heating, followed by cooking and lighting. Electricity consumption for appliances is increasing rapidly, and the use of air-conditioning is especially important for commercial buildings and it is being used increasingly in households as well.

The rate of construction of new buildings is high due to increases in population, rising standards of living and demands for more living space per person, and the continuing process of urbanization as people migrate toward areas with greater economic development. The majority of the new buildings, however, have poor energy performance. This is not unlike what happened in Europe in the years of reconstruction after World War II. The urgency of supplying new housing and commercial space, pressure to hold down initial investment costs, and low energy prices mean that little attention is paid energy performance. Designs are not adapted to local climatic conditions and ignore the potential for day lighting in commercial buildings.

As a result, energy costs are much higher than expected on economic grounds, even without considering the positive environmental and health impacts of better building design. In the northern part

TABLE III

Energy Intensity in China and Industrialized Countries for Selected Products

Product	Specific energy use	Country	Year
Steel (GJ/ton steel)	60	China (average)	1980
	41		1996
	32		1999
	21	China (best)	2001
	25	United States	Mid-1990s
	18	Japan	
	21	Sweden	
Cement (GJ/ton cement)	6	China (large and medium-sized)	1980
	5		1996
	4	United States	Mid-1990s
	3	Japan	1990
Paper (GJ/ton paper)	46	China	1997
	21	OECD countries	
Ethylene (GJ/ton)	36	China	
	26	OECD countries	
Glass plate (GJ/box weight)	0.8	China	
	0.4	OECD countries	
Ammonia (GJ/ton)	41	China	
	28	OECD countries	
Copper (GJ/ton)	40	China	
	24	OECD countries	
Cotton yarn (kWh/ton)	2300	China	
	2100	OECD countries	

of China, energy consumption for space heating during winter is approximately twice as high as in areas with similar climatic conditions in industrialized countries. As the new building energy code is implemented, new buildings are expected to have a 20% energy use savings compared to existing buildings.

3.2.4 Transport Sector Potential

In recent years, the number of automobiles has increased dramatically in China, especially private cars, but also those for freight and passenger transport. Compared to rail, road transport uses much more energy but is generally faster and more convenient. Energy intensity for overall transport sector increased from 19 kg oil equivalent per ton-kilometer (kgoe/t-km) to 23 kgoe/t-km between 1990 and 1997.

Railway transport in China has been undergoing a transition from steam to diesel and electric locomotives, which has greatly improved energy efficiency because diesel and electric locomotives are 30 and 25% thermally efficient, respectively, compared to 8% for steam locomotives. This shift decreases the energy needed to move passengers and freight by approximately three-fourths. Nonetheless, China's energy consumption per ton-kilometer of freight is still 60% higher than that in the United States and 30% higher than in Germany.

Improved energy efficiency in road transport will derive from using more new automobiles and improving the transportation management system. These trends are already starting to emerge in China in fright transport, with the energy use per ton-kilometer decreasing 15–20% since 1980. For passenger transport, however, energy intensity (measured as energy per passenger-kilometer) has actually increased during the past two decades as a result of lower load factors for public buses.

3.2.5 Agricultural Sector Potential

As China continues to modernize the agriculture sector, mechanization will result in increased energy use. Nevertheless, significant potential for increasing energy efficiency can be achieved with more efficient water-pumping and agricultural equipment. The Chinese government is generally emphasizing rural energy development as supplying more clean and convenient energy to farmers but not the efficient use of that energy.

3.3 Africa

The major challenge for energy development in Africa is how to increase most Africans' access to modern energy services while taking into consideration the economic costs and environmental impacts of these energy sources. Africa has vast energy resources but extremely limited energy and industrial development and the lowest rates of access to electricity in the world.

3.3.1 Trends in Energy Intensity and Consumption per Capita

As mentioned previously, energy consumption in Africa is among the world's lowest, although energy

TABLE IV

Summary of Energy Efficiency Potentials for China and Southeast Asia

Sector	Technological options/area	Southeast Asia 2020 (%)	China 2010 (%)
Industry	Fertilizer	20	10–20
	Iron and steel		15–25
	Nonferrous metals		3–16
	Cement		10–20
	Pulp and paper		20–40
	Electric motors		15–20
	Textiles		15–28
	Aluminum		5–20
	Refineries		5–10
	Brick-making		17–32
	Foundries		8–14
	Ethylene		10–30
	Calcium carbide		10–22
	Sulfate		14–25
	Caustic soda		10–30
	Glass		22
	Ceramics		30
Residential	Electric appliances	20–60	
	Illumination	20–60	
	Lighting		10–40
	Refrigerators		10–15
	Air-conditioning		15
	Washing machines		15
	Cooking appliances		20–40
	Space heating appliances		10–30
Transport	Total transport	2275 PJ	
	Two- and three-wheelers		10–15
	Cars		5–15
	Trains (diesel)		8–14
	Trains (electric)		10
Agriculture	Pump sets		20–50
	Motors		10–30

intensity is relative high. Despite the low base, primary energy consumption per capita has increased by less than 1% per year during the past two decades (Fig. 11). At the same time, energy intensity has actually increased, so African countries need more energy to produce $1 of GDP (Fig. 12). This is true even considering the purchasing power parity difference between Africa and the rest of the world. Data for the continent, however, obviously hide vast differences between countries (Fig. 13).

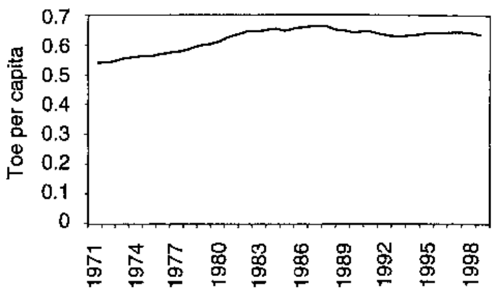

FIGURE 11 Energy consumption per capita in Africa.

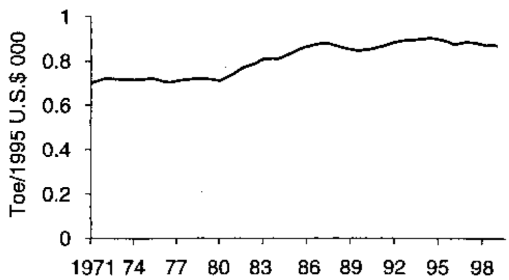

FIGURE 12 Energy intensity trends in Africa (energy use per unit GDP).

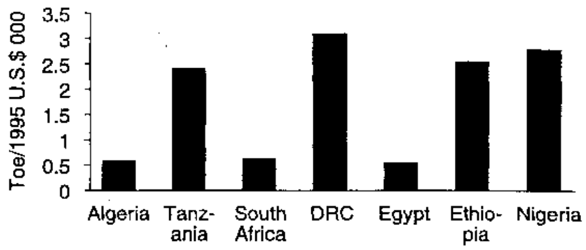

FIGURE 13 Energy intensity in African countries (energy use per unit GDP).

Although a number of African countries have included energy efficiency as part of their national energy policies, few have taken concrete steps toward legislation or specific programs and measures to promote it. Only Tunisia and Ghana have implemented mandatory appliance standards, whereas South Africa is implementing a mandatory commercial building code and has a voluntary residential building energy guideline. Ghana has created an independent body with multistakeholder support called the Energy Foundation, which has been highly successful in implementing energy efficiency programs in a range of sectors. Egypt is also considering a similar path and has set up an energy efficiency council to help develop a national energy efficiency strategy.

3.3.2 *Industrial Sector Potential*

Many African countries have relatively small industrial sectors, with the exception of large resource extraction industries such as mining and oil production. Even those countries, such as South Africa and some in the north, that have larger industrial sectors tend to rely on heavy, energy-intensive industrial subsectors and processes. Moreover, several southern African countries' dependence on coal, which tends to have a lower conversion efficiency in industrial boilers and power stations, also implies significant opportunities for cost-effective energy savings. An example of this is shown in Fig. 14, which compares the specific energy intensity (i.e., energy use per unit of sectoral output) of Zimbabwe to benchmark international energy intensity levels in industrialized countries.

Key industrial end uses for which industrial energy efficiency can be improved include electric motors, compressed air, lighting, process heating (boilers), and efficiency heating, ventilation, and air-conditioning (HVAC) systems. A wide range of studies suggest that the economic potential for energy efficiency in the industrial sector is 20–30%. In other words, achieving these savings is possible without increasing the cost of production, given current energy prices and technology availability.

Another useful set of examples derives from analysis of major industries in South Africa, in which better compressed air management, lighting, boilers, and changing to variable-speed drives can save 20% of the energy use for those end uses at paybacks of less than 5 years.

An important area that is not covered in the summary table for Africa is the possibility of fuel switching, particularly from coal or oil to natural gas for industrial boilers. As Table V shows, gas boilers are considerably more energy efficient. Although electrical process heat is efficient at the point of use, the large losses in power stations mean that the overall system efficiency is closer to 25%.

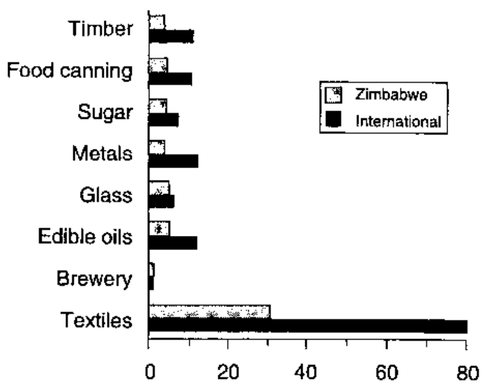

FIGURE 14 Examples of relative energy use efficiencies in industry (GJ/ton).

3.3.3 *Residential and Commercial Sector Potential (Buildings and Appliances)*

The majority of households in Africa rely primarily on biomass for energy services, particularly cooking. Given that traditional use of wood and charcoal for cooking is only 15–20% efficient, whereas kerosene, LPG, and electric stoves are approximately 40, 55, and 65% efficient, respectively, an important intervention is to move households to commercial fuels for cooking. In addition, improved biomass stoves can increase efficiencies to 25–30%. The problem with assessing the economics of these options is that traditional fuel wood is generally collected and thus outside the commercial energy market. Even purchasing an improved biomass stove costs money, and purchasing fuels for stoves adds even more to household energy costs. Nevertheless, kerosene is preferred over fuel wood in most areas where it is available, and a number of successful programs to increase the use of LPG and electricity for cooking have been implemented, such as in Senegal, Botswana, and South Africa.

Where electric appliances are used in the home or for commercial applications, the potential for savings is significant. Switching to compact fluorescent lighting, for example, can save two-thirds of the lighting energy use, and proper passive solar design of houses along with ceilings and insulation (especially in low-cost housing) can save 60–70% of space-heating energy from a variety of sources. Commercial energy intensity, as with industrial energy use, tends to be high, with many opportunities for improving the efficiency of HVAC systems, lighting, and office

TABLE V

Energy Efficiency of Boilers by Fuel

Fuel technology	Overall efficiency including steam system losses (%)
Electrical process heating	75
Coal-fired boilers	60
Oil-fired boilers	65
Wood-fired boilers	60
Gas-fired boilers	70

equipment. Many housekeeping measures can save energy with almost no capital cost.

3.3.4 Transport Sector Potential

As with industry, South Africa and most north African countries have much higher levels of motorization than other countries in Africa. Road transport is the main mode in Africa. Most vehicles are imported and generally old and poorly maintained, which decreases their efficiency, as does their operation in congested urban areas and on poor-quality road networks. Improving the quality of the road network, maintaining vehicles properly, and shifting road transport to rail could all significantly improve the energy efficiency of transport. Providing affordable, safe public transport systems would also shift passenger travel away from road traffic and increase energy efficiency as well as reduce traffic congestion. The estimates in Table VI are based on a combination of shifting to public transport and improved road and rail transport efficiency.

3.4 Latin America

During the last decade of the 20th century, the energy sector in Latin America underwent profound changes. In many countries, formerly state-owned monopolies were privatized, electricity and gas sectors restructured, and energy markets liberalized. Foreign direct investment in the energy sector in Latin America has been higher than in any other region in the world. Interconnections between countries are increasing and the market penetration of natural gas is changing the energy mix in many countries. Although energy prices are declining due to competition and alternative sources of commercial energy, many of the notorious problems of energy supply in the region have remained as serious and urgent as they were before the reform process started. Among these problems are (i) disparities of energy supply in more developed urban and less developed rural areas, (ii) insufficient access to clean and convenient energy services by the urban and rural poor, (iii) poor quality of service and protection of consumers, and (iv) only marginal attention to energy efficiency and decentralized renewable energies in official mainstream energy policies. The efficient use of energy in the whole supply chain, from energy extraction and transformation to the end user, could be drastically improved to allow for the expansion of energy services while safeguarding sustainable economic and social development.

TABLE VI

Summary of Energy Efficiency Potentials for Africa

Sector	Technological options/area	Economic potential (% of current use)
Industry	Total industry	15–35
	Industry, compressed air	>20
	Industry, variable-speed drives	>20
	Industry, efficient motors	>1–5
	Industry, efficient HVAC	>10
	Industry, efficient boilers	15–20
	Iron and steel	7
	Cement	10–15
	Aluminum (secondary)	45
	Refineries	6
	Inorganic chemicals	19
	Consumer goods	25
	Food	16–30
	Cogeneration	20–25
Residential	Total energy	5–20[a]
	Electric appliances	11–25
	Lighting, compact fluorescent lights	50–70
	Refrigerators	30
	Space heating	60–70
Commercial/public	Commercial air-conditioning (heat and cool)	50
	Commercial lighting	10
	Computers	10
		20–25
Transport	Cars, road system	30
	Total transport	30
	Road transport	30

[a] Market potential.

3.4.1 Trends in Energy Intensity and Consumption per Capita

Energy intensity in Latin America is substantially higher than in industrialized countries but lower than that of many developing regions (Fig. 4). At the same time, energy consumption per capita is only one-fourth that of industrialized countries (Fig. 1). As shown in Figs. 15 and 16, the energy intensity of Latin American economies has remained quite constant during the past 30 years, whereas the total primary energy supply per capita has increased only 30% during this period, with stagnation during the 1980s and early 1990s. Both energy intensity and per capita consumption differ substantially among different countries of the region (Fig. 17).

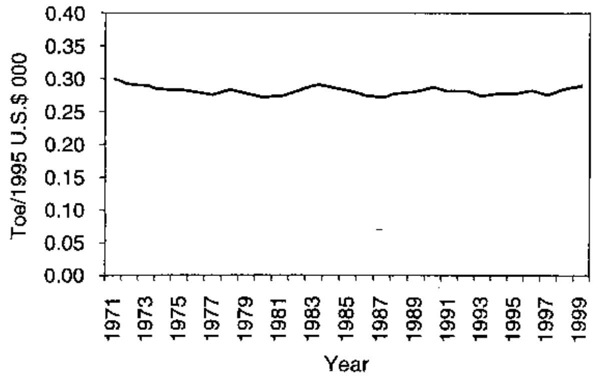

FIGURE 15 Energy intensity in Latin America.

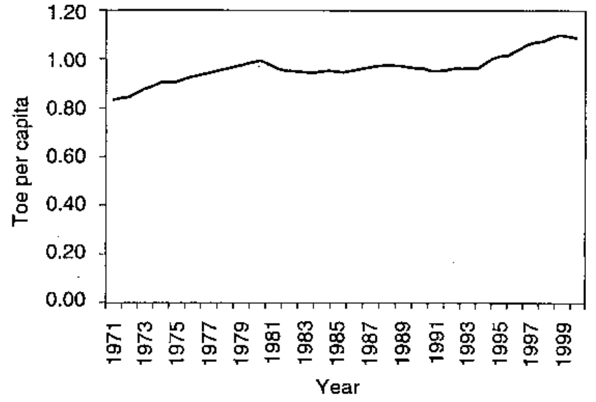

FIGURE 16 Primary energy consumption per capita in Latin America.

The use of noncommercial energy such as fuel wood is still high, particularly in rural areas, whereas low-grade and polluting fuels, such as charcoal and kerosene, are widely used in low-income urban areas. In Peru, for example, 63% of the energy consumption in the residential and commercial sectors in 1995 was fuel wood, 13% kerosene, and 6% animal dung compared to 9% electricity, 6% LPG, and 0.1% natural gas.

During the 1980s and 1990s, energy efficiency programs and legislation were developed and implemented in various countries of the region. Pioneers in this area are Brazil and Mexico, followed in the early 1990s by Costa Rica and later by other countries, such as Argentina, Colombia, Chile, Ecuador, and Peru. These energy efficiency programs were financed partly from own national sources but also with contributions from international donors. Although foreign funds have been crucial, the lack of commitment of national governments has in some cases impeded the wider uptake of the energy

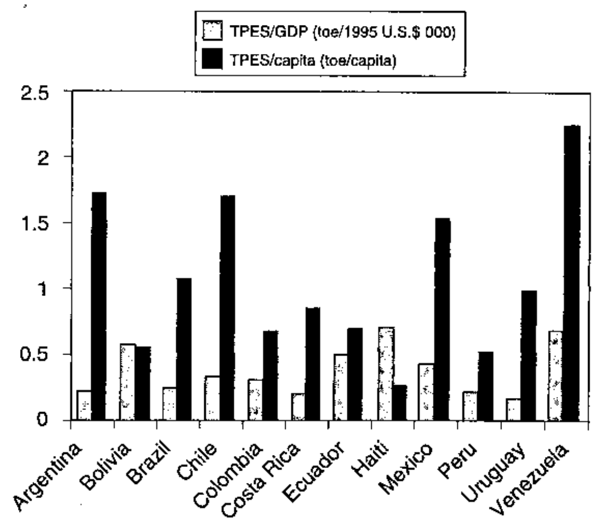

FIGURE 17 Energy intensity and per capita consumption in various Latin American and Caribbean countries, 1999.

efficiency message by the market and society. Brazil, Colombia, Costa Rica, and Peru have introduced new specific legislation for the promotion of energy efficiency and renewable energies, and bills for energy efficiency laws have been presented in other countries. These energy efficiency laws basically define the authority of governments to act in specific areas, such as information dissemination, energy efficiency standards and labeling, mandatory energy audits, the promotion of energy service companies or fiscal incentives. For example, although the elaboration of technical standards and energy efficiency labeling schemes is gaining momentum in various Latin American countries, important and visible schemes have been implemented only in Brazil and Mexico. Although the application of the standards in Mexico is mandatory and includes minimum levels of energy efficiency, the labeling scheme applied in Brazil has been voluntary. However, mandatory minimum efficiency standards are under serious consideration following the energy crisis in 2001 (Table VII).

3.4.2 Industrial Sector Potential

The market opening during the 1990s has forced many industries in Latin America to modernize their production processes in order to compete with foreign companies in domestic and international markets. Foreign direct investment has taken place in many industrial sectors and substantial technology transfer has been achieved. The modernization of industrial processes often involves higher energy efficiency and fuel switching. An example is the

TABLE VII

Summary of Energy Efficiency Potentials in Latin America

Sector	Technological options/area	Economic potential (% of current use)
Industry	Industry, efficient motors and drives	15–30
	Industry, process heat	20–50
	Industry, refrigeration	15–40
	Industry, efficient boilers and steam systems	20–40
	Iron and steel	10–30
	Cement	10–40
	Food and beverages	20–30
	Textiles	20–30
	Cogeneration	20–30
Residential	Total residential	20–40
	Electric appliances (general)	20–40
	Lighting, compact fluorescent lights	30–50
	Refrigerators	35–50
	Space heating	25–50
Commercial/ public	Total commercial/public	15–40
	Air-conditioning	20–30
	Commercial lighting	30–40
	Public lighting	20–45

large-scale substitution of pyrometallurgical processes in the Chilean copper industry by modern, more efficient electrochemical processes. Whereas large industries are successfully adapting to more efficient processes, small- and medium-scale industries in Latin America often face many problems adapting to the more competitive environment.

The energy-intensive sectors cement, iron and steel, chemicals, and food and beverages consume approximately 60% of industrial energy in Latin America. Several studies carried out during the 1990s estimate that the energy conservation potential in these activities is 10–30%. The same range of savings potential also applies for the textile, other nonmetallic minerals, and machine building industries, with the majority of measures having favorable payback periods. Electrical motors and drives, process heat, and refrigeration are important areas of industrial energy end use. The energy savings potential in the field of electrical motors and drives is up to 30%, depending on the kind of measures taken. Losses in industrial thermal processes are as high as 70%, and energy conservation potentials in industrial steam systems are as high as 40%. There is also a significant potential for industrial cogeneration in Latin America, which is largely untapped because of unfavorable legal frameworks.

3.4.3 Residential and Commercial Sector Potential (Buildings and Appliances)

Residential, commercial, and public buildings offer high energy savings potentials throughout Latin America. Building codes, where existing and enforced, do not normally include requirements concerning thermal insulation. This is particularly relevant for housing for the poor, where low-cost materials and designs are usually applied. Forthcoming standards for energy certification of residential, commercial, and administrative buildings in Chile are an encouraging step in the right direction.

Another area with major energy savings potential is household appliances. The widespread use of low-grade fuels, such as kerosene, fuel wood, and charcoal, in rural and poor urban households leads not only to high levels of pollution but also to high energy losses (up to 90%). Studies indicate that the economic potential for energy efficiency improvements in residential end uses such as cooking, lighting, and refrigeration is 20–50%. On a national basis, the Costa Rican government estimates that the combined energy savings potential of efficient refrigeration and lighting systems in the residential and commercial sectors is 12–22% until 2015, taking into consideration different levels of efficiency and market penetration of the equipment. Similar potentials for end-use efficiency (typically 20–40%) exist in commercial and public buildings (e.g., shopping centers and hotels) and in street lighting.

Social problems, such as poverty and unequal distribution of income, are an important barrier to a more rigorous transformation of the residential end-use sector. Attention to energy efficiency is dampened because of more urgent, basic service needs, and new, efficient equipment and housing are often not affordable to low-income households. Several projects in the region funded by the GEF focus on end-use efficiency in the residential, commercial, and public sectors, particularly on efficient residential and street lighting.

3.4.4 Transport Sector Potential

Road transport is the most important transport mode in Latin America, with problems such as traffic congestion, air pollution in cities, and poor fuel economy due in part to the age of the car and truck fleet. Effective transportation systems combined with supportive urban planning, building on the model originally established in Curitiba, Brazil, in the 1970s, and the increasing use of compressed natural gas and LPG in passenger and goods transport in Argentina, Brazil, and other countries are examples of measures taken to mitigate this situation. Nevertheless, energy use in the transport sector is growing and will further grow with increasing welfare and consumption levels. Measures to reduce the energy intensity of the transport sector would require improving the quality of roads, implementing effective regulation to maintain vehicles properly, as well as incentives to use cleaner and more efficient fuels and cars, introducing effective transport systems in more cities and revitalizing railway transport in Latin America. Energy savings potential due to more efficient driving habits and preventive maintenance have been estimated to be 15–25% of the fuel consumption in passenger cars, trucks, and buses.

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