policy

Climate change mitigation in developing countries

Brazil, China, India, Mexico, South Africa, and Turkey

William Chandler
Battelle Memorial Institute

Roberto Schaeffer
Federal University of Rio de Janeiro

Zhou Dadi
China Energy Research Institute

P.R. Shukla
Indian Institute of Management

Fernando Tudela
El Colegio de Mexico

Ogunlade Davidson
University of Cape Town

Sema Alpan-Atamer
Med-Consult, Turkey

Pew Center on Global Climate Change

Climate change mitigation in developing countries

Brazil, China, India, Mexico, South Africa, and Turkey

Prepared for the Pew Center on Global Climate Change

by

William Chandler
Thomas J. Secrest
Jeffrey Logan
Battelle Memorial Institute

Roberto Schaeffer
Alexandre Salem Szklo
Marcio Edgar Schuler
Federal University of Rio de Janeiro

Zhou Dadi
Zhang Kejun
Zhu Yuezhong
Xu Huaqing
China Energy
Research Institute

P.R. Shukla
Indian Institute of Management

Fernando Tudela
El Colegio de Mexico

Ogunlade Davidson
Stanford Mwakasonda
Randal Spalding-Fecher
Harald Winkler
Pierre Mukheibir
University of Cape Town

Sema Alpan-Atamer
Med-Consult, Turkey

October 2002

Contents

Foreword *Eileen Claussen, President, Pew Center on Global Climate Change*

One of the most contentious issues in the debate over global climate change is the perceived divide between the interests and obligations of developed and developing countries. Equity demands that developed countries—the source of most past and current emissions of greenhouse gases—act first to reduce emissions. That principle is embedded in the 1992 United Nations Framework Convention on Climate Change and in the 1997 Kyoto Protocol, which sets binding emission targets for developed countries only. With the Protocol now likely to enter into force, the focus will turn increasingly to the question of developing country emissions.

Addressing climate change in developing countries poses a fundamentally different challenge. For most, emission reduction is not a viable option in the near term. With income levels far below those of developed countries—and per capita emissions on average just one-sixth those of the industrialized world—developing countries will continue to increase their emissions as they strive for economic growth and a better quality of life. But their steadfast resistance to the idea of limiting their emissions has led to claims in some quarters that developing countries are not doing their fair share. Indeed, the Bush administration, in rejecting Kyoto, declared the Protocol unfair to the United States because it does not mandate action by large developing countries.

Accepting emission limits, however, is not the only measure of whether a country is contributing to climate change mitigation. Efforts that serve to reduce or avoid greenhouse gas emissions, whether or not undertaken in the name of climate protection, nonetheless contribute to climate mitigation. These efforts can occur across virtually every sector of an economy. This report seeks to document and quantify the climate mitigation resulting from such efforts in six developing countries—Brazil, China, India, Mexico, South Africa, and Turkey.

The report demonstrates that efforts undertaken by these six countries have reduced their emissions growth over the past three decades by approximately 300 million tons a year. Further, it finds that many of these efforts are motivated by common drivers: economic development and poverty alleviation, energy security, and local environmental protection. Put another way, there are multiple drivers for actions that reduce emissions, and they produce multiple benefits. The most promising policy approaches, then, will be those that capitalize on natural synergies between climate protection and development priorities to simultaneously advance both.

Just as equity demands that developed countries act first, the physical workings of our planet demand that in time developing countries limit and, ultimately, reduce their emissions as well. The search for consensus on an equitable sharing of responsibility must begin with a fair accounting of how nations already are contributing to this common effort.

The authors and the Pew Center gratefully acknowledge Charles Feinstein, Alan Miller, Jiahua Pan, Cedric Philibert, and Leena Srivastava for their review of previous drafts of this report.

Executive Summary

Greenhouse gas emissions from developing countries will likely surpass those from developed countries within the first half of this century, highlighting the need for developing country efforts to reduce the risk of climate change. While developing nations have been reluctant to accept binding emissions targets, asking that richer nations take action first, many are undertaking efforts that have significantly reduced the growth of their own greenhouse gas emissions. In most cases, climate mitigation is not the goal, but rather an outgrowth of efforts driven by economic, security, or local environmental concerns. This study attempts to document the climate mitigation resulting from such efforts in six key countries—Brazil, China, India, Mexico, South Africa, and Turkey—and to inform policy-making aimed at further mitigation in these and other developing nations.

The six countries examined here reflect significant regional, economic, demographic, and energy resource diversity. They include the world's two most populous nations, a major oil exporter, Africa's largest greenhouse gas emitter, and the country with the largest expanse of tropical forest. While their circumstances vary widely, these countries share common concerns that have motivated actions resulting in reduced greenhouse gas emissions growth. Primary among these concerns are economic growth, energy security, and improved air quality. The analysis presented here demonstrates that actions taken by these countries to achieve these and other goals have reduced the growth of their combined annual greenhouse gas emissions over the past three decades by nearly 300 million tons a year. If not for these actions, the annual emissions of these six countries would likely be about 18 percent higher than they are today. To put these figures in perspective, if all developed countries were to meet the emission targets set by the Kyoto Protocol, they would have to reduce their emissions by an estimated 392 million tons from where they are projected to be in 2010.[1]

The six case studies identify a broad range of mitigation activities and potentials:

Brazil's annual emissions are 91 million tons, or 10 percent lower than they would be if not for aggressive biofuels and energy efficiency programs aimed at reducing energy imports and diversifying energy supplies. A tax incentive for buyers of cars with low-powered engines, adopted to make transportation more affordable for the middle class, accounted for nearly 2 million tons of carbon abatement in the year 2000. If alcohol fuels, renewable electricity, cogeneration, and energy efficiency are encouraged in the future, carbon emissions growth could be further cut by an estimated 45 million tons a year by 2020. Deforestation, however, produces almost twice as much carbon dioxide as the energy sector. Government policy, with few exceptions, indirectly encourages emissions growth in the forestry sector.

China has dramatically reduced its emissions growth rate, now just half its economic growth rate, through slower population growth, energy efficiency improvements, fuel switching from coal to natural gas, and afforestation. Emissions growth has been reduced over the past three decades by an estimated 250 million tons of carbon per year, about one-third of China's current emissions. Continued policies for economic reform, efficiency, and environmental protection could reduce emissions growth by an additional 500 million tons a year in 2020.

India's growth in energy-related carbon dioxide emissions was reduced over the last decade through economic restructuring, enforcement of existing clean air laws by the nation's highest court, and renewable energy programs. In 2000, energy policy initiatives reduced carbon emissions by 18 million tons—over 5 percent of India's gross carbon emissions. About 120 million tons of additional carbon mitigation could be achieved over the next decade at a cost ranging from $0-15 per ton. Major opportunities include improved efficiency in both energy supply and demand, fuel switching from coal to gas, power transmission improvements, and afforestation.

Mexico was the first large oil-producing nation to ratify the Kyoto Protocol. Major factors affecting Mexican greenhouse gas emissions are population growth, economic development, energy supply growth, technological change, and land use change. Mexico has begun to reduce deforestation rates, switch to natural gas, and save energy, reducing annual emissions growth over the last decade by 5 percent, or 10 million tons of carbon per year. Mexican carbon dioxide emissions are projected to grow 69 percent by 2010, but alternative strategies could cut this growth by 45 percent.

South Africa's post-Apartheid government places its highest priority on development and meeting the needs of the poor. Over one-third of the nation's households are not even connected to a power grid. Yet, emissions growth could be reduced 3-4 percent a year by 2010 through efforts to reform the economy and improve energy efficiency. The government is already taking steps to phase out subsidies to its unusual, carbon-intensive coal liquefaction industry and to open the country to natural gas imports. As in many other developing countries, the absence of rigorous and publicly available studies of future energy use and greenhouse gas emissions remains an obstacle to future emissions mitigation.

Turkey's high rate of energy-related carbon emissions growth is expected to accelerate, with emissions climbing from 57 million tons in 2000 to almost 210 million tons in 2020. Carbon intensity in Turkey is higher than the western developed nation average. Energy-intensive, inefficient industries remain under government control with soft budget constraints, contributing to undisciplined energy use. Planned industrial privatizations may close the oldest and most inefficient operations and modernize surviving ones. Elimination of energy price subsidies could stimulate energy conservation, reducing energy and emissions growth below current projections.

Taken together, these six country studies support four broad conclusions:

- Many developing countries are already taking action that is significantly reducing their greenhouse gas emissions growth.
- These efforts are driven not by climate policy but by imperatives for development and poverty alleviation, local environmental protection, and energy security.
- Developing nations offer large opportunities for further emissions mitigation, but competing demands for resources may hamper progress.
- Developing countries can use policies to leverage human capacity, investment, and technology to capture large-scale mitigation opportunities, while simultaneously augmenting their development goals.

The six case studies also identified common barriers to climate mitigation. In many cases, the lack of good data impedes efforts to identify and realize mitigation potential. Insufficient human capacity—to analyze energy and emission futures, identify mitigation opportunities, execute economic reforms, and cultivate investment opportunities—represents another significant barrier. In most countries, public control of at least a portion of energy resources works against emissions mitigation by preventing the emergence of more efficient private actors. Finally, a range of concerns—from the absence of transparency and rule of law to the extra risk associated with nontraditional energy investment—impedes investment and technology transfer that would contribute to emission mitigation.

The experiences of these six countries have implications for future policy at multiple levels—for national efforts within developing countries, for the evolving international climate framework, and for other bilateral or multilateral efforts aimed at encouraging emission reduction in developing countries.

One broad lesson, given the diversity of drivers and co-benefits, is the need at both the national and international levels for flexible policy approaches promoting and crediting a broad range of emission reduction and sequestration activities. Other policy priorities include: continuing to promote market reforms, such as more realistic energy pricing, that can accelerate economic growth while reducing emissions growth; working within developing countries and through bilateral and multilateral efforts to improve investment environments and create stronger incentives for climate-friendly investments; targeting capacity-building assistance to most effectively capitalize on natural synergies between climate mitigation and other development priorities; and supporting policies that address both climate and local environmental needs, such as improving air quality and reducing deforestation.

While this analysis has documented significant greenhouse gas mitigation in key developing countries, energy use and emissions will continue to climb as these countries attain higher levels of development. Far greater efforts to reduce emissions in both developed and developing countries will be required in the coming decades to avert the worst consequences of global climate change. These efforts must include stronger national policies as well as an evolving international regime that ensures adequate efforts by all major emitting countries. By highlighting the current and potential contribution of developing countries to emission mitigation, this report aims to enhance the prospects for stronger international cooperation toward the shared goal of climate protection.

I. Introduction

The risk of global climate change as a result of rising greenhouse gas (GHG) emissions presents a profound challenge to the international community. Emissions of carbon dioxide, the principal greenhouse gas, have risen more than ten-fold since the start of the industrial revolution. Atmospheric concentrations of carbon dioxide have risen more than 30 percent as a result and, at present emission rates, are projected to reach twice the pre-industrial level by the middle of this century. Although there is no consensus on a safe concentration level, stabilizing concentrations at any given target will ultimately require reducing net emissions to zero.

Developed countries account for over half of global GHG emissions, and historically have accounted for a much larger share. The Kyoto Protocol, expected to enter into force in 2003, would establish the first binding international limits on greenhouse gas emissions. The Protocol establishes targets for developed countries only and aims to reduce their collective emissions 5.2 percent from 1990 levels. However, the actual reduction will likely be substantially less because of compromises negotiated by the parties and the withdrawal of the United States.

In developing countries, rising populations, income levels, and energy use are leading to rapid increases in GHG emissions. At present growth rates, developing country emissions are expected to surpass those of developed countries within a matter of decades. The magnitude of this future emissions growth, however, is by no means certain. This report examines measures already underway that are tempering the growth of developing country emissions, the forces that drive these measures, and the opportunities that may exist for furthering them.

The six countries chosen for this study—Brazil, China, India, Mexico, South Africa, and Turkey—reflect broad economic, demographic, and resource diversity (see Table 1). Brazil is the most populous nation in South America, has more tropical forest than any other country, and is almost unique in its heavy reliance on water power and biomass energy. China, the world's most populous nation, has reduced its energy intensity impressively for economic reasons, but within decades could surpass the United States as the largest emitter of greenhouse gases. India will soon overtake China in population, and remains very poor, but has undertaken innovative renewable energy programs. Mexico, an oil producer and exporter, is undergoing economic restructuring and reform and is becoming more integrated with its North American trading partners. South Africa is the largest national source of emissions in Africa, almost equal to that of France. Turkey stands at a cultural crossroads between Asia, Europe, and Africa, and is a transit route for energy exports from Caspian Sea oil and gas fields.

Table 1

Key Indicators by Country

Country	Population, 2000 (millions)	Primary Energy per Capita, 2000 (GJ per year)	CO_2 per Capita, 1998 (Tons of Carbon per year)	CO_2/GDP (Tons of Carbon/ million 1995 US$ in PPP)
Brazil	170	44	0.5	73
China	1,262	27	0.7	175
India	1,016	13	0.3	121
Mexico	98	56	1.1	210
South Africa	43	106	2.3	233
Turkey	65	47	0.9	137
World	6,057	63	1.1	155
OECD	1,116	200	3.0	128
USA	282	341	5.4	186

Sources: World Bank Development Indicators, 2002; British Petroleum, BP Statistical Review of World Energy 2002; OECD: Basic Statistics, August 2002; Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, 2002.

Each of the six national analyses is presented in three parts. Each begins with an energy and emissions profile of the country. This profile identifies principal energy sources and uses, recent energy trends, and the leading sources of energy-related and other GHG emissions.

Second, each case study describes significant actions, policies and other measures already underway that serve to reduce the growth of that country's greenhouse gas emissions. In most instances, these efforts are not motivated by climate concerns. Rather, they are driven by concerns higher on the agenda of most developing countries, such as promoting economic growth, increasing energy security, and improving local environmental conditions. Because reducing emissions growth is not a primary objective, relatively little work has been done to reliably estimate the emissions impact of these measures. The case studies provide the best data available, in some cases drawing on previous analyses, and in other cases generating new estimates. The methodologies employed to generate these new estimates vary and are summarized in the text or in endnotes for the respective figures. In the case of South Africa and Turkey, the paucity of data precludes reliable estimates without additional analysis.

Third, the case studies identify opportunities for further GHG mitigation. They examine influential studies projecting future energy trends and the associated growth in emissions. Specific measures are presented with significant potential to reduce emissions below the levels projected. Where possible, the case studies quantify the potential emissions impact of those measures, again drawing on previous analyses and new estimates generated for this report.

Any attempt to quantify the emissions impact of ongoing efforts, or to project the likely emissions impact of future efforts, encounters significant uncertainties. First, data may be incomplete or difficult to verify. This is particularly true when examining developing countries. Second, any such analysis turns heavily on assumptions. For instance, estimates of "baseline" emissions—the level of emissions that would occur in the absence of mitigation efforts—rest in part on empirical data but also on critical assumptions about economic and social behavior. These, in turn, rest in large measure on the analysts' best judgment. Here, the authors employ the most recent and reliable data available and, where judgments are necessary, draw on their extensive experience to provide their best expert opinion.

A closer examination of efforts undertaken explicitly to address climate change—such as establishing new focal points within government, establishing partnerships with other governments or the private sector, or launching pilot projects—would also contribute to a fuller understanding of developing country actions with the potential to affect future emissions. However, such a review was beyond the scope of this analysis, which focuses instead on the broader underlying forces that directly shape emissions paths in these countries.

Following the case studies, the report draws policy implications from the experiences of these six countries. It identifies common drivers, or forces, operating across most or all of the countries to reduce the growth of GHG emissions, and common barriers to emission mitigation. Finally, the report suggests a set of robust policy approaches to promote further climate change mitigation while advancing key development objectives of developing countries.

II. Brazil

Brazil ranks as the world's ninth largest economy with a gross domestic product (GDP) per capita of about $7,300. With 170 million people, the nation ranks as the fifth most populous country. More than 10 percent of the population has no access to electricity and 20 percent live in poverty (see Table 2).

Table 2

Key Socio-Economic Indicators

for Brazil

Annual carbon emissions (energy-related) 2000	91[1] million tons
Population, 2000	170.4 million
Population growth rate	1.3% per year
Per capita GDP, 2000	
Based on exchange rate	$3,580
Purchasing power parity	$7,300
GDP growth rate	4.4% per year in constant local currency units
Primary energy consumption, 1998	42 Gigajoules per capita
Electricity consumption	1,949 Kilowatt-hours per capita/year
Persons below poverty line	37.4[2] million
Persons without electricity	20 million

Notes:
(1) Includes CO_2 emissions derived from fossil fuel and non-renewable biomass consumption;
(2) This level is defined as persons earning less than $0.20 per day, in exchange rate values.

Sources: World Bank Development Indicators, 2002; Instituto Brasileiro de Geografia e Estatística, 2002; Ministry of Mines and Energy, National Energy Balance, 2001.

Rapid economic growth and industrialization over several decades has brought increasing reliance on fossil fuels and increasing GHG emissions. Brazil's 91 million tons of energy-related carbon emissions are estimated to be 20 million to 25 million tons, or 20 percent, lower than they would be if not for measures intended primarily to reduce dependence on energy imports, diversify energy supplies, increase energy efficiency, reduce local environmental impacts, and spur social and economic development.

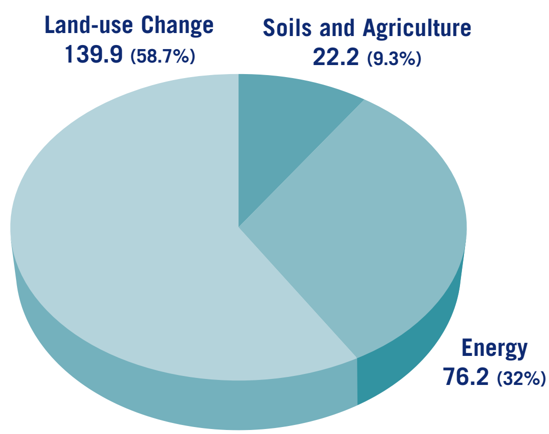
Brazil ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the Kyoto Protocol in 2002.

Energy and Emissions Profile

Brazil's GHG emissions in the early 1990s averaged 225 million tons of carbon per year, with about one-third coming from energy-related activities and the remainder from land use practices, primarily deforestation (see Figure 1). Brazil ranks relatively low in energy-related carbon emissions because the nation derives almost half of its energy from hydropower and biomass. Over 90 percent of the country's electricity comes from hydroelectric plants and about 15 percent of total energy from renewables. In 2000, the nation produced energy-related carbon emissions of about 91 million tons, or about one-half ton per capita. This figure is slightly lower than the average for developing countries but only one-sixth and one-half, respectively, of the average for members of the Organization for Economic Cooperation and Development (OECD) and for the world.

Figure 1

Annual **Carbon Dioxide Emissions** in Brazil, 1990-94



Million Tons of Carbon

Note: Removals from planted forests account for approximately 11 MtC annually, resulting in net CO_2 emissions of 227.3 MtC.

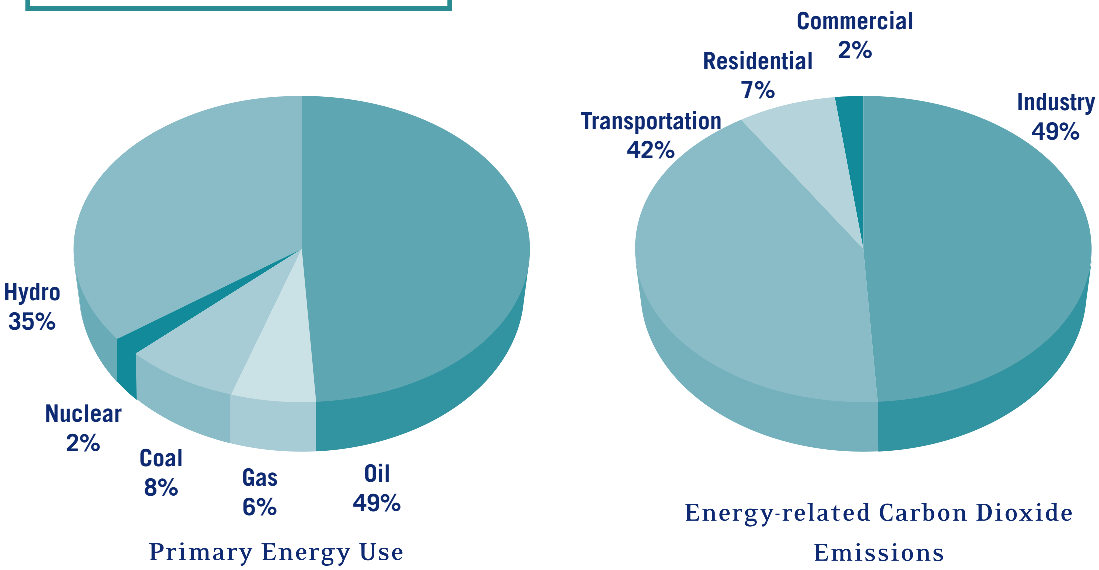
Source: Ministério da Ciéncia e Tecnologia. First Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions. 2002.

Petroleum use accounts for roughly half of all commercial energy use excluding biomass (see Figure 2). The transportation sector accounts for over 40 percent of all energy-related carbon emissions, reflecting Brazil's heavy reliance on no- or low-carbon fuels in other sectors.

The largest share of Brazil's GHG emissions derives from non-energy sources such as agriculture and livestock, land use change and forestry, and waste treatment. A recent series of studies from 1990 to 1994[2] shows that land use change and forestry were the most important sources of carbon dioxide emissions, followed by energy, soils and liming. New forest plantings, mainly eucalyptus and pine, provide the single most important carbon dioxide removal in this sector.

Figure 2

Energy and Emissions in Brazil, 1998



Source: Energy Information Administration, U.S. Department of Energy, 2002.

Deforestation in the Brazilian Amazon over the last decade increased some 32 percent, from almost 14,000 square kilometers per year to just over 18,000 square kilometers per year.[3] Some analysts believe that public policy in Brazil indirectly serves to increase emissions related to forestry.[4] The major causes of deforestation include development of the highway transportation system, settlement programs, government incentives for agriculture, financing of large-scale projects such as hydro dams, and land speculation.[5] More recently, some specialists have also cited the influence of export-oriented companies moving to the Amazon and Cerrado regions where they log, produce beef, and grow soybeans, all with detrimental impacts on the forests.[6] Historically, the Brazilian government has expressed strong reservations about international climate efforts that could affect forest management.[7]

Mitigating Measures

Brazilian mitigating measures—measures that reduce greenhouse gas emissions regardless of whether that was their direct purpose—include production and use of ethanol and sugar-cane bagasse, development of the natural gas industrial market, and use of alternative energy sources for power generation. Also successful has been a set of demand-side programs promoting conservation and efficiency in the electricity and transportation sectors, which accounted for 7.1 and 1.5 million tons of emissions reduction, respectively, in 2000. These measures accounted for almost all the 10 million tons of carbon emissions abatement by 2000.[8]

Sugar production has given rise to the large-scale use of two major alternative sources of energy used in Brazil—automotive ethanol and sugar-cane bagasse used to generate electricity. These biomass fuels reduced Brazil's carbon dioxide emissions by 7 percent in 2000.

The alcohol program was a key element of Brazil's energy policy for more than a quarter-century. Brazil first launched its National Alcohol Fuel Program (PRO-ALCOOL) in 1975 to promote ethanol production as a substitute for gasoline. The first oil embargo had shaken the nation, which was then importing over 80 percent of its oil supply, and the international price of sugar was also very low. Ethanol production was justified to reduce dependence on oil imports and the environmental impacts of energy use, and to create domestic jobs and income. The government offered a variety of incentives including low-interest loans to build distilleries, ethanol purchase guarantees, favorable pricing relative to gasoline, and sales tax reductions.[9]

From 1985 to 1990, 90 percent of new cars sold were fueled on pure ethanol. However, rising sugar prices led to ethanol shortages and price hikes, and sales of ethanol-fueled cars fell almost to zero by the late 1990s.[10] About 4-5 million cars were fueled solely by pure ethanol in 2000, about a quarter of the total automobile fleet.[11] But with few ethanol-only cars being manufactured and about 300,000 to 400,000 ethanol-fueled cars being scrapped each year, the market for pure ethanol fuel is in sharp decline. Today, ethanol is used in Brazil mainly as a gasoline additive. About one-quarter of gasoline sold in Brazil today contains ethanol in a blend required by law to control local air pollution. Alcohol fuel in 2000 still avoided 5.4 million tons of carbon emissions.[12]

The use of sugar-cane bagasse is a special case of renewable energy use in Brazil. Bagasse is a waste by-product of alcohol production and is used in combined heat and power (cogeneration) plants. In 2000, bagasse used for power generation reduced carbon emissions in Brazil by almost 1 million tons. A recent program to promote bagasse is noteworthy because it finances more efficient power generation that channels surplus electricity to power utilities on a steady basis. Almost 1,000 megawatts (MW) of bagasse-fired cogeneration capacity has been created, some 40 percent of that added in 1999-2001. A recent incentive program for alternative energy sources launched in 2002, known as the PROINFA Program, established a goal for 2006 of increasing sugar-cane bagasse fired-cogeneration capacity by 1,100 MW.

The Brazilian government has also promoted importing natural gas in a deliberate effort to diversify the nation's energy supply.[13] For example, the Bolivia-Brazil Gas Pipeline was put into service recently and authorization has been granted to import natural gas from Argentina.[14] Similarly, Brazil has opened access to the transmission grid to independent power producers and to certain types of power customers, thus liberalizing the power supply market. This move opens market opportunities for new gas-fired cogeneration plants.[15]

A recent power supply crisis, brought on by a long drought that dramatically reduced hydroelectric power generation, forced the government to quickly devise incentives for expanding electricity supplies. In May 2001, Brazil faced nationwide power rationing intended to avert major blackouts and save valuable water in severely depleted reservoirs. Households were required to reduce consumption by 20 percent or face significantly higher rates or even electricity cuts of up to three days. Industrial and commercial users were required to reduce consumption by 15-20 percent, and to postpone any major expansions that would require additional electric power.

Trying first to avoid and then to solve the power supply crisis, an emergency power-supply program launched in 2000 helped increase gas-fired cogeneration capacity, encouraging gas use instead of fuel oil. In 2000, the reduction in carbon emissions due to industrial fuel switching to gas amounted to 0.4 million tons. Gas use by Brazilian industry should continue to expand over the next decade, assuming competitiveness of natural gas prices and expansion of the natural gas distribution network. The resulting reduction in carbon emissions growth should reach 1.1 million tons by 2005 and 1.4 million tons by 2010.

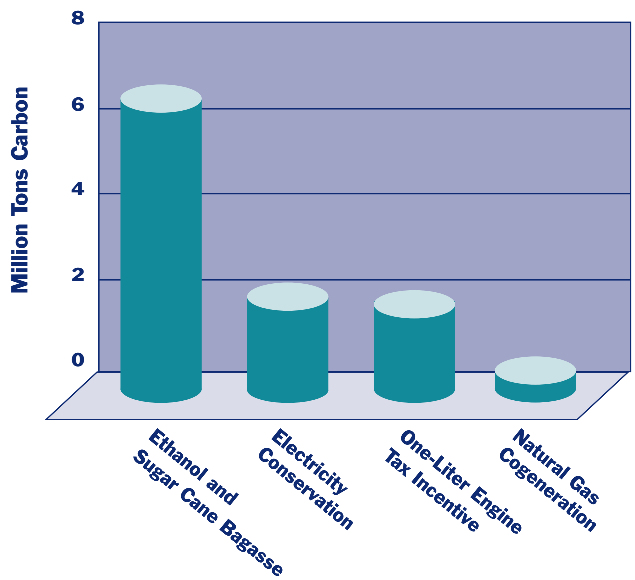
Demand-side measures have yielded large emissions reductions in Brazil. The government created the National Electricity Conservation Program (PROCEL) in 1985. PROCEL funds or co-funds a wide range of energy efficiency projects focused on information, utility demand-side management programs, direct implementation of efficiency measures, and technical support.[16] PROCEL long advocated mandatory efficiency standards for household appliances, lighting products, and motors; appliance and lighting standards were enacted in 2001. PROCEL's target is to reduce electricity consumption and supply-side losses by about 8.4 terawatt-hours per year by 2003, equivalent to 2.5 percent of Brazil's power consumption. The program is on-track to meet these targets.

A tax incentive introduced in 1993 to encourage the use of less powerful cars (cars with engines less than 1 liter in size) reduced emissions by nearly 2 million tons of carbon per year. For qualifying cars, the so-called Tax on Industrialized Products was cut from 25 percent to 10 percent. This policy was meant to encourage production of more efficient automobiles and make them accessible to lower-income buyers. By 2001, almost three-quarters of domestic sales of new automobiles consisted of one-liter engine automobiles. Assuming that the tax reduction did not lead to a net increase in car sales, and that one-liter engine cars replaced more powerful automobiles, the policy saved nearly 2 million tons of carbon in 2000 (see Figure 3).[17]

Figure 3

Key Mitigation Measures

in Brazil, 2000



Source: Estimates by Roberto Schaeffer, Alexandre Salem Szklo, and Marcio Edgar Schuler, Federal University of Rio de Janeiro, 2002.

A small group of programs and measures related to forestry and land use has probably, as a side-benefit, reduced emissions. For example, nullification of land titles by Brazil's land reform agency has shifted control of more than 20 million hectares from land speculators, loggers, and ranchers back to small-scale farmers, probably decreasing deforestation.[18] Fire control programs and tax incentives for landowners who protect forest cover on their property also may have helped reduce emissions. However, emissions reductions from these programs and measures are difficult to quantify.

Future Mitigation Opportunities

A "business-as-usual" scenario of future energy-related carbon emissions, the government-sponsored "CNPE Scenario," ranks among the most influential studies of its type in Brazil.[19] This scenario projects that Brazilian GDP will grow at about 5 percent per year for the next two decades, and industry will grow faster than services and much faster than agriculture. Energy use will grow slightly less quickly, but will nearly double from 2000 to 2020. These results assume that population grows more slowly; energy intensity remains constant while energy use per capita almost doubles; energy efficiency continues to improve in end-use equipment and appliances; ownership of electric appliances grows in lower-income households; and natural gas continues to penetrate the industrial sector.[20] Total energy-related carbon emissions would grow from 91 million tons in 2000 to 139 million tons in 2010 and to 223 million tons in 2020.

The CNPE scenario further assumes that the hydrated ethanol production is halted, with no more automobiles fueled by pure ethanol after 2010, thus dramatically increasing transportation sector emissions. The scenario also assumes that ethanol composes only 22 percent of gasoline compared to 26 percent in 2002. The scenario is also very modest regarding bagasse-fired cogeneration and alternative energy sources. Although 4 gigawatts (GW) of wind power is already planned for 2004, the scenario assumes an addition of only around 1 GW by 2020. Small-scale hydro is projected to reach only half its estimated economic potential of 14 GW. The scenario estimates an increase in the average fuel economy for the passenger car fleet to 14 kilometers per liter (about 31.5 miles per gallon) in 2020.

An alternative scenario developed for this analysis assumes that the measures underway and analyzed here will continue over the long term. Unlike the CNPE Scenario, it assumes that 10 percent of the car fleet uses ethanol in 2020,[21] the efficiency of bagasse-fired cogeneration is improved by some 50 percent, small-scale hydro reaches 14 GW by 2020, all-natural gas-fired cogeneration replaces all thermal power plants, and additional electricity conservation saves 20 percent of projected

Table 3

Mitigation Potential

in Brazil, 2010 and 2020

Mitigation Options	Incremental abatement in emissions (MtC)[1] 2010	2020
Use of ethanol[2]	1.2	1.7
CHP fired by sugar-cane bagasse[3]	3.4	5.3
Wind power[4]	1.9	3.5
Small-scale hydro[5]	2.9	4.5
CHP fired by natural gas	1.8	4.4
Electricity conservation[6]	7.1	25.2

Notes:
(1) Reductions from CNPE Scenario's projected CO_2 emissions of 138.7 MtC/year in 2010 and 223.1 MtC/year in 2020.
(2) Assumes that 5% of the fleet still consists of automobiles fueled solely by ethanol in 2010 and 10% in 2020.
(3) Assumes that the power generation efficiency enhancement program for cogeneration plants continues.
(4) Assumes the pace of implementation forecast for the next four years and 15 GW installed by 2020.
(5) Assumes that capacity reaches 7 GW in 2010 and 14 GW in 2020.
(6) Assumes conservation savings of 10% of energy consumption in 2010 and 20% in 2020.

Mitigation potentials may not be completely additive.

Source: Estimates by Roberto Schaeffer, Alexandre Salem Szklo, and Marcio Edgar Schuler, Federal University of Rio de Janeiro, 2002.

electricity consumption in 2020.[22] If all these measures were successful, emissions would fall below the CNPE Scenario by 18 million tons of carbon, or 13 percent, in 2010; and by 45 million tons, or 20 percent, in 2020 (see Table 3).

A comparison of the alternative and the CNPE Scenario shows that the government forecast is modest regarding the potential reduction in carbon emissions from maintaining or expanding current programs. For instance, merely maintaining a fleet of 5 percent of vehicles fueled solely by ethanol and upgrading bagasse-fired cogeneration systems would abate approximately 5 million tons of carbon in 2010 and 7 million tons in 2020.

Alternative sources of power generation are becoming increasingly competitive in Brazil. Bagasse-fueled generation can supplement hydropower very effectively at costs as low as $0.03 per kilowatt-hour.[23] Regarding small-scale hydropower, this technological alternative tends to be competitive over the short- and medium-term. Despite wind power's considerable potential of almost 144 GW, it has a low capacity factor at around 25 percent. However, wind could supplement hydropower in some regions of Brazil.[24] For gas-fired cogeneration, doubts over the purchase and sale of electricity and lack of an incentive policy still hamper wider use of this alternative.[25] Finally, enhancing the efficiency of electricity use in Brazil is extremely cost-effective. A recent survey of electricity conservation measures implemented by distribution utilities shows an average cost of $0.02-0.03 per kilowatt-hour saved through efficiency measures.[26] In contrast, the average residential rate in Brazil was $0.08 per kilowatt-hour in early 2002.

In summary, while little progress has been made in reducing emissions from the land use sector, the energy-related programs and measures reviewed here have provided a broad range of benefits for the Brazilian economy, and helped lower carbon emissions. These programs and measures have cut investment requirements in the energy sector, reduced net energy imports and improved the balance of trade, enhanced energy efficiency, expanded renewable energy use, and ushered in several positive social and environmental changes. If implemented on a broader scale, these programs and measures would sharply curtail projected increases in carbon emissions. However, the largest source of carbon dioxide emissions in Brazil remains land use change. A top priority for carbon mitigation is the adoption of specific measures to curb deforestation.

III. China

China ranks second among nations in GHG emissions, mainly as a result of fossil fuel combustion. The nation's leaders view this fact in the context of China's large population, which is more than four times that of the United States, the world's largest emitter. Chinese decisions profoundly affect global emissions growth, and these decisions are, as elsewhere, driven by trends in economic development, local environmental protection, and technological change. Development policy in China has reduced its emissions growth well below expected levels, and a convergence of environmental issues with development imperatives offers an ongoing if uncertain opportunity to continue to slow emissions growth.

China remains a developing nation with per capita GDP averaging only one-eighth that of developed countries (see Table 4).[27] Three decades ago, China ranked among the world's poorest countries and had strictly a planned economy. Economic liberalization was adopted in 1979, with the Chinese government explicitly setting out to reduce energy demand growth while expanding the economy. The government believed that China could not afford the capital required to meets its development goals without dramatic change. The program of economic restructuring and liberalization it set in motion has achieved significant economic growth and improvements in living standards over the past quarter-century. As part of its broader structural reforms, China has undertaken extensive efforts in energy efficiency, renewable

Table 4

Key Socio-Economic Indicators

for China

Annual carbon emissions (energy and cement), 2000	848 million tons
Population, 2000	1.262 million
Population growth rate	0.7% per year
Per capita GDP, 2000	
Based on exchange rate	$855
Purchasing power parity	$3,830
GDP growth rate	7.8% per year in constant local currency units
Primary energy consumption, 1998	30 Gigajoules per capita
Residential energy consumption, 1998	8 Gigajoules per capita
Electric power consumption	913 Kilowatt-hours per capita/year
Persons below poverty line	30.0 million
Persons without electricity	23 million

Source: China Statistical Yearbook 2001; OECD: Basic Statistics, August 2002; World Bank Development Indicators, 2002; Oak Ridge National Laboratory, 2002.

energy, and reforestation. The resulting energy-intensity reduction remains unmatched in the history of economic development.

China has begun to make environmental protection a basic national priority. Many government leaders now recognize that economic growth cannot be sustained in the long term without reversing the damage to human health, national infrastructure, agricultural output, and natural ecosystems resulting from environmental pollution and resource depletion. Sustainability has become a key concept for Chinese leaders, and the government has begun to formulate policies and measures to promote sustainable development.

China ratified the Framework Convention in 1992 and the Kyoto Protocol in 2002. The government established the inter-ministerial National Climate Change Coordinating Committee in 1990, making it responsible for policies and measures to address climate change.

Energy and Emissions Profile

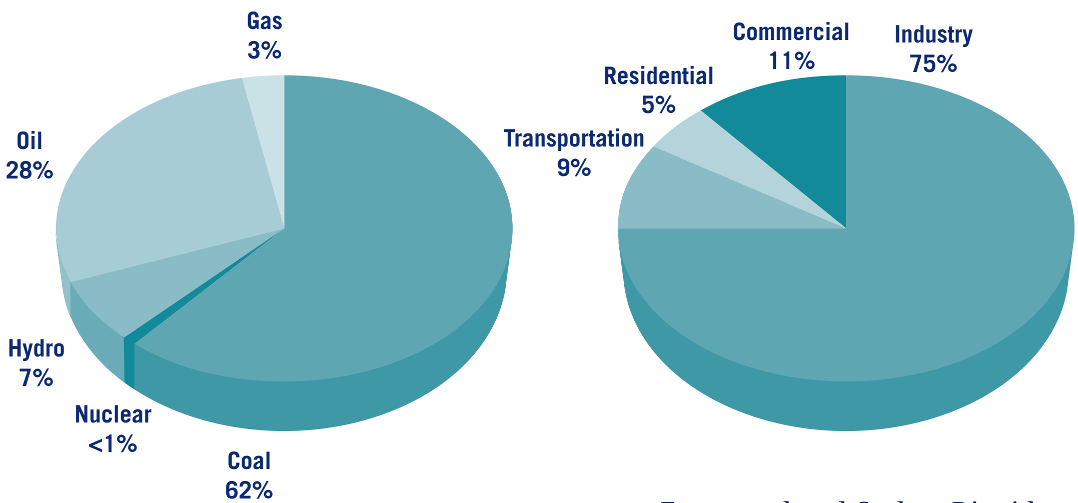
The nation's per capita use of commercial energy is roughly one-eighth the OECD level, though rapid economic growth continues to drive energy demand growth. In many rural areas, people still lack access to commercial energy supplies and instead use firewood and crop waste for cooking and heating. Use of these non-commercial forms of biomass energy fell in both relative (as a percentage of total energy use) and absolute terms since the late 1980s, but still accounted for about 14 percent of total energy use in 1998.[28] Some 23 million Chinese have no access to electric power of any kind. Industry consumes about two-thirds of all energy used in China, but this ratio is rapidly changing. As the country develops, more energy will be used in buildings and transportation.

Two-thirds of China's energy use is now supplied by coal (see Figure 4), which when burned releases sulfur and particulates that cause severe air pollution. Coal releases nearly twice as much carbon dioxide per unit of energy as natural gas. In order to take advantage of cleaner-burning, more efficient fuels, China is reducing coal's dominant position by increasing the share of natural gas, oil, hydropower, and renewable energy. The current five-year plan (2001-2005) sets goals of improving the energy infrastructure, increasing the share of energy provided by natural gas, and reducing coal use.

In 1998, China's energy-related carbon emissions totaled nearly 850 million tons of carbon. The transportation sector is currently responsible for only 9 percent of these emissions, but that figure is likely to grow dramatically even with strong government action. Rising incomes and China's entry to the World Trade Organization are making cars more affordable to the growing number of middle-income Chinese. Car sales during the first five months of 2002, for example, were up nearly 40 percent from 2001.[29] Many policymakers in China believe that the automobile sector can help spur economic growth over the coming decades, much as it did in some industrialized countries. Others challenge this assumption and call for greater reliance on modern mass transit systems and smart growth policies. The resolution of this debate will have a dramatic impact on China's future environmental profile.

Figure 4

Energy and Emissions in China, 1998



Primary Energy Use

Energy-related Carbon Dioxide Emissions

Source: Energy Information Administration, U.S. Department of Energy, 2002.

Renewables contribute only small amounts of energy. Modern renewables such as wind, biogas, and solar thermal and photovoltaic sources (as opposed to firewood, crop waste, and dung) contribute several million tons of coal equivalent annually.

Mitigating Measures

Growth in GHG emissions has been slowed to almost half the economic growth rate over the past two decades through economic reform, energy efficiency improvements, switching from coal to natural gas, renewable energy development, afforestation, and slowing population growth. Chinese researchers have not comprehensively documented the reductions in emissions growth resulting from these efforts. The following analysis documents reductions of 250 million tons a year—150 million as a result of slower population growth and 100 million as a result of reduced energy intensity.

Population growth is a principal driver of economic and energy demand growth. China, the world's most populous nation, has in recent decades sought to reduce pressure on social and economic development in China by slowing population growth. The government calculates that over the past 30 years the fertility rate has declined to within two, reducing births by more than 300 million—more than the population of the United States. Although motivated by other concerns, reduced population growth has made a real if indirect contribution to greenhouse gas mitigation in China. The resulting reduction in emissions growth amounts to approximately 150 million tons of carbon per year.[30]

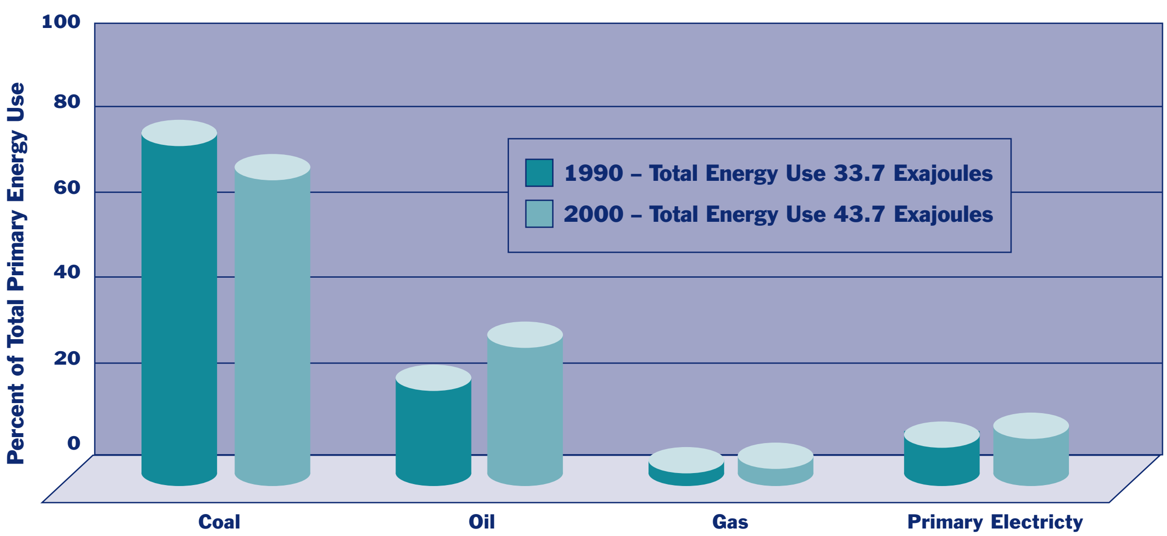
China's energy intensity—the amount of energy needed to fuel economic growth—declined approximately 60 percent between 1977 and 1997, an average of 4 percent a year.[31] Most developing countries at China's level of economic development have either steady or rising levels of energy intensity. Much of the technological progress achieved in China since the late 1970s can be considered "normal" due to the very inefficient state of the economy then. However, by 2000, additional measures in economic restructuring, energy price reform, and technological progress beyond the status quo are estimated to have resulted in 100 million tons of carbon mitigation a year.[32]

The Chinese economy of 2002 is vastly different from that of 1979 when economic reforms were first initiated. State-owned enterprises now account for half the GDP and the market now sets almost all prices for goods and services. Industrial policies enacted during the 1980s and 1990s, especially structural adjustment, tax reform, hard-budget constraints (removal of subsidies for unprofitable enterprises) and price rationalization played an important role in China's energy efficiency improvement. Energy prices are generally set by market mechanisms today and reflect world levels.[33]

One major consequence of China's energy and economic reforms has been a sharp reduction in the share of coal in total Chinese primary energy consumption. Official statistics show that coal production peaked in 1996 and declined nearly 25 percent by the end of 1999. A significant factor was the government effort begun in the late 1990s to close small, inefficient coal mines. By 2001, the government had shut down some 47,000 mines producing 350 million tons of coal. Fuel switching and improved coal quality also contributed to the steep decline in coal consumption. However, there has been considerable debate over the precise reduction in coal consumption, the degree to which it can be sustained, and its impact on carbon emissions. It appears likely that at least a portion of the reported decline is due to previously unreported coal production and consumption. Also, reduced consumption does not translate directly to reduced carbon emissions. Improved coal quality means less ash is burned, so less coal by weight is consumed, but net emissions may be unchanged. While coal use and associated emissions probably have not declined as much as earlier reported, more recent estimates show a decline of 10 percent or more in the 1990s, reducing coal's share of primary energy consumption from 76 percent in 1990 to 66 percent in 2000 (see Figure 5).[34]

Figure 5

Energy Supply Shift in China, 1990 vs. 2000



Source: China Statistical Yearbook, 2001.

The government at the same time has increased exploration and development of natural gas resources and has made significant discoveries in central and western China.[35] Some 28 new large- and medium- scale gas fields are now under development, with resources estimated at more than 38 trillion cubic meters. The city of Beijing has required the use of gas in place of coal in new fuel applications, a measure made possible by the 1997 completion of the Shan-Jing gas pipeline from Shaanxi Province. A much larger step was taken in 2000 to help meet demand for high-quality energy along the populous east coast. The west-to-east project, a 4,200-kilometer high-pressure gas transmission line from Xinjiang Province in far western China to Shanghai is expected to be completed by 2007. The gas pipeline will supply 12 billion cubic meters per year (almost one-half exajoule, or one half quadrillion BTU per year), and will substitute for over 20 million tons of coal annually. A natural gas development project began in the East China Sea in 2000 and is expected to produce 10 billion cubic meters per year by 2010. In addition, a project to import liquefied natural gas (LNG) has been started with an initial annual target of importing 3 million tons a year (equivalent to roughly 4 billion cubic meters of natural gas).

China is endowed with only 159 million hectares of forest, less than 4 percent of the world's total forested area and less than half the size of the U.S. National Forest system.[36] But forest cover has increased from 13 percent of the country in 1986 to almost 17 percent today. Forestry protection is China's largest ecological investment program. Major afforestation efforts have been undertaken since 1978 along the Yangtze River, in the eastern coastal area, on the plains, in the north and western deserts, and elsewhere. Similar efforts have been made to replace croplands with woods and grass.

The goals of the forestry protection drive are to reduce wood production by approximately 20 million cubic meters per year and to afforest almost 13 million hectares, protecting 94 million hectares of forests in 18 provinces. While motivated by the need to improve local environmental quality and to support development efforts, these projects also have increased the carbon sink in China by 47 million hectares. The contribution to carbon dioxide absorption by afforestation over the last half century has reached 123 million tons of carbon.[37]

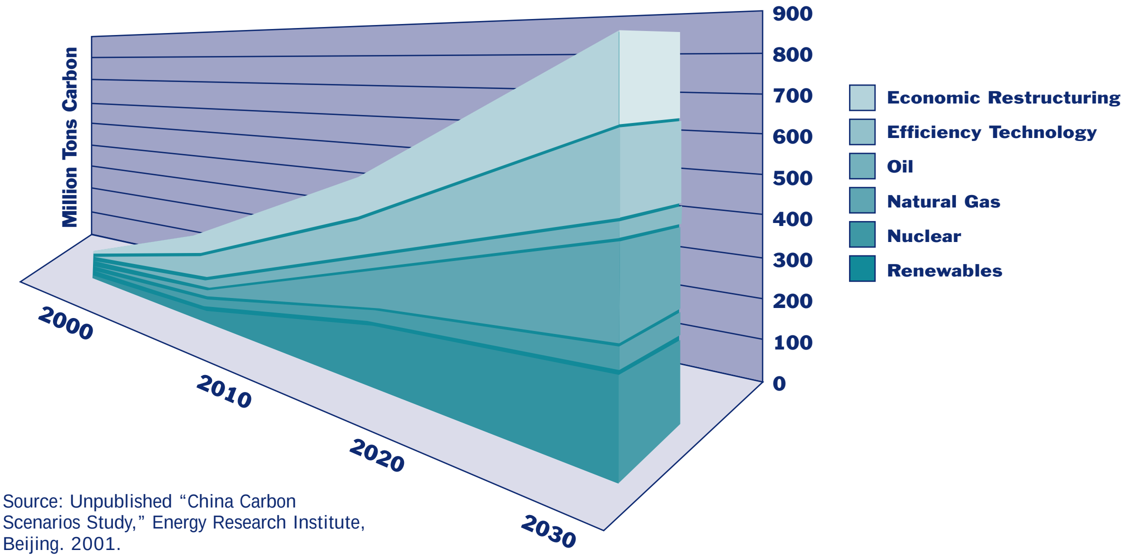
Future Mitigation Opportunities

Because the nation's top priorities are social and economic development and the eradication of poverty, China expects to continue high rates of economic growth for decades. Even so, per capita GDP will reach that of today's middle-income countries only after several decades. While China anticipates reaching higher income levels, it hopes to do so with much lower per capita GHG emissions than is common in developed countries today.

Over the past decade, Chinese researchers, often through international partnerships, have produced scenario-based studies of future emissions pathways. These studies incorporate assumptions about key factors of population growth, the rate and structure of economic growth, and changes in energy supply and demand technologies. China's ability to continue to slow the growth of GHG emissions for non-climate reasons depends on four major factors: sustaining economic reform; promoting energy efficiency in a more market-oriented economy; committing the country to clean air through fuel switching and enforcement of environmental regulations; and continuing slower population growth trends. The greatest perceived uncertainties are not in population and economic growth assumptions, however, but in economic structure, energy efficiency, and technological progress.[38]

Figure 6

Projected Emissions Mitigation in China, 2000-2030



Source: Unpublished "China Carbon Scenarios Study," Energy Research Institute, Beijing. 2001.

Chinese researchers also project that energy demand will grow nearly four-fold by 2050 to 122-150 exajoules. The resulting range for energy-related carbon emissions is large—from 1.5 billion-2.8 billion tons of carbon per year in 2030. China's economic structure is expected to continue to change, with agriculture declining and services increasing. Manufacturing and heavy industry, however, are projected over the long term to maintain their current share of GDP. The service sector is expected to develop more quickly than the rest of the economy, gradually providing the largest share of economic output.

One of China's most recent attempts to define future mitigation options in the energy sector is the China Energy and Carbon Scenarios Project undertaken by China's Energy Research Institute and international partners. Economic restructuring, efficiency technology, natural gas substitution, and renewable energy options contribute in roughly equal proportions to potential carbon mitigation, estimated at more than 800 million tons by 2030 (see Figure 6). The lowest emissions scenarios envision a greater shift to higher value-added service jobs at the expense of heavy industry. Energy supply will continue to shift from coal to oil and gas, but with no clear trend yet in sight for nuclear power. Technological improvement will also play an important role in energy efficiency. Energy use per unit of output for China's basic material products remains 40 percent higher than in more technologically advanced countries. Scenarios in this study with lower fossil energy demand were driven by policy measures assumed to introduce new energy conservation technologies, new power generation and clean energy systems, modern renewable technologies, and economic instruments such as taxation and incentives.

Additional climate mitigation could be achieved through tax and subsidies reforms. Tax reform in China started 10 years ago and energy subsidies have been reduced. Although a fuel tax for transportation will be introduced soon, to date there is no centralized energy tax. Chinese policymakers attempted to introduce such a tax in the late 1990s to replace steep and inconsistent local taxes. Implementation has been postponed due to relatively high international fuel prices and domestic political issues.[40] A carbon tax may not be possible in the short term, but could be implemented through a mixed energy tax.

Economic reform, fuel switching, population planning, and other measures have dramatically altered China's emissions trajectory. Many emissions mitigation opportunities that are consistent with economic development remain and can be realized through greater international cooperation, and direct and indirect domestic climate policy measures.

IV. India

India has the world's second largest population and fourth largest economy, with a per capita annual GDP of $2,358 (see Table 5).[41] The nation aims to reduce the poverty rate to 10 percent, provide full employment, ensure food, energy, and economic security, and double per capita income—all by 2012.[42] In pursuit of these goals, India has developed an open, market-based economy, and a highly sophisticated science and technology sector.

India's economy grew at a rate of almost 6.6 percent per year during the 1990s, nearly doubling over that time. Energy use grew even faster, at a rate close to 7 percent. Electric power demand has grown still faster—on the order of 8 percent per year. While these trends contrast with China's, where both power and energy have grown more slowly than the economy, India's per capita electricity use averages only one-half that of China, and one-sixth of the world average.

Table 5

Key Socio-Economic Indicators

for India

Annual carbon emissions (energy and cement), 1998	290 million tons
Population, 2001	1.027 million
Population growth rate	1.5% per year
Per capita GDP, 2000 **Based on exchange rate** **Purchasing power parity**	 $472 $2,358
GDP growth rate	5.1% per year in constant local currency units
Primary energy consumption, 1998	12 Gigajoules per capita
Electric power consumption	413 Kilowatt-hours per capita
Persons below poverty line	350 million
Persons without electricity	440 million

Source: World Bank Development Indicators, 2002; India Census, 2002; Tata Energy Research Group, 2002; U.S. DOE Energy Information Administration, 2002; Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, 2002.

India's carbon emissions per capita rank among the lowest in the world, averaging only one-quarter of the global average and one-twentieth the U.S. rate.[43] While India places a higher priority on development needs, policies driven by economic and environmental challenge have reduced growth in greenhouse gas emissions. The greatest challenge has been economic liberalization and restructuring to improve living standards. Pressure from citizen activists to reduce air pollution has also led to court decisions mandating strong clean air measures that affect energy systems.

India ratified the United Nations Framework Convention on Climate Change in 1993 and the Kyoto Protocol in 2002.

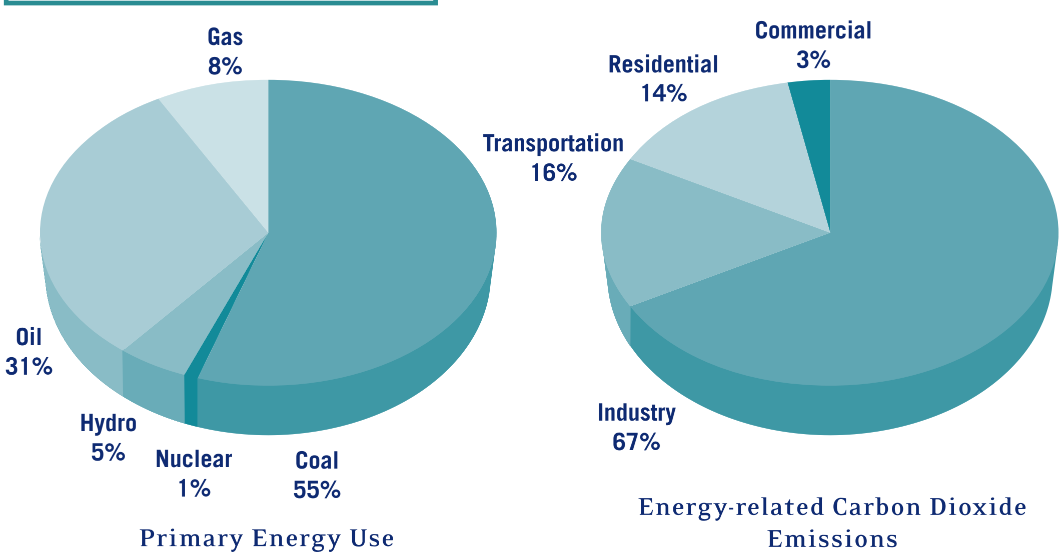
Energy and Emissions Profile

After climbing steadily for at least two decades, India's energy, power, and carbon intensities all began to decline rapidly after 1995. This shift suggests the start of a decoupling of energy and economic growth, as has historically occurred in industrialized nations at higher per capita income levels.

Industrial development has contributed significantly to economic growth in India, though not without an environmental price. With coal accounting for over half of total primary energy consumption, this industrial development has been fueled by a relatively high-polluting energy source (see Figure 7). Industrial pollution is increasing public health risks, and abatement efforts are consuming a significant portion of India's GDP. Energy consumption by the industrial sector accounted for 41 percent of total energy consumption in 1998.[44]

Figure 7

Energy and Emissions in India, 1998



Source: Energy Information Administration, U.S. Department of Energy, 2002.

Industrial energy intensity has declined gradually over the past decade, mainly due to the adoption of new and efficient technologies and rapid expansion of non-energy-intensive industries.

Because Indian industry is still highly energy intensive compared to industrialized countries, there is considerable room for improvement.

Non-commercial biomass energy meets the cooking needs of most rural Indian households and nearly half of urban households.[45] Although commercial forms of energy are penetrating rural and traditional sectors, biomass still accounts for roughly one-third of total Indian energy use.

India's carbon emissions have grown by 63 percent over the last decade, despite the decline in carbon intensity later in the decade. This emissions growth results primarily from energy use associated with economic development and heavy dependence on coal. Methane, originating primarily from rice paddies and ruminant cattle, contributed one-third of India's total GHG emissions, although its share decreased rapidly with the rise in energy-related carbon emissions.

Mitigating Measures

Growth of energy-related carbon dioxide emissions in India was reduced over the last decade by an estimated 111 million tons.[46] The key factors in these reductions have been economic restructuring, local environmental protection, and technological change. These drivers have been mediated through economic reform, enforcement of existing clean air laws by the nation's highest court, and renewable energy incentives and development programs funded by the national government and foreign donors. In 2000 alone, energy policy initiatives reduced carbon emissions growth by 18 million tons—about 6 percent of India's gross energy-related carbon emissions.

Market reform driven by domestic policy and international dynamics over the past decade has improved India's fuel quality, technology standards, infrastructure, and operating practices. A key example is power sector restructuring and reform. The Electricity Supply Act of 1905 designated electricity as essentially a human right in India. The advent of market-based pricing for both power and liquid fuels is replacing the administered-price system of the old planned economy. Current prices and bill collections now cover about two-thirds of the cost of power; the remainder is covered by various forms of subsidy. In some cities such as Ahmedabad, power costs more than the U.S. average. Many people still do not pay for power, meaning that the high price reflects a large cross subsidy for the poor and free riders. Liquefied petroleum gas, which is used widely for cooking, is modestly subsidized, but prices are headed toward international levels. Other market reforms have allowed the import of foreign cars and appliances, which generally are more energy-efficient than those they replace.

Restructuring of the coal sector has been encouraged through privatization, price reform, and technological improvements. Historically, subsidies for coal production encouraged coal use and therefore increased carbon dioxide emissions. Price reforms have reduced subsidies, bringing the coal price close to world levels. The private sector still accounts for less than 10 percent of coal production, and the shift from state ownership of mines is proceeding slowly because of political resistance by unions and vested interests. Moreover, mineral rights belong to the states, ensuring a public-sector role in coal development.

Technology development measures in the energy sector have contributed a series of small but notable reductions in emissions growth. Improvements in stoves, reduction of gas flaring in fossil-fuel production, improvements in demand- and supply-side efficiency, and the introduction of modern renewable energy systems now mitigate about 18 million tons of carbon per year. None of these measures has been exploited to its full potential, and many could lead to further reductions in emissions growth in the future.

There has been sweeping change in India's vehicle stock over the past decade. Economic reforms enlarged the vehicle market and prompted rapid penetration by foreign brands. Rising concern about air quality prompted the introduction of emissions-limiting performance standards in 2000. European-level emission norms for new cars and passenger vehicles were introduced in 2002 in Delhi, Mumbai, Chennai, and Kolkatta.[47] Apart from mitigating local pollutants, vehicles meeting these norms are more energy efficient and emit fewer GHGs for the same level of service.

In Delhi, 84,000 public vehicles—all buses, taxis, and three-wheelers—were converted from gasoline and diesel to compressed natural gas (CNG).[48] This rapid achievement, accomplished in about one year, was mandated by the Indian Supreme Court in response to a lawsuit filed by a non-governmental organization seeking enforcement of clean air laws. Though the compliance cost per vehicle was relatively high—up to $300 for a three-wheel vehicle and $1,000 for a car—the policy has been applied uniformly and effectively. The resulting reduction in carbon emissions is not yet certain and the CNG mandate is unlikely to be replicated in other cities due to its cost. However, vehicle emissions limits are likely to be enforced elsewhere, requiring other solutions that may also reduce carbon emissions.

The Indian electricity sector has long been carbon intensive and the largest source of carbon dioxide emissions. In 2000, the sector emitted 115 million tons of carbon, about 42 percent of India's carbon emissions. Natural gas has penetrated this market in recent years and helped to reduce the carbon intensity of electric power generation. Improvement in the combustion efficiency of conventional coal technologies along with strong promotion of renewable technologies has made measurable contributions to mitigation. Improved combustion in coal-fired power plants slowed the growth of carbon emissions by 2.5 million tons between 1990 and 2000. The Indian government has set a goal of using renewables for 10 percent of new power generating capacity by 2010.

Lower carbon emissions also have resulted from important technological advancements in coal washing. Indian coal averages approximately one-third ash, wreaking havoc with boilers and their efficiency, driving up transportation costs, and creating serious air pollution. One recent government policy restricts the transportation of unwashed coal to less than 1,000 kilometers. As Poland experienced after the collapse of Communism, the appearance of market competition and consumer choice made it possible to buy higher quality coal.[49] Customers are motivated to reduce ash content to improve efficiency, reduce local pollution, and cut freight costs. New combustion technologies, including supercritical coal-fired power plants, are being introduced, and the capture of coal-bed methane is being promoted.

Annual reporting of energy conservation measures, mandatory for private companies since 1995, has helped identify significant opportunities for efficiency improvement. One notable example is a dramatic reduction in gas flaring, which amounted to 29 percent of gas production in 1990, and less than 6 percent by 2000.[50] This improvement was supported by government investment in natural gas collection and delivery pipelines.

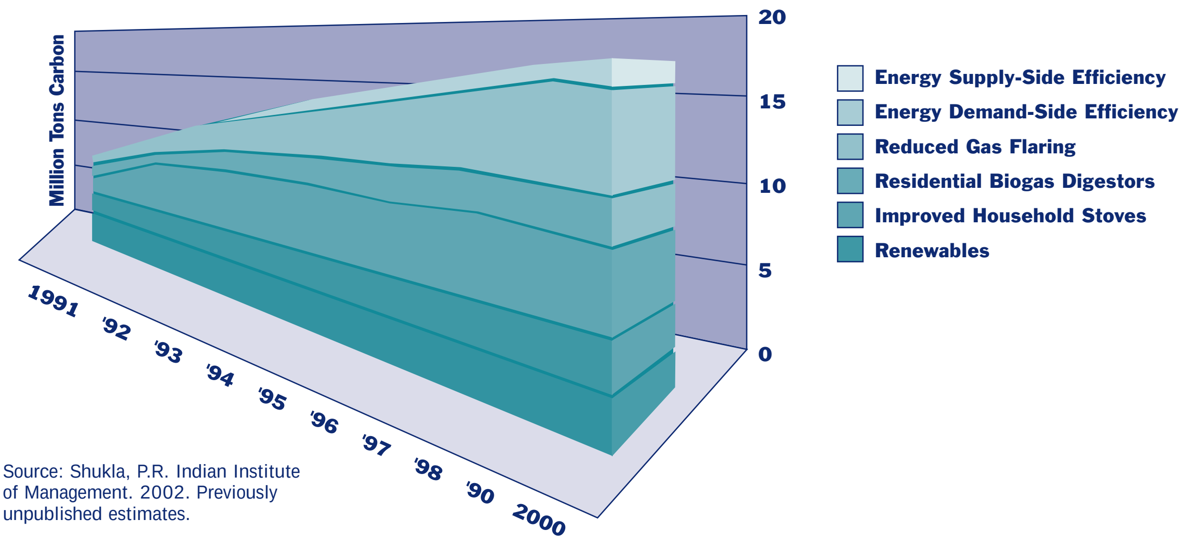
Government policy has included public investment to develop the natural gas infrastructure for long-distance and local distribution. One example is the HBJ 1,500-kilometer high-pressure gas pipeline from near Mumbai to the north of Delhi, which carries 4 billion to 5 billion cubic meters of gas from offshore production. The share of gas in power generating capacity has risen to 8 percent from only 2 percent ten years ago. Liquefied petroleum gas has significantly replaced commercial coal and kerosene in urban households. Public vehicles have been converted to compressed natural gas.

India has instituted a sizable renewable energy program over the past 20 years, including the creation of the Ministry of Non-Conventional Energy Sources in 1992. About 3.3 million household biomass gasification systems have been built. These systems produce 3-4 cubic meters of biogas per unit per day, enough to supply cooking fuel for a large percentage of rural homes. A larger scale program has improved the efficiency of wood stoves in 34 million homes, reducing deforestation in areas where wood fuels were unsustainably harvested.

“Technology push” programs, supported by subsidies, have created niche markets for otherwise expensive solar technologies. These include solar lanterns (photovoltaic cells) capable of powering a 100-watt bulb, home and street lighting systems, water pumps, and stand-alone power plants. Direct solar water heating systems have also found a market in urban buildings. Similar strategies have led to high initial penetration of wind, small hydro, biomass, and industrial waste-based electricity generation technologies. While the quantitative impact of these systems may appear quite small, Indian analysts argue that the most significant achievement of the renewable energy program is the creation of domestic capacity that could sustain renewable energy markets in the future (see Figure 8).

Figure 8

Emissions Mitigation in India’s Energy Sector, 1991-2000



Source: Shukla, P.R. Indian Institute of Management. 2002. Previously unpublished estimates.

On the demand side, rationalization of power rates has been slow due to political resistance, but has nevertheless been the most significant action. The resulting carbon mitigation is small and difficult to measure, but the policy has prepared the way for future efficiency improvements through consumer response to prices. Transmission and distribution reforms to minimize the theft of electricity, coupled with consumer education, have produced some carbon emissions reductions.

Forests cover nearly one-fifth of India's land mass. The per capita deforestation rate has been among the lowest of the major tropical countries. In recent years, closed forests have actually increased in total area.[51] Forest conservation measures include prohibiting the use of forest land for non-forestry purposes, encouraging agroforestry and private plantations to meet industrial wood needs, and expanding areas under protection. During the last decade, over 14 million hectares were protected under Indian forestry programs. These efforts have led to a steady increase in the rate of forestation, significantly contributing to the removal of atmospheric carbon.

Future Mitigation Opportunities

Business-as-usual projections, assuming sustained economic growth and continued dependence on domestic coal resources, suggest sharply rising energy use and GHG emissions in India. One influential study, the Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS), projected energy-sector carbon emissions of at least 688 million tons in 2030, nearly three times the current level. Forestry-related emissions would reach 21 million tons of carbon by 2020 and about 29 million tons by 2030. More recent studies have given lower energy-related estimates, one projecting 572 million tons in 2020.[52]

The ALGAS scenario is driven by a continuation of economic, demographic, and energy trends and current policies. The economy would grow at an annual rate of 5 percent, increasing GDP in 2030 to nearly five times the present level. India's population would increase from 1 billion to 1.35 billion. However, energy use would only triple, mainly because the current energy intensity reduction rate of 1.5 percent per year is assumed to continue. Carbon emissions would increase at about half the rate of GDP—2.7 times—because carbon intensity would decrease as gas and renewables substitute for coal. Methane emissions would grow slowly due to low growth in the agriculture and livestock sectors, the main contributors of methane emissions. Local air pollutants would rise at much lower rates—and particulate emissions would actually decline—due to policies that are already being implemented as a result of increasing public pressure.

Most studies of future emissions in India suggest a hierarchy of mitigation options. These include energy efficiency and forest sinks, fuel switching from coal to gas and renewables, and advanced technologies such as solar photovoltaics and nuclear power under more stringent mitigation requirements.

Indian experts estimate that India could reduce projected emissions over the next 30 years by nearly one-quarter for less than $25 per ton of carbon equivalent, with a substantial portion available at a very low cost (see Table 6). Over the next decade, 120 million tons of carbon mitigation could be achieved at a cost of $0-15 per ton avoided. Major opportunities include demand- and supply-side efficiency measures, fuel switching from coal to gas, afforestation, and power transmission improvements. Demand- and supply-side efficiency measures alone could avoid 45 million tons of emissions.

The cost of these measures depends on the extent to which they would be applied, which in turn depends in part on the stringency of GHG reduction policies. India could in the midterm help finance these mitigation measures by selling emission reduction credits, either through the Clean Development Mechanism established under the Kyoto Protocol, or in a futures market based on expectations that future global policies will impose more stringent GHG restrictions, provided that credits could be banked and sold.

Table 6

Mitigation Potential in India

Greenhouse Gas	Mitigation Options	Mitigation Potential 2002-2012 (million tons)	Long-term Marginal Cost ($/ton of carbon equivalent)
Carbon	Demand-side energy efficiency	45	0-15
	Supply-side energy efficiency	32	0-12
	Electricity transmission and distribution	12	5-30
	Renewable electricity technologies	23	3-15
	Fuel switching (gas for coal)	8	5-20
	Forestry	18	5-10
Methane	Enhanced cattle feed	0.66	5-30
	Anaerobic manure digesters	0.38	3-10
	Low methane rice varieties	marginal	5-20
	Cultivation practices	marginal	0-20
Nitrous Oxide	Improved fertilizer application	marginal	0-20
	Nitrification inhibitors	marginal	20-40

Source: Based on modeling exercises reported in Rana, A. and Shukla, P.R. (2001), Ghosh et al. (2001); Garg A. and Shukla, P.R. (2002); and ALGAS (1998).

V. Mexico

Like most Latin American and Caribbean countries, Mexico, with its population of nearly 100 million is more than halfway through the process of demographic transition. Population growth rates have steadily declined from 3.3 percent per year in 1965 to 1.4 percent per year today, and the population is aging.[53] Poverty affects more than half the population, three-fifths of whom live in urban areas (see Table 7).[54]

Factors driving the evolution of Mexican emissions include population, economic development, energy sector growth, technological change, and land use policies. Measures undertaken to reduce deforestation rates, switch to natural gas, and save energy have indirectly reduced carbon emission growth by over 50 million tons, cumulatively, over the last decade.

Mexico has so far been unable to decouple to any clear extent the dynamics of emissions growth from those of the economy as a whole. Mexico's agitated economic history of the last two decades included the 1994-95 crisis during which GDP declined over 6 percent, followed by an economic recovery that lasted until 2001. Mexican carbon intensity, though much lower than the world average, seems to have stagnated over the last two decades.

Mexico ratified the Framework Convention in March 1993, as a developing (non-Annex I) country. This status did not change when Mexico joined the OECD, historically considered an association of developed or industrialized countries. Mexico at that time withdrew from the G-77, the group of developing countries

Table 7

Key Socio-Economic Indicators

for Mexico

Annual carbon emissions, 1996	187 million tons
Population, 2000	100.5 million
Population growth rate	1.4% per year
Per capita GDP, 2000	
Based on exchange rate	$6,000
Purchasing power parity	$9,100
GDP growth rate	1.5% expected for 2002
Residential energy consumption, 2000	333 Kilowatt-hour per capita/year
Persons below poverty line	54 million
Persons without electricity	5 million

Sources: OECD Basic Statistics, August 2002; National Institute of Statistics, 2000; Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, 2002; World Bank Development Indicators, 2002.

aligned as a negotiating bloc in multilateral climate negotiations. Mexico became the first large oil-exporting country to ratify the Kyoto Protocol. It was also the first non-Annex I country to submit two National Communications summarizing emissions data and measures, as required under the Framework Convention.

Energy and Emissions Profile

Mexico is the largest source of energy-related greenhouse gases in Latin America, but remains well below the per capita average of industrialized countries. Mexican net emissions of carbon dioxide in the mid-1990s represented less than 2 percent of the world's total.[55] Per capita net emissions amounted to 2 tons of carbon equivalent, almost half of which come from fuel combustion.[56]

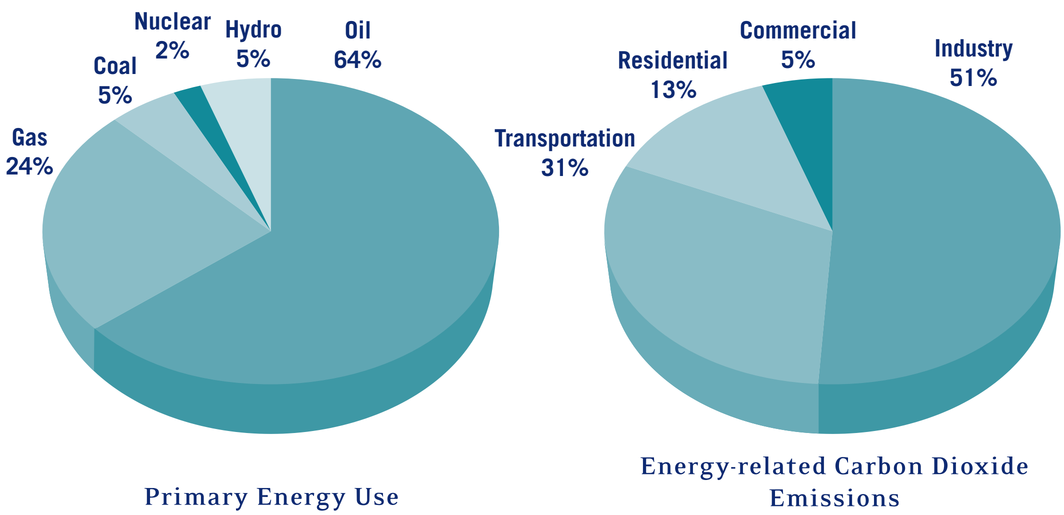
GHG emissions totaled 143 million tons of carbon equivalent in 1990, and grew about 31 percent to 187 million tons by 1996. Carbon dioxide, methane, and nitrous oxide contributed 140 million, 43 million, and just under 4 million tons, respectively.[57] (Half the apparent absolute increase corresponded to "industrial processes" and "municipal and industrial wastes," two areas where major changes occurred in the inventory methodology.[58]) Methane fugitive emissions from the oil and natural gas industry amounted to 12 million tons of carbon equivalent, more than 6 percent of Mexico's total emissions.

Energy-related activities, including transportation, industrial processes, and fugitive methane emissions, produced almost 60 percent of Mexico's total emissions. Urban and industrial wastes accounted for nearly 9 percent, with agriculture, livestock, land use change, and forestry accounting for the remaining 32 percent. Industrial processes, especially in the cement, metal, chemical, and mining sectors, produced 6 percent of total greenhouse gases, but are growing fast. The transport sector, dominated by trucks, buses and small vehicles, accounts for over 30 percent of Mexico's energy-related carbon dioxide emissions (see Figure 9).

Mexico's oil and gas industries were nationalized in 1938, as were electric utilities in 1960. The energy sector has essentially remained a state monopoly for the last four decades. The discovery in the 1970s of huge crude oil deposits, particularly in the southern Gulf of Mexico, determined the current structure of Mexico's primary energy supply. Dominated by oil and gas, it is quite different from that of most developed nations and even from the world average. While Mexico evolved from an oil importer to one of the world's largest exporters, domestic consumption of primary energy has remained quite low.

Figure 9

Energy and Emissions in Mexico, 1998



Source: Energy Information Administration, U.S. Department of Energy, 2002.

Total primary energy supply in 2000 reached 9.7 exajoules, growing at an annual rate of 4.1 percent over the previous 5 years. Over half of all crude oil produced—some 3 million barrels per day in 1998—is exported, primarily to the United States. Although steadily decreasing since 1983, Mexico's proven reserves of crude oil rank ninth worldwide.[59] Known natural gas reserves are smaller, with Mexico ranking behind 20 other countries in that low-carbon resource. The Mexican government runs to a large extent on oil, which provides 37 percent of all federal revenues. The government has stressed the view in recent years that the long-run adverse effects of climate change may represent a much more serious threat than the loss of income derived from reduced international demand of oil.

Domestic primary energy consumption totaled 6.4 exajoules in 2000, some 16 percent higher than in 1995. Consumption is dominated by the energy sector itself, transport, and industry. Oil provides 53 percent of energy supply, followed by natural gas at 30 percent. Biomass, coal, hydro, and nuclear supply 6, 4, 4, and 2 percent, respectively. Geothermal and wind together provide less than 1 percent.

Production of electricity increased 5.2 percent per year over the last decade, much faster than GDP.[60] This growth has nevertheless been insufficient to satisfy expanding demand. The industrial, household, commercial, and agricultural sectors consumed 60, 23, 8, and 5 percent of Mexican electricity, respectively. A large part of the power generation and transmission infrastructure has become obsolete and inefficient due to insufficient public investment. A constitutional provision giving the government primacy in the power sector[61] has thwarted private-sector participation in power production.

Power has long been subsidized in Mexico. Rates are 30-49 percent lower than real costs. The resulting subsidies amounted to nearly $6 billion in 2000. The industrial power rate is nevertheless among the highest in Latin America, and higher than industrial power rates in Canada and the United States, the two other parties to the North American Free Trade Agreement. Transport fuel prices have also been steadily increasing in Mexico during the last decade, with gasoline costing more than in the United States. High energy prices in Mexico and specific air pollution control efforts in Mexico City contributed to some decrease in demand and associated emissions. However, efforts in the capital city have fallen short of achieving compliance with air quality norms, especially with respect to ozone and particulate matter.

Mitigating Measures

In the 1990's, Mexico adopted policies and measures that have helped curb the growth of the country's energy-related GHG emissions by 10 million tons of carbon per year.[62] Expanding use of natural gas in place of more carbon-intensive fuels, promoting energy efficiency, and abating some deforestation are the main contributors to climate mitigation.

The most significant efforts in the energy sector have been improving energy efficiency and fuel substitution, by means that include energy pricing mechanisms. Capacity-building efforts assisted by the World Bank and others led to the creation of two important institutions for energy efficiency: the National Commission for Energy Saving (CONAE) and the Fund for Saving Electric Energy, created in 1989 and 1990, respectively. The former promotes energy savings nationwide, fosters the use of renewable energy, develops official norms for energy use, and supports research and development for rational energy use. The latter, a non-profit organization, helps implement a utility-based program for power savings.[63] The substitution of compact fluorescent lamps for home lighting began in the early 1990s with small-scale projects that proved the feasibility of this energy-saving strategy, which was eventually expanded. By 1999, approximately 3.3 million lamps had been replaced, with annual savings of 500 gigawatt-hours, thereby avoiding the addition of over 100 MW in generating capacity. CONAE has successfully promoted energy efficiency standards for various appliances and equipment. Existing legislation mandates 18 appliance efficiency standards that reduced Mexican energy consumption in 2000 by 7.5 terawatt-hours, avoiding the need for 1,000 MW of base-load generating capacity, the equivalent of a large power plant.

Demand-side efficiency and clean energy project savings directly reduced 1999 emissions in Mexico by 2.1 percent[64] and reduced peak power capacity requirements by over 5 percent, saving $1.2 billion. About one-fifth of total energy savings and emission reductions in electricity use stemmed from more efficient electric pumping for irrigation.

Petróleos Mexicanos (PEMEX), the state-owned oil company that monopolizes crude oil and gas extraction in Mexico, is also one the country's largest energy consumers. A program of energy saving within the company has already reduced its emissions by about 11 million tons of carbon a year.[65]

Mexico has considerably expanded natural gas use, for environmental as well as economic reasons, although demand has continued to outstrip supply. Reforms established in 1995 allow the private sector to participate in the transport and distribution of natural gas. However, exploration and development is still largely controlled by PEMEX. Natural gas consumption grew by 2.5 percent annually during the 1990s, faster than growth in the petroleum sector. In May 2002, natural gas imports reached an unprecedented level of 0.6 exajoules, while production fell to 4.4 exajoules.[66] Most of Mexico's natural gas supply is located in the south, far from centers of demand, but budget constraints have slowed construction of new natural gas pipelines.

The availability of cheap fossil fuel has restricted the expansion of renewable energy, which previously played an important role through the construction of hydropower dams. Nevertheless, Mexico has a large potential for renewable energy, which the government has been exploring through a series of demonstration projects since the mid-1970s. These projects have significantly increased industrial capacity in areas such as the manufacture of solar technologies.[67]

The terrestrial carbon stock in Mexico's vegetation represents nearly 24 billion tons of carbon, more than the equivalent of three years of global energy-related emissions.[68] The biotic quality of this carbon pool is striking: Mexico is one of 12 countries recognized as "mega-diverse." With just under 2 million square kilometers, or 1.5 percent of the world's terrestrial surface, Mexico possesses 10-12 percent of all known animal and plant species. A large proportion of these species is endemic—that is, found only in Mexico.[69]

Decades of deforestation, habitat destruction, and land transformation have erased 45 percent of Mexico's original forests since the 1950s. The situation in the humid tropics was even more serious, with less than one-fourth of the original rainforest remaining.[70] Deforestation continues, affecting

600,000-800,000 hectares per year over the past decade. The expansion of extensive cattle ranching has been the main cause of deforestation, particularly in the humid tropics of the southeast. Rough estimates of 1996 emissions from land use change and forestry suggested that the carbon sequestration of Mexican natural areas had been reduced by 44 million tons of carbon equivalent. Natural vegetation still covers about 135 million hectares, or two-thirds of the total terrestrial surface, with about half of that amount covered by forests.

Future Mitigation Opportunities

The Mexican government projects that nearly 29 million people will be added to Mexico's population before it stabilizes after around 2040 at about 131 million.[71] Keeping pace with population growth and maintaining the present per capita GDP would raise domestic energy consumption by nearly 2 exajoules a year.

Baseline projections of energy sector growth indicate that carbon dioxide emissions will continue rising. National consumption of electric power is expected to grow at a rate of 6.3 percent a year. Marketed electric power may grow from 162 terawatt-hours in 2001 to 265 terawatt-hours in 2010, a 63 percent increase.[72] By 2010, capacity to generate electric power is expected to grow by at least 3,000 MW per year, requiring investments up to $72 billion. This is beyond the reach of the government's investing capacity, so new reforms will likely be necessary. The speed and depth of the renovation of electric infrastructure will depend on the outcome of the ongoing constitutional debates on public delivery of energy services.[73]

The dynamics of natural gas production and distribution will determine energy sector emissions for at least the next decade. Domestic reserves of natural gas are highly uncertain. Gas development faces many of the same constitutional and political obstacles as the power sector. Natural gas production is expected to grow at a rate of over 6 percent per year, reaching 7.6 exajoules annually by 2010.[74] Domestic demand is expected to continue to grow faster than supply, pointing to the need to expand imports. Nuclear power has faced strong opposition from broad sectors of Mexican society, and the government has no plan to expand existing nuclear power generating capacity. Specific plans have been drawn to foster the development of renewable energy.[75]

One influential study projected an increase in Mexico's carbon dioxide emissions of 149 percent from fuel combustion, and a decrease of one-third from land use and forest changes, between 1990 and

2010.[76] According to this study, total carbon dioxide emissions would grow 69 percent. Should sufficient investment be available, mitigation strategies identified in the study could reduce emissions 45 percent below the baseline projection for 2010, reaching a level close to that of 1990.

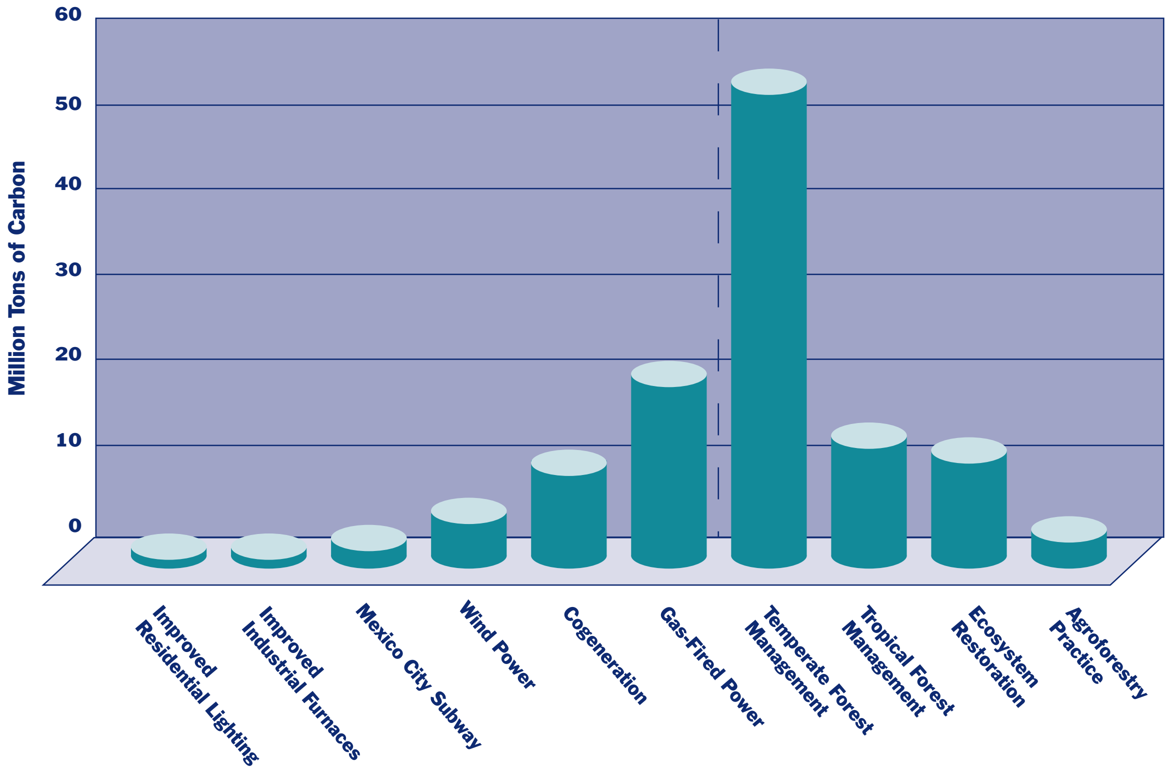
According to Mexico's Second National Communication, the climate change mitigation potential is 107 million tons of carbon in 2010. About one-third from fuel combustion (see Figure 10) and two-thirds from the forestry sector.[77] In both sectors, insufficient investment is the main bottleneck. The evolution of energy-related emissions will depend on the outcome of negotiations to change the energy sector's legal framework. Ideological differences and the existing balance of power in Congress make it difficult to reach a consensus to amend the Mexican constitution, which currently limits participation of the private sector in the production and distribution of energy. A recent attempt by the government to circumvent some of the existing legal barriers by means of stretching regulations was stalled by a resolution of the Supreme Court of Justice on a constitutional controversy raised by Congress. Full-fledged legal reform is therefore necessary to expand private participation in a significant way.[78]

An evaluation of the costs of viable mitigation strategies in the energy and land use sectors was undertaken recently as part of Mexico's Second National Communication.[79] Actions such as replacing light bulbs and improving pumping systems are considered to be "no-regrets" options, providing benefits even in the absence of emissions mitigation. While sustainable management of agroforestry and plantations is not the least expensive mitigation option—contrary to widespread perception—its potential is much greater than that of the no-regrets alternatives in the energy sector. A recent comparative study of mitigation potential and forestry options demonstrates that negative cost options, abundant in other developing countries, are not easily found in Mexico.[80] As elsewhere, market failures and institutional and socio-cultural barriers limit the feasibility of forestry options.

The country's largest city, Mexico City, and its largest company, PEMEX, both are developing plans to deal with climate change. Mexico City, in hopes of achieving multiple benefits, plans to become the largest local government in the western hemisphere to adopt a formal strategy for mitigating climate change. PEMEX is the first oil company or large enterprise of any kind in a developing country to establish a voluntary internal emissions trading system.[81] Twenty-five business units participate in this experimental market, based on a cap-and-trade system. PEMEX has met its early emissions reduction targets with virtual, or shadow, internal trades amounting to over 3 million tons of emissions, a value of nearly $19 million.[82] The trading will use real exchanges of money beginning in 2003.

Figure 10

Energy and Forestry **Mitigation Potential** in Mexico, 2010



Source: Adapted from information included in the Second National Communication.

Two-thirds of the potential for mitigating climate change is to be found in the forestry sector and could, through an administrative reform process, be achieved without any radical change in Mexico's legal framework.[83] However, other restrictions such as lack of investments and infrastructure, market failures, and ill-defined property rights and other factors may prevent the full realization of these mitigation options. Total land area suitable for forestation on degraded forest land may be much greater—from 21 million to 36 million hectares.[84] The total mitigation potential for these lands reaches 300 million tons of carbon in 2012 and 1,382 million tons in 2030.[85]

Mexico demonstrates that a large developing, oil-exporting country may nevertheless carry out mitigation efforts and adopt a proactive stance in the climate change negotiations, including early ratification of the Kyoto Protocol. While overall mitigation results in Mexico are still modest, activities undertaken to date may pave the way for more ambitious goals in the near future.

VI. South Africa

South Africa is the most industrialized country in Africa. Located at the southern end of the African continent, South Africa has a population of about 43 million people (see Table 8). It is the world's largest producer of gold and platinum, the fifth largest producer of diamonds, and the fourth largest producer of hard coal. The nation's economy is tied to energy production and use, with coal accounting for about 75 percent of total energy use and 91 percent of power generation.

South Africa continues to undergo profound economic change following the democratic elections of 1994, which shifted the government from Apartheid to democracy. This gave new direction to almost all aspects of government. South Africa's ruling party, the African National Congress, outlined a development path in its Reconstruction and Development Programme in 1994. The program's objective is to meet basic human needs for housing, water, sanitation, transport, telecommunications, and energy, and to create jobs through public works. A new macroeconomic policy launched in 1996, known as the "Growth, Employment, and Redistribution" strategy, outlined goals for reducing the trade deficit, creating jobs, and lowering inflation and interest rates. While the overriding objective of these development efforts is sustainable economic development, they offer the complementary benefit of reducing GHG emissions growth.

Table 8

Key Socio-Economic Indicators
for South Africa

Annual carbon emissions (energy and cement), 1998	94 million tons
Population, 2000	43 million
Population growth rate	2.0% per year
Per capita GDP, 2000	
Based on exchange rate	$3,020
Purchasing power parity	$9,401
GDP growth rate	3.4% per year in constant local currency units
Primary energy consumption, 1998	110 Gigajoules per capita
Electric power consumption	4,221 Kilowatt-hours per capita/year
Persons below poverty line	6.1 million
Persons without electricity	15 million

Sources: World Bank Development Indicators, 2002; U.S. DOE Energy Information Administration, 2002; Statistics South Africa, 2000; South African Reserve Bank, 2002; National Electricity Regulator, 2001, "Lighting Up South Africa 2001," available at www.ner.org.za.

South Africa ratified the Framework Convention in 1997 and the Kyoto Protocol in 2002.

Energy and Emissions Profile

South Africa's total GHG emissions in 1999 equaled 1.6 percent of global emissions.[86] The energy and cement sectors in 1999 produced 94 million tons of carbon, or 2.3 tons per capita—nearly ten times the African and twice the world average. While total emissions increased substantially from 1990 to 2000, per capita emissions remained roughly constant.[87]

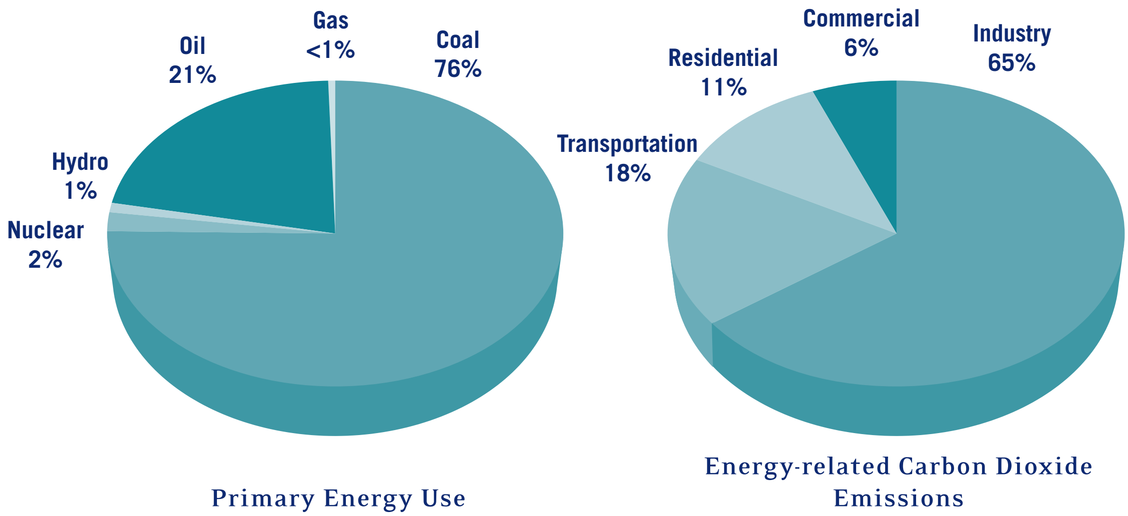
Compared to other major developing countries, South Africa's emissions intensity—emissions per unit of economic output—is relatively high. While coal use in electricity production is a main reason for this emission profile, other reasons include the production of synthetic liquid fuels from coal, a high proportion of energy-intensive industry and mining, and inefficient use of energy. The driving force behind dependence on these high-carbon fuels was the need to produce fuel from domestic sources during the period of isolation brought on by Apartheid. Natural gas currently accounts for only about 2 percent of total primary energy consumption (1.6 billion cubic meters), but 86 billion cubic meters of confirmed reserves were found offshore in late 2000. This was the first major domestic find.

The energy sector contributed 78 percent of South Africa's total GHG emissions in 1994, and more than 90 percent of carbon dioxide emissions. Although South Africa represents only 5 percent of Africa's population, the nation consumes half the electricity produced on the continent. Industry accounts for 55 percent of the nation's overall annual energy consumption, with transportation, residential buildings, and commercial buildings responsible for only 17, 16, and 11 percent, respectively. Industry's share of energy-related carbon dioxide emissions is even higher, at 65 percent (see Figure 11).

Fifteen million South Africans, one-third of the population, meet their daily energy needs using firewood. Only about two-thirds of households are connected to the power supply grid. An initiative to increase residential power connections, a priority since 1991, connects about 300,000 homes per year. The connection cost in 1999 had been cut almost by half from 1992. While increasing access to energy increases emissions, it is fundamental to economic development. The government recently began to provide free electricity up to 60 kilowatt-hours per household per month to the very poor as a means of alleviating poverty. This subsidy is intended to help displace the use of paraffin, coal, wood, candles, and batteries, thus reducing local and indoor air pollution as well as tree cutting.

Figure 11

Energy and Emissions in South Africa, 1998



Source: Energy Information Administration, U.S. Department of Energy, 2002.

Little information has been gathered concerning non-energy GHG emissions. Two-thirds of South Africa, roughly the size of Texas, is pastureland, with only 7 percent containing forests and woodland. According to a recent report by the Department of Environmental Affairs and Tourism, land use change, agriculture, and forestry are a net carbon sink due to the absorption of carbon in forests and woodlands.[88]

Mitigating Measures

South Africa has initiated a number of actions that will reduce the pace of carbon emissions growth. These include policies to restructure the energy sector, stimulate economic development, increase access to affordable energy services, manage energy-related environmental impacts, and secure energy supply through diversification, as articulated in the government's 1998 "Energy White Paper."[89] The impact of these measures can be estimated only in a qualitative sense, however, because resources have not been available in South Africa to conduct detailed studies.

Restructuring of the energy sector is underway with privatization of government-owned enterprises, including the state-owned utility Eskom and the transportation company Transnet. The motivation for these reforms is to improve economic performance and increase economic well-being by introducing private-sector involvement and economic incentives. The government will sell 30 percent of Eskom's assets by 2006, and combine Eskom and municipal power distributors into six new regional electricity companies. Reforms are aimed at improving economic efficiency and freeing government budgets to focus on more pressing issues. Discussion continues on whether and how to allow independent power producers and competition in the electricity sector. The Southern African Power Pool now has a control center in Harare, Zimbabwe that will facilitate electricity trading among countries in the region. Regional energy cooperation will provide improved capacity utilization and efficiencies while diversifying electricity supplies.

South Africa has set in motion changes that will replace coal-based synthetic fuel with cleaner regional sources, especially natural gas and hydroelectric power to be obtained from neighboring members of the Southern African Development Community. The lifting of the international embargo imposed on Apartheid South Africa permitted the nation to pursue external energy sources. Significantly, Sasol (South Africa's main synthetic fuel producer) has invested in large natural gas fields in Namibia and Mozambique, and South Africa and Mozambique have signed an agreement to build a gas pipeline to supply South Africa. Sasol will build the pipeline and use the natural gas to replace the coal feedstock for making liquid fuels. Subsidies and purchase requirements for Sasol's coal-based liquid fuels and coal liquefaction are expected to end by 2005 since this process is no longer economically competitive. Natural gas use has been promoted through passage of the Gas Act of 2001, which creates a regulatory body to regulate the energy sector. New legislation is expected to establish pricing and access rules for oil and gas pipelines.

South Africa has several programs addressing energy efficiency in energy production and the main energy-consuming sectors. Programs in the electricity sector are largely oriented around load management at peak hours, introducing consumers to efficient equipment such as compact fluorescent lamps and power management practices. Selected industries are involved with Eskom in trial programs to introduce efficient motors and other equipment. These programs are expected to save the region 1,000 MW within three years, largely in South Africa.[90] A recent study showed that a 5 percent increase in electricity efficiency in 2010 would lead to a net increase of some 39,000 jobs and income of about $80 million. A national drive toward energy efficiency of this scale would reduce emissions of carbon dioxide by roughly 1.5 million tons of carbon in 2010.[91]

At the household level, a major initiative has disseminated compact fluorescent lamps to replace incandescent bulbs. The Global Environment Facility and Eskom targeted all households with the intention of installing around 18 million compact fluorescents over 20 years. Eskom estimates a total energy savings of 4 terawatt-hours per year, with carbon dioxide savings of almost 1 million tons of carbon per year.[92] Other activities include installing ceilings for proper light reflection in inexpensive houses and no-cost measures such as proper site orientation for taking advantage of solar energy. Efforts have encouraged use of more efficient refrigerators and switching from paraffin to natural gas for cooking. These initiatives aim to improve the standard of living, reduce electricity bills, and improve health. For example, harmful paraffin combustion products are a significant cause of death among South African children.

The government plans to establish energy efficiency norms and standards for commercial buildings. Guidelines in place for energy efficiency in commercial buildings will, after a five-year trial period, become mandatory. The guidelines cover minimum energy performance of the building shell and major energy-using services, including insulation values for walls, roofs, ceilings, and floors. The Department of Housing has also developed national standards for permanent residential structures, including low-cost housing.[93] These residential standards, however, are not mandatory. The government is moving toward the introduction of a commercial and domestic appliance labeling program, but progress has been slow and research on appliance labeling limited.

In the transportation sector, efforts are being made to correct the effect of urban planning under Apartheid, which forced low-income commuters to travel much longer than high-income commuters. The Department of Transport is addressing this legacy in part by trying to introduce clean energy systems for transportation, including conversion of internal combustion engines to natural gas, gas-to-liquids technology, and fuel-cell technology.

Renewable energy sources provide less than 2 percent of electric power generation, but Eskom is developing over 100 MW of wind and solar thermal power. These would be the largest such investments ever in South Africa. The electrification program goes beyond grid electricity with an off-grid rural concessions program that is to provide 350,000 solar home systems in seven concession areas. Proposals have been made to extend the concept to a package that would also include liquefied petroleum gas for cooking and other uses. There are also five combined bagasse-and-coal-fired power stations run by private sugar companies, primarily using sugar cane residues with coal as a back-up.

Recently, nuclear power has received much attention following Eskon's announcement of plans to develop and build a new generation of 'pocket sized' nuclear reactors, for export as well as domestic power generation. Like all other nuclear projects, this has been the subject of significant controversy. Eskom is planning a test site for these 100 MW modular reactors, with support from several local and possibly some international investors.

Future Mitigation Opportunities

Relatively little work has been done to project future energy use and GHG emissions in South Africa. Merely extrapolating from emissions trends of the past decade would imply that economic and energy growth will continue as they have since Apartheid was abolished. Such a scenario, however, would not take into account the expected impact of restructuring and economic reform that is currently underway. It is likely that the economy will not continue to grow without the productivity and competitive benefits of energy reform, meaning that extrapolation would probably over state both future emissions and economic development. Failing to account for the fuel-substitution and efficiency improvements that can be expected from reform will also overstate future emissions.

Carbon dioxide emissions from energy and cement production increased over the last decade at a rate of 2 percent per year. The economy grew at about the same pace. Simple extrapolation suggests an increase in energy- and cement-related emissions from about 94 million tons in 1998 to 120 million tons in the year 2010. If the economy were to benefit from reforms and accelerate to 4 percent growth, emissions would reach 150 million tons in 2010, unless reform and fuel switching contributed to reduce energy and carbon intensity. Emissions could grow much slower than the economy under a reform scenario, but it is difficult to quantify the potential in the absence of detailed studies. Against that context, a variety of ongoing and proposed policy measures would have an effect on this emissions growth trajectory (see Table 9).

Table 9

Mitigation Potential in South Africa

Development Objectives	Implementation Measures	Reductions from Projected Emissions
Stimulate economic development	Remove trade barriers; facilitate energy sector investment; promote demand-side management; eliminate subsidies	4 million tons in 2010
Stimulate new and renewable energy sources	Renewable portfolio standard of 5% of electricity generation by 2010, and 20% by 2025	3 million tons in 2010
Diversify energy sources	Replace coal used to produce synthetic petroleum with natural gas	5-10 million tons if entire capacity is switched from coal to natural gas

Source: Estimates by Davidson, O. Energy & Development Research Centre, University of Cape Town, 2002.

Several policies that could make the most difference have as their primary intent improving the quality of life in South Africa. Economic restructuring can have a continuing impact, particularly by removing subsidies for emissions-intensive synthetic fuels production and replacing those fuels with imported natural gas. As part of power sector restructuring, regulators can adjust rates to allow return on investment in energy efficiency, and include external, or environmental, costs in power prices, thus shifting emissions downward. On a macroeconomic level, removing energy trade barriers and facilitating investment in the energy sector would have a positive effect. These economic measures could, if completely implemented, reduce carbon emissions by 4 million tons per year by 2010. However, a more realistic value, based on the experience of other developing countries, is probably about one-third that amount.

In the energy sector, increasing access to affordable energy services will mean continuing electrification under restructured markets and maintaining the pace of 300,000 connections per year. The goal remains providing universal access to modern energy services. Implementing free basic electricity of 20-60 kilowatt-hours per household per month for 1.4 million poor households will improve health by reducing indoor air pollution, but will increase GHG emissions by requiring more power generation. The upper bound of this estimate is an increase of a negligible 0.04 million tons per year.

A national energy efficiency program that ensured a 5-percent reduction in electric power demand growth by 2010 would create jobs and wealth. These demand-side management measures could lead to reductions of annual carbon emissions of 2.2 million tons and 5.2 million tons per year in 2010 and 2025, respectively. In the housing sector, where there is a shortage of 2.6 million units, part of the existing housing subsidy could be diverted toward requiring that all new low-cost houses be built according to energy-efficiency standards. The estimated impact on carbon dioxide emissions would be 0.16 million tons of carbon per year if aggregated across all low-cost housing.[94]

South Africa's Department of Minerals and Energy recently released for public comment a draft white paper on promoting renewable and clean energy. This paper communicates the government's principles, goals, and objectives for a renewable energy strategy, and sets a 10-year target to increase the share of renewable energy in final energy consumption from 9 percent today to 14 percent by 2012. There is great potential for using solar, wind, biomass, ocean energy (waves), and hydropower. Renewable energy, through enactment of portfolio standards, could provide 5 percent and 20 percent of power generation in 2010 and

2025, respectively. Reductions in carbon emissions of 3 million and 19 million tons of carbon are conceivable in 2010 and 2025, respectively, based on baseline emissions projections for bulk electricity.[95]

South Africa is approaching a decade of liberation from Apartheid and is beginning to succeed in addressing its many legacies. Importantly, the government is improving standards of living for the very poor; enacting reforms needed for an efficient, open economy; and liberalizing energy-sector policies that have a largely positive impact on GHG emissions. The development challenges South Africa faces are enormous, yet it remains the richest nation on the African continent. Lessons it learns in reforming its economy and providing a higher quality life for its citizens could serve as instructive examples for other developing countries.

VII. Turkey

Turkey is at the crossroads of Asia, Europe, and Africa, occupying a strategic position on the energy transit route linking the oil- and gas-rich Caspian Sea to demand centers in Europe and the Mediterranean.

Turkey's population of about 65 million is growing at a rate of 1.5 percent per year (see Table 10).

Table 10

Key Socio-Economic Indicators

for Turkey

Annual carbon emissions (energy and cement), 2000	62 million tons
Population, 2000	65 million
Population growth rate	1.5% per year
Per capita GDP, 2000	
Based on exchange rate	$3,061
Purchasing power parity	$6,974
GDP growth rate	3.8% per year in constant local currency units
Primary energy consumption, 1998	50 Gigajoules per capita
Electric power consumption	1,756 Kilowatt-hours per capita/year
Persons below poverty line	12 million

Sources: World Bank Development Indicators, 2002; U.S. DOE Energy Information Administration, 2002; Turkish State Institute of Statistics; State Institute of Statistics, 2002; Statistical Yearbook of Turkey, SIS, Ankara, 1999.

After more than a century of effort to modernize and industrialize the country, Turkey's economy presents a picture of contrasts. Modern industries coexist with pockets of subsistence farming. The major cities of western Turkey are cosmopolitan centers of industry, finance, and trade, whereas the eastern part of the country is relatively underdeveloped. Over the last few decades, Turks have migrated in large numbers from the eastern to the western part of the country. This change exacerbated highly uneven economic distribution among socio-economic groups and widened regional disparities.

Turkey's economy grew 3.2 percent a year between 1990 and 2000. Though it slipped into recession in 2001, the nation competes successfully in the global economy. The industrial sector has been the driving force for Turkey's development since 1980. Tourism has also grown more rapidly than GDP. The number of passenger cars has tripled over the last decade. Overall energy supply grew about one-third during the 1990s, parallel to the GDP growth rate.

Seeking to capitalize on its key position on energy transit routes, the government has set a goal of becoming a Eurasian Energy Corridor. Great importance is attached to realizing large-scale projects such as the Baku-Tibilisi-Ceyhan crude oil Main Export Pipeline, as well as the Trans-Caspian Turkmenistan-Turkey-Europe gas pipeline.

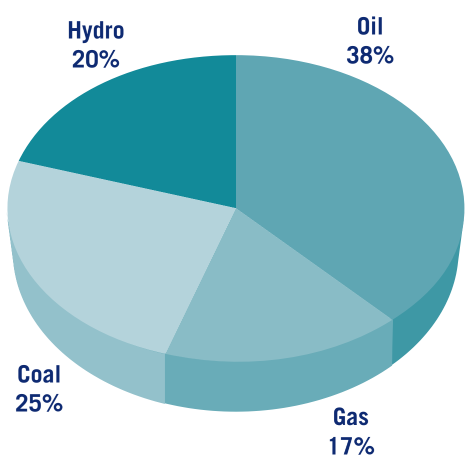
Turkey's rapid energy demand growth, combined with its low income compared to Europe, Japan, and the United States, led the government to insist that it not be treated as a developed country under the Framework Convention even though it is a member of the OECD. Parties agreed to the request in 2001 and Turkey is now expected to ratify the Convention.[96] The nation has long agreed in principle that it will attempt to limit emissions, but so far it has not developed specific greenhouse policies. However, other measures undertaken for local environmental and economic reasons are helping to reduce GHG emissions growth.

Energy and Emissions Profile

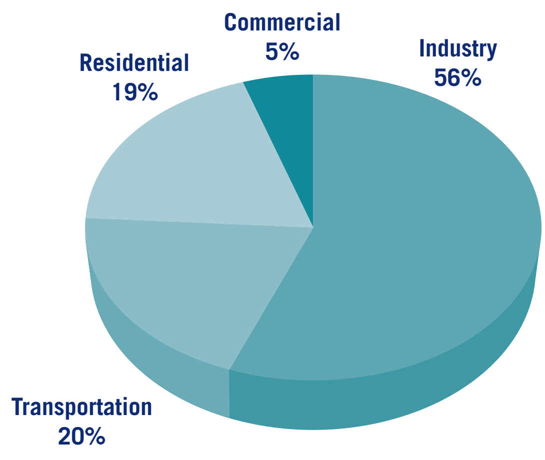
Turkey ranks among the fastest growing energy markets in the world and is the fastest among member countries of the International Energy Agency. Oil accounted for 38 percent of Turkey's energy use in 2000, followed by coal at 25 percent and natural gas at 17 percent (see Figure 12). Gas use, however, is increasing rapidly. Energy-related

Figure 12

Energy and Emissions in Turkey, 1998



Primary Energy Use



Energy-related Carbon Dioxide Emissions

Source: Energy Information Administration, U.S. Department of Energy, 2002.

carbon emissions have been growing much faster than the economy at an annual rate of 6 percent per year since 1990. By 2000, they totaled about 57 million tons of carbon. Emissions per capita stood in 1998 at almost 0.9 tons of carbon, in sharp contrast with the 3 tons per capita average for members of the OECD.[97] Industry accounts for over half of total carbon dioxide emissions, with the residential and transportation sectors contributing roughly one-fifth each. Turkey's high rate of growth in energy-related emissions is expected to continue and even increase, leading to a projected emissions level of almost 210 million tons in 2020.

Over 40 percent of all energy is used by the industrial sector and nearly 35 percent in the residential sector. The rest is split between transportation and commercial services. Industry in Turkey is energy intensive, with the iron and steel manufacturing and cement production sectors by far the largest energy users.

In the residential and commercial buildings sector, more than 80 percent of energy is used for space heating. Use of electrical appliances is rapidly increasing and boosting power demand. Increasing use of air-conditioning, especially in the Mediterranean region, has shifted the peak hours of electricity demand to noon in the summer. Electricity consumption for lighting accounts for 30-40 percent of power consumption in the residential sector.

The transport sector is dominated by road transport (90-95 percent or more of passenger transport and 85 percent of freight transport). Vehicle ownership is only seven vehicles per hundred inhabitants compared to the OECD average of 50.[98] Capacity utilization of available rail lines for passenger transport is low for inter-city traffic and higher for suburban lines.

Turkey has limited reserves of oil and natural gas, but has proven reserves of lignite on the order of 8.4 billion tons. The nation also possesses renewables, especially wood and hydropower. Natural gas production and use in Turkey began in 1976. Gas demand began to grow rapidly around 1987. Gas is imported mainly through a pipeline from Russia, which supplies power plants, several large industries and the cities of Ankara, Istanbul, Izmit, Eskisehir and Bursa. A new pipeline, Izmir, is expected to come on line in 2002. Conversion of central heating systems from low-quality lignite to natural gas has already improved air quality in Ankara, Istanbul and Bursa, specifically in terms of sulfur concentration. Sulfur dioxide emissions grew about five-fold from 1982 to 1990 but since 1990, they have grown at a slower rate.[99]

Methane emissions totaled about 1.4 million tons in 1997, a carbon equivalent of 8 million tons. Most arose mainly from enteric fermentation, animal wastes, and sanitary landfills. Nitrous oxide emissions in 2000 totaled 17,500 tons, or about 1.5 million tons of carbon equivalent, with most generated in nitric acid production.

Mitigating Measures

As in South Africa, the overall impact of Turkey's emission mitigation measures can be estimated only qualitatively because resources have not been available to conduct detailed studies. Ongoing emissions mitigation in Turkey is driven by economic restructuring, European integration, price reform, fuel switching, and energy efficiency measures. Restructuring and reform have resulted from government moves to adopt market-oriented policies since the 1980s. Turkey established a Customs Union with the European Community in 1996, thus achieving a much higher level of integration both in commercial and legislative terms, and ratified the Energy Charter Treaty in 2001.[100] The treaty requires each party to minimize energy-related environmental impacts in an economic manner.

Turkey's most recent Five-Year Development Plan, adopted in 2000, affects all policies in all economic sectors and has an indirect impact on GHG emissions. The first Special Expert Committee on Climate Change was established as one of 98 consultative committees during preparation of this plan. The committee's recommendations were published by the Turkish prime minister as official policy for the current planning period (see Table 11). These recommendations serve to guide government actions, but their actual implementation depends on the actions of various agencies and regulators.

Table 11

Mitigation Potential in Turkey

- **Privatizing energy resource production.**
- **Increasing the share of natural gas in consumption.**
- **Transferring electricity production and distribution to the private sector to make utility services more efficient.**
- **Encourage power savings by matching costs to prices and preventing theft.**
- **Developing new and renewable energy sources and ensuring their greater role in the market.**
- **Converting railway management to commercial orientation to ensure efficient, market-oriented services.**
- **Investing in natural gas pipelines and storage facilities.**
- **Increasing energy efficiency and ensuring energy saving.**

Source: "Eighth Five-Year Development Plan (2001-2005) of Turkey," SPO, Ankara, 2001.

Under the Electricity Market Act adopted in 2001, the power sector will soon undergo profound reform, leading to the introduction of competition and increasing private involvement. The new Natural Gas Market Law, also adopted in 2001, establishes a competitive gas market and harmonizes Turkish legislation with European law. The Turkish Council of Ministers has adopted several measures to stabilize fuel prices. An automatic pricing formula was abolished and gasoline taxes were made consistent with European countries. For example, taxes comprised over 60 percent of the price of gasoline by late 2000.[101]

To increase energy efficiency in industrial sectors, energy conservation regulations were issued in 1995. These required industrial establishments with annual consumption above 84 terajoules to establish an internal energy management system, conduct energy audits, and appoint an energy manager in their plants. Some 1,250 plants accounting for 70 percent of Turkish industrial energy use are covered by this regulation.[102] Government incentives are provided for installation and on-site use of combined heat and power plants with 1,500 MW capacity or less. By the end of 2001, 132 cogenerators were in operation with a total capacity of about 2,860 MW.[103]

An insulation standard was made compulsory for new buildings in 2000. Together with regulations published by the Ministry of Public Works and Settlements, the standard will cut heating requirements by 100-150 kilowatt-hours per square meter in colder regions. After 1990, approximately 75 million square meters of indoor area was added to the building stock for an annual increase of 5 percent. Refrigerators must now be labeled for energy consumption and annual energy cost in compliance with the efficiency standard adopted in 2002, and a similar standard for washing machines has been prepared.

The 1998 Law on Rangelands was intended to conserve, rehabilitate, maintain, and manage rangelands by introducing limitations on their use and allocating them to villages and municipalities. The law is expected to bring about sustainable use of rangelands, pasturelands, and grasslands, which have been neglected for centuries and prone to be barren, thus increasing their carbon sink capacity.

Future Mitigation Opportunities

The Turkish Ministry of Energy and Natural Resources has recently undertaken energy futures analysis. Based on the MAED energy demand model, forecasters have developed an "intermediate scenario" as the most probable outcome for future energy use.[104] This MAED baseline assumes unchanged government energy policies and programs, and serves as a benchmark for changes in emissions estimated for the five-year plan as well as supplementary measures examined in alternative scenarios. In this baseline, the government projects energy demand growth of 7.2 percent through 2005, 6.2 percent between 2005 and 2010, and 5.9 percent between 2010 and 2020. Turkey's annual per capita energy use, about 53 gigajoules in 2000, is projected to triple by 2020. However, experience elsewhere suggests that this growth is unlikely, at least over such a long period.[105]

Industrial energy demand is expected to represent about 54 percent of total consumption in 2020, consistent with the rapid industrialization expected over that period. In contrast to most developed and many developing countries, Turkey's industrial energy use is expected to increase as a share of total consumption. Car ownership and distances traveled are expected to rise, as is electricity consumption per dwelling, especially for space heating, water heating, cooking, and other thermal uses.

The share of hydroelectric generation and other renewables is expected to fall to around 21 percent by 2010, while thermal power generation will increase from 60 percent to 79 percent. Government projections for the near future indicate a progressive decrease in use of wood, animal wastes, and other combustible and renewable energy sources. The reasons for this are the expected rise in living standards as well as limits on deforestation.

Turkey's power planning includes the huge South-east Anatolia Project, a combined hydroelectric and irrigation project. Situated in the lower reaches of the Euphrates and Tigris rivers and covering the plains between them, the 22-dam project will flood an area of at least 74,000 square kilometers, one-tenth of Turkey's total land surface. The project is supposed to provide capacity of 7,476 MW, and 27,300 gigawatt-hours of hydroelectricity annually.

Major energy transit projects underway, such as the Baku-Tibilisi-Ceyhan oil pipeline and Trans-Caspian Turkmenistan-Turkey-Europe gas pipeline, are important for bringing energy diversification and security not only to Turkey but also to the region. By permitting increased natural gas consumption, the pipelines offer the opportunity to lower GHG emissions through gas substitution for low-quality indigenous coal.

Separate studies of Turkey's energy supply and demand system have suggested specific technical and policy options that differ from the MAED baseline and which, if implemented, could reduce energy-related carbon emissions to around 100 million tons in 2010, 9 percent lower than the baseline projection (see Figure 13).[106] Potential measures include reducing power transmission losses, increasing use of biomass energy, and improving residential and industrial energy efficiency.

Further increasing the use of natural gas in power generation and space heating in Turkey could bring large environmental benefits.[107] New gas plants, especially combined-cycle gas turbines, have lower capital costs than new coal plants, and can be installed quickly and in small increments. Private operators in competitive power markets needing new capacity have shown a marked preference for combined-cycle gas turbines where natural gas was available.

Solar energy has significant potential in Turkey. An estimated 3.5 million square meters of flat plate collectors for solar heating have been installed, primarily in the southern and western regions in the residential and commercial sectors. Solar energy use is expected to increase by a factor of four by 2020, but will remain a small percentage of total energy use.[108] Installed solar cells are located in rural and remote locations and are not connected to the transmission grid system. Power generation by solar energy is not envisioned in the current Five-Year Development Plan because the government does not view it as cost-effective.

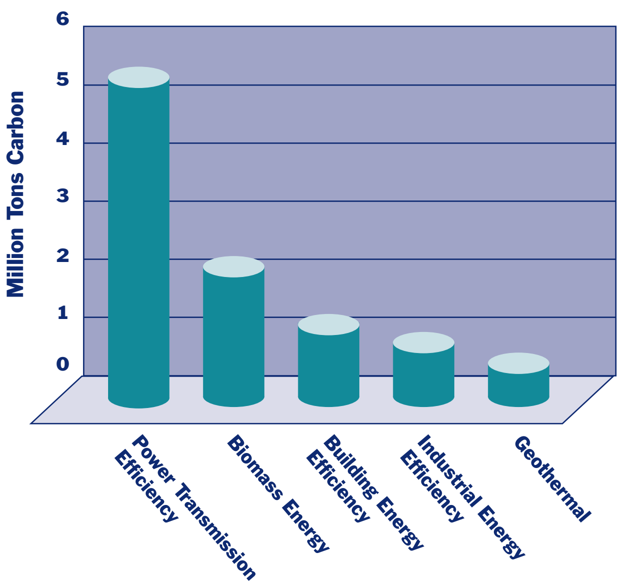
The western coast and southeastern Anatolia have been identified as favorable locations for wind power generation. Progress in wind energy technology in recent years has drawn private-sector attention, and three new wind power plants have been commissioned. The Five-Year Plan sets specific targets for implementation of alternative energy measures. The target for wind-generated power is 2,000 MW by 2005. Other government-sanctioned studies have set targets to cut energy intensity by 2 percent and 3 percent per year, respectively, in residential and commercial buildings.[109]

Demand-side measures could also significantly reduce Turkish emissions relative to the baseline. According to the National Energy Conservation Centre (NECC), the technical potential for conservation in heavy industry sectors ranges from 20 percent to 35 percent. A considerable share of the energy-intensive industries, including some of the most inefficient ones, remains under government control. Industry privatization, if pursued according to plan, is likely to result in closure of the oldest and most inefficient operations and in modernization of the surviving ones. The progressive elimination of energy price subsidies will also stimulate energy conservation. This process may well boost the overall energy efficiency of Turkish industry and government projections of industrial energy demand may prove to have been significantly overestimated.

Energy use per unit of building area could be reduced by nearly half according to a study conducted by the Electric Power Resources Survey and Development Administration.[110]

Figure 13

Mitigation Potential in Turkey, 2010



Source: Estimates by Alpan-Atamer, S. Med-Consult, 2002 utilizing studies referenced in endnote 106.

According to a country review by the International Energy Agency (and based on the MAED baseline), energy-sector reforms plus massive investment in gas pipelines and power plants would bring much needed new technology and higher energy conversion efficiencies.[111] Because more efficient gas turbines, for example, generate lower GHG emissions per unit of power, along with lower local pollution, it appears unlikely that private investors would install flue gas desulfurization equipment in existing coal-fired power plants, opting instead for natural gas-fired plants. Thus, the expectation of massive use of domestic lignite and imported hard coal in industry and power generation appears exaggerated.

Policies and measures have significant potential to effect changes in carbon emissions while achieving Turkey's economic and environmental goals. This can be accomplished by encouraging wider use of natural gas and high-quality coal, especially through financing mechanisms that would result in poor households switching from coal to gas, and by making natural gas available to smaller gas consumers through extended distribution grids. If Turkey becomes a party to the Framework Convention and the Kyoto Protocol, the nation will be eligible to market carbon credits through the Clean Development Mechanism, which could introduce new technologies and funds to the country. To accomplish this, institutional capacities and information systems would also need to be improved.

VIII. Conclusions

The six country studies support four broad conclusions. First, efforts underway by developing countries have significantly reduced growth in their GHG emissions. Second, these efforts have been driven not by climate concerns but by imperatives for development, poverty reduction, local environmental protection, and energy security. Third, while their energy use and emissions will continue rising for the foreseeable future, developing nations offer continuing, large opportunities for emissions mitigation if social and economic barriers can be overcome. Finally, policy makers can combine mitigation efforts with development objectives and augment the outcomes for both.

Together, the six countries examined in this report have over the past 30 years reduced their carbon emissions growth by nearly 300 million tons a year. Their annual emissions would likely be about 18 percent higher than they are today if not for the measures they have undertaken. To put these figures in perspective, if all developed countries were to meet the emission targets set by the Kyoto Protocol, they would have to reduce their emissions by an estimated 392 million tons from where they are projected to be in 2010.[112]

Developing country mitigation has been inadvertent in the sense that it has been driven largely by concerns other than climate. Some of these drivers are unique to specific countries. For instance, a substantial portion of the total mitigation attributable to these six countries results from China's effort to slow population growth, an effort unique in its scale and results. Taken together, however, the case studies demonstrate that there are common drivers for climate mitigation operating across most or all of the six countries. The most powerful are development and poverty alleviation, energy security, and local environmental protection.

The drive for economic development has led to significant market reforms and economic restructuring. In each of the six countries, economic reform—especially making energy prices realistic and requiring consumers to pay—has both accelerated economic growth and reduced energy waste. In China, for example, rising coal prices and hard budget constraints at state-owned enterprises have disciplined producers and consumers to waste less energy. South Africa is cutting subsidies to manufacturers of synthetic petroleum derived from coal and relying instead on cleaner, more efficient natural gas. While market mechanisms alone will by no means solve all development, security, and environmental problems, they can be a powerful force for climate mitigation.

Likewise, meeting energy security needs can also help nations reduce GHG emissions. Brazil has cut reliance on imported oil by providing incentives for alcohol production and consumption and one-liter car engines, reducing carbon emissions growth by 7 million to 8 million tons per year in the process. India has reduced dependence on imported oil by expanding natural gas use, which also reduces emissions growth.

Efforts to protect local environments can also contribute to carbon mitigation. Improving local air quality often results in fewer GHG emissions (exceptions include sulfur scrubbing on power plants).[113] Fuel switching from high- to low-carbon fuels and promoting energy efficiency result in better air quality and lower carbon emissions. Reducing deforestation protects water supplies and agricultural land while increasing carbon sequestration.

Each of the six nations studied here offers large-scale emissions mitigation opportunities. In Brazil, encouraging alcohol fuels, cogeneration, and energy efficiency could cut emissions by an estimated 45 million tons in 2020. By continuing policies for economic reform, efficiency, and environmental protection, China could reduce emissions growth by an additional 500 million tons in 2020. In India, about 120 million tons of carbon mitigation could be achieved by 2012 at a cost of no more than $15 per ton. Similar opportunities exist in Mexico, South Africa, and Turkey. The uniformity of these results, and the diversity of cultures and conditions represented in these six countries, suggest that developing countries everywhere offer large mitigation potentials.

However, continuing mitigation in these and other developing nations can by no means be taken for granted. The six case studies also reveal significant barriers to mitigation opportunities—indeed to development itself. These include:

- ***Lack of information.*** Of these countries, only Mexico has consistently submitted emissions inventories and national communications to the UNFCCC Secretariat. South Africa and Turkey lack rigorous, transparent studies of future energy and emissions trends, making more difficult the challenge of responding to opportunities identified. Efforts to mitigate emissions on any level will not be credible unless mitigation measures are made transparent and verifiable. At the international level, the paucity of reliable data raises questions about the viability of any approach relying heavily on data to establish or monitor progress toward emission objectives for developing countries.

• ***Lack of capacity.*** The efficiency gains and technological advances described here attest to the strong and growing technical expertise of some developing countries. However, in many developing countries, further mitigation is seriously impeded by a lack of institutional capacity—specifically, the expertise and personnel to analyze energy and emission futures, identify mitigation opportunities, integrate climate efforts with other development priorities, execute economic reforms, and cultivate investment opportunities.

• ***Market distortion.*** Public control of energy resources, and public subsidies for certain types of energy use, often stand in the way of carbon mitigation. In most of the countries studied here, public control of at least a portion of energy resources has prevented the emergence of private actors more likely to promote emissions-reducing efficiencies. State-owned institutions play major roles in supplying energy in China, Mexico, and South Africa, for example. In many countries, both developed and developing, energy subsidies favor fuels and patterns of energy use that promote higher carbon emissions.

• ***Lack of technology and investment.*** Technology transfer happens primarily through private-sector investment. But investment in developing countries is impeded by lack of transparency in business transactions and uncertainty in recovering loans and equity investments. While many potentially profitable projects can be identified, as the six case studies attest, prospects for return on investment are made uncertain by unclear policies regarding ownership, pricing, and contract enforceability. Often the perceived risk is so high that would-be investors are unwilling to finance even a feasibility study, which developing country industries and governments frequently cannot undertake on their own.

In light of these barriers, efforts to promote further emissions mitigation will require new policies leveraging drivers for other developing country objectives. Policy makers can employ a variety of strategies to support development, security, and environmental goals as a way of encouraging emissions mitigation. One broad lesson, given the diversity of drivers and co-benefits, is the need for flexible policy approaches promoting and crediting a wide range of emission reduction and sequestration activities. Appropriate policies would do the following:

- ***Promote continuing market reforms.*** Each country study showed that national policies making energy prices realistic, making prices matter, and removing subsides for consumption reduce both economic and energy waste, hence accelerating economic growth while cutting emissions growth. National and international policy makers can support programs that shape energy-sector reform to accelerate financial performance and provide incentives for energy-technology innovation. Further, allowing prices to rise to global market levels provides incentives for industry to achieve global levels of efficiency and competitiveness.

- ***Mobilize investment.*** Each country study demonstrates both the need for international technology transfer and investment, and the need for reforms to facilitate investment. Some reforms—such as increased transparency and stronger rule of law—are needed to improve the investment environment broadly. Other efforts should be directed specifically at promoting climate-friendly investment. Investment opportunities often are obscured by lack of funds to identify good projects for mitigating measures; an important role for international assistance would be to demonstrate how any investment will be repaid. Market-based approaches such as the Clean Development Mechanism could help generate investment in cleaner energy. However, given the reduced demand for carbon credits resulting from the U.S. withdrawal from Kyoto, the price of carbon credits in the foreseeable future is unlikely to cover much of the cost of mitigation projects.[114] Additional resources could be brought to bear through multilateral banks and bilateral mechanisms that traditionally have supported trade and development, but now are in need of an updated mission.[115]

- ***Build capacity.*** Bilateral and multilateral programs can mobilize private- and public-sector experts to provide technical and policy advice, particularly for price reform and imposition of hard budget constraints. Sometimes human capacity exists but is underutilized due to insufficient funding for relevant efforts such as project identification and preparation. Priority investments also include developing the supporting data and models that would enable analysts to understand emissions profiles, trajectories, and mitigation opportunities.

- ***Promote environmental improvements.*** Efforts should be made wherever possible to realize synergies between climate mitigation and local environmental objectives, such as improving air quality and encouraging forest and land conservation. Priorities include removing subsidies and incentives that accelerate deforestation—policies, for example, that develop highways, agriculture, and large projects leading to land speculation. Another priority is funding for forestry intended to protect water supplies and reduce erosion and dust.

While much of the mitigation potential in developing countries can be realized through national policies, or with bilateral or multilateral assistance, emission reductions on the scale needed to avert climate disaster likely will be achieved only with agreement on an international regime that includes all major emitting countries. A fuller understanding of the ongoing and potential contribution of developing countries to greenhouse gas mitigation can help achieve further progress toward the shared goal of climate protection.

Endnotes

1. Reilly, J. 2002. "MIT EPPA Model Projections and the U.S. Administration's Proposal." MIT Joint Program on the Science and Policy of Climate Change (March). Available at http://web.mit.edu/globalchange/www/MITJPSPGC_TechNote3.pdf. If the United States remains outside the Kyoto Protocol and does not reduce its emissions and all other developed countries meet their Kyoto targets, those countries would have to reduce their emissions by 285 million tons from the levels projected for 2010. These estimates of developed country mitigation assume that all excess tons held by Russia and other economies in transition are available for emissions trading and therefore are credited against emissions in 2010. If some excess tons are held off the market, as some analysts expect, the emission reductions required for developed countries to meet their Kyoto targets would be higher.

2. Ministério da Ciéncia e Tecnologia (MCT). 2002. "First Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions." Available at http://www.mct.gov.br/clima.

3. Instituto Nacional de Pesquisas Espaciais (INPE). 2002. "Monitoring the Brazilian Amazon Forest." Available at http://www.grid.inpe.br/amz/html.

4. Da Costa, R. C. "Double Dividends from Producing Bio-fuel in the Amazon Deforested Areas." *Biomass and Bioenergy* (2002). Submitted.

5. Fearnside, P. M. "Forests and Global Warming Mitigation in Brazil." *Biomass and Bioenergy* 16 (1999): 171-189; Pfaff, A. S. "What Drives Deforestation in the Brazilian Amazon?" *Journal of Environmental Economics and Management* 37 (1999): 26-43; and Reis, E. J. 1992. "An Econometric Model of Amazon Deforestation." Rio de Janeiro: IPEA.

6. Rodrigues, R. L. V. Personal communication, 2002.

7. Camargo, A. et al., ed. 2002. *The State of the Brazilian Environment 1992-2002.* Getulio Vargas Foundation: Rio de Janeiro.

8. All the installed sugar-cane bagasse-fired CHP capacity in Brazil derives from the PRO-ALCOOL Program. Two alternatives were considered for estimating the Brazilian power sector's avoided CO2 emissions from CHP fueled by sugar-cane bagasse. The first approach assumes that sugar-cane bagasse CHP avoids CO2 emissions derived from the operation of the current power generation mix in Brazil's power sector (84 percent hydropower generation plus 16 percent thermal power generation). The second approach assumes that sugar-cane bagasse avoids expanding Brazil's power generation capacity on a short-term basis. In this case, the avoided reference plant for the interconnected systems is a natural gas-fired thermal power plant with 45.5 percent efficiency and a capacity factor of 70 percent. For the stand-alone systems, this is a diesel-fired generator system with 30 percent efficiency and a capacity factor of 40 percent. These operating data for the reference plants comply with the business-as-usual scenario adopted by the forecast of the future trends of the Brazilian Energy Matrix, issued by the Ministry of Mines and Energy.

9. Geller, H. 2002. "Strategies for a Sustainable Energy Future." D.Sc. Thesis. University of São Paulo, Brazil.

10. Poole, A. D., J. B. Hollanda, and M. Tolmasquim. 2002. "Energy Conservation and Greenhouse Gas Emissions in Brazil." Available at http://www.inee.org.br.

11. Grupo Executivo para a Integração da Política de Transportes (GEIPOT). 2002. "Anuário dos Transportes Rodoviários." Available at http:///www.geipot.gov.br.

12. Estimated by staff at the Federal University of Rio de Janeiro based on data provided by GEIPOT.

13. On this topic, see Cecchi, C. 2001. Indústria Brasileira de Gás Natural: Regulação Atual e Desafios Futuros. Séries ANP II. ANP: Rio de Janeiro.

14. Although to a lesser extent than the Bolivia-Brazil Gas Pipeline, the Zero Burn-Off Plan also boosts natural gas supplies in Brazil. The plan was introduced by Petróleo Brasileiro in 1998 to reduce burn-offs of natural gas as much as possible on offshore rigs. The years 1998 through 2000 were a benchmark for the natural gas industry in Brazil because expansion of the gas pipeline network eliminated the last constraint on expanding supplies of this energy source in the country.

15. Szklo, A., and M. Tolmasquim. "Strategic Cogeneration: Fresh Horizons for the Development of Cogeneration in Brazil." *Applied Energy* 69 (2001): 257-268.

16. At the urging of PROCEL, the federal regulatory agency (ANEEL) required distribution utilities to allocate at least 1 percent of their revenues (about $160 million a year) to energy efficiency enhancement measures. The Brazilian Congress modified this policy in 2000 by assigning a portion of the 1 percent to research and development. But the revised policy still requires distribution utilities to spend at least 0.25 percent of their revenues on end-use energy efficiency programs. Due to power shortages in 2001, utilities spent about $80 million—approximately 0.5 percent of their revenues—on end-use efficiency programs in 2001. Villaverde, V. S. Personal communication, 2002.

17. The estimated avoided carbon emissions were based on the number of 1-liter engine automobiles sold after 1992, the average distance covered by the vehicles, and their different fuel economies. The last two parameters vary according to the year in which the vehicle was manufactured.

18. Nepstad, D. et al. "Frontier Governance in Amazonia." *Science* 295 (2002): 629-631.

19. This description of the CNPE work is based on the final report issued by the CNPE working group conducted by the National Energy Policy Council of the Ministry of Mines and Energy. See Machado, G.V. 2001. "Review of Brazil's Energy Matrix for 2005, 2010 and 2020." Technical Report. Ministry of Mines and Energy/Technical Group 3. MME: Brasília.

20. Machado, 2001.

21. Leading candidates in the 2002 presidential election have expressed strong support for reviving the alcohol program. Technical evidence suggests that alcohol is now competitive with gasoline in Brazil. Volkswagen recently announced plans to manufacture 100,000 new ethanol-fueled cars in Brazil. Government incentives support the production and use of ethanol. See Moreira, J. R. "Sugarcane for Energy—Recent Results and Progress in Brazil." *Energy for Sustainable Development* 4 (2000): 43-54; "Driven to Alcohol: Brazil Has Another Try at Running Its Cars on Ethanol Made from Sugar Cane." *The Economist* (5 September 2002). Available at http://www.economist.com/science/displayStory.cfm?story_id=1313810.

22. See also Schaeffer, R., J. Logan, A. Szklo, W. Chandler, and J. Marques. 2000. "Developing Countries & Global Climate Change: Electric Power Options in Brazil." Pew Center on Global Climate Change: Arlington, VA.

23. Góes, R. A. 2001. "Complementaridade entre a Geração Hidrelétrica e a Geração Termelétrica a Partir do Bagaço e Resíduos de Cana em Sistemas de Cogeração em Usinas Sucroalcooleiras." MSc. Thesis. COPPE/UFRJ: Rio de Janeiro.

24. MME/Eletrobrás. 2001. "Atlas do Potencial Eólico Brasileiro." MME: Brasília. Available on CD-ROM.

25. Szklo, A., and M. Tolmasquim. "Analysis of Brazil's Cogeneration Legal Framework." *Energy Conversion and Management* (2002). In press.

26. Schaeffer, R., M. Schuler, and M. Costa. 2001. "Avaliação dos Programas de Combate ao Desperdício de Energia Elétrica Desenvolvidos por Empresas Distribuidoras de Energia Elétrica no Ciclo 1998/1999." COPPE/UFRJ and PROCEL: Rio de Janeiro.

27. Measured in Purchasing Power Parity for 2000 in 2000 dollars. See World Bank. 2001. *World Bank Indicators.*

28. Lawrence Berkeley National Laboratory. 2001. *China Energy Databook* 5.0 (May).

29. Automotive Resources Asia, Ltd. July 2002. Available at http://www.auto-resources-asia.com/m_newsrelease.php.

30. This assumes emissions of 0.5 tons of carbon per capita, the same as in 1990. Using today's rates, the total would be 210 million tons per year. Personal communication. Kejun Zhang, Beijing, July 2002.

31. Battelle Memorial Institute and the Woodrow Wilson International Center for Scholars. 1998. "Climate Action in China and the United States." Washington, DC.

32. Battelle researchers believe an accurate baseline of normal efficiency improvements in China over two decades beginning in the late 1970s would have led to a decline in energy intensity of 3.5 percent each year. Under this scenario, energy consumption would now be approximately 6 exajoules higher, resulting in about 100 million tons of additional carbon emissions.

33. See Logan, J. "Balancing the Books on Energy Pricing." *IEEE Spectrum* 36 (1999).

34. Logan, J. 2001. "An Update on Recent Energy and Carbon Dioxide Trends in China." Pacific Northwest National Laboratory: Richland, Washington (June).

35. Ibid.

36. The amount of forest land is only 0.13 hectares per capita. The total reserve of living wood is 12.49 billion cubic meters.

37. Liu, J. 2001. "Study on China's Sustainable Development Strategy." China Agriculture Publishing House: Beijing.

38. GDP and population were virtually the same in all cases.

39. *BP Statistical Review of World Energy 2002.* Available at http://www.bp.com.

40. See "Fuel Tax Delayed Due to High Oil Prices." *China Daily* (24 February 2001).

41. *United Nations Development Program Annual Report.* Measured using currency exchange rates, India's economy ranks as the world's 15th largest.

42. Government of India Planning Commission. 2001. "Tenth Action Plan Report." New Delhi.

43. This includes carbon from cement production and fossil fuels.

44. Energy Information Administration, US Department of Energy. 2001. "Online Country Analysis Briefs." Washington, DC. Available at http://www.eia.doe.gov/international.

45. Shukla, P.R. 1996. "Wood Energy and Global Climate Change." Wood Energy News, Food and Agricultural Organization: Bangkok.

46. The methodology applied in making this estimate is described in detail in Garg, A., and P. R. Shukla. 2002. *Emissions Inventory of India.* Tata-McGraw-Hill Publishing Company: New Delhi.

47. Mumbai, Chennai, and Kolkatta are the new names for the Indian cities formerly known as Bombay, Madras, and Calcutta.

48. Mashelkar, R.A. et al. 2002. "Report of the Expert Committee on Auto Fuel Policy." Ministry of Petroleum and Natural Gas, Government of India (March): 5.

49. See Chandler, W. 2000. Energy and Environment in the Transition Economies. Westview Press: Boulder, CO.

50. Center for Monitoring the Indian Economy (CMIE), 2000.

51. Closed forests are those with more than 40 percent crown cover.

52. Shukla P.R. "The Modeling of Policy Options for Greenhouse Gas Mitigation in India." *AMBIO* 25 (June 1996): 240-248; Rana, A., and P.R. Shukla. "Macroeconomic Models for Long-term Energy and Emissions in India." *OPSEARCH* 38 (February 2001); ALGAS. 1998. "India National Report on Asia Least-Cost Greenhouse Gas Abatement Strategy." Asian Development Bank and the United Nations Development Programme: Manila, Philippines; Rana and Shukla, 2001. Based on a presentation by Bhattacharya , S. National Communications Workshop, 23 November 2001, New Delhi; Garg, Ghosh, and Shukla, 2001; and Garg and Shukla, 2002.

53. Consejo Nacional de Población (CONAPO), 2000.

54. Secretaría de Desarrollo Social. 2002. Subsecretaría de Prospectiva, Planeación y Evaluación. The figure corresponds to 2000.

55. According to the last inventory, Mexican carbon dioxide emissions in 1996 may have resulted in 0.15 GtC, including the agriculture and forestry sectors and excluding absorption by sinks. This would represent 1.9 percent of the possible 7.9 GtC world's total emissions (6.3 GtC from fuel combustion, 1.6 GtC from deforestation in the tropics).

56. The estimate of carbon dioxide emissions from fuel combustion included in the last Mexican inventory is somewhat smaller than the one published in IEA (1998), which is 342.19 Mt. Except for international comparisons and unless stated otherwise, this document adopts data from the national inventories. IEA (1998) also overestimated total population at 96.58 million inhabitants in 1996. The estimate of 92.2 million people for this same year is based on the results of the 2000 Census. GDP totaled $68 billion USD90 in purchasing power parity (PPP), making carbon intensity of emissions from fuel combustion equivalent to 0.47 kg CO_2/ USD90(PPP) (1.06 kg CO_2/ USD90 at exchange rates).

57. Figures reproduced here correspond to those published in the Second National Communication. However, a minor error was identified in the CD-ROM, a detailed version of the 1994-98 inventory, concerning the estimate of the carbon uptake from abandoned lands (2,173 Kt C instead of the published 3,214 Kt C). The Third Assessment Report of the Intergovernmental Panel on Climate Change may also lead to future methodological changes reflecting slight variations in the 100-year global warming potential of greenhouse gases. For the sake of comparability, conversion factors adopted in this document are those published in the Second National Communication: Methane= x 21 CO_2; Nitrous Oxide= x 310 CO_2.

58. In the "industrial processes" item, only the cement industry was considered in the evaluation of 1990 emissions. The 2001 inventory also included emissions from sectors such as mining, metal, and chemical industries. In general, the quantification of energy-related carbon dioxide emissions is probably an acceptable proxy for the general increase in overall emissions since they are less affected by methodological changes. Energy-related carbon emissions grew 18 percent between 1990 and 1998.

59. The introduction in 1998 of methodological changes in the evaluation of crude oil reserves revised previously published figures downwards. In January 2001, proven reserves of crude oil were considered equivalent to 26,941 million barrels. Reserves may amount to 18,551 million additional barrels. Secretaría de Energía. 2001a. *Programa Sectorial de Energía* 2001-2006. México: 32.

60. Secretaría de Energía, 2000a.

61. Article 27 of the Constitution specifies that power generation, transmission, transformation, distribution, and supply as a public service is restricted to the State. A semantic battle is raging over what should be considered public service. Narrowing the scope of these words may circumvent the need to negotiate a change in the Constitution.

62. Natural gas substitution, increased energy efficiency, and reduced deforestation are estimated to have reduced emissions growth by 10 million to 20 million tons of carbon a year, or 5-10 percent of baseline emissions. See Masera, O., and C. Sheinbaum. "Mitigating Carbon Emissions while Advancing National Development Priorities: The Case of Mexico." *Climatic Change* 47 (2000): 259-282. This total comprises 5 million tons of mitigation in the energy sector and a much less certain amount of mitigation in the forestry sector. The review conducted for this report, based on an assessment of individual mitigation measures, indicates a reasonably high level of confidence that a reduction of at least 5 percent from the baseline has occurred.

63. Unless stated otherwise, information is extracted from the Second National Communication to the UNFCCC Secretariat.

64. Including indirect effects may increase reductions up to 7.5 percent of the consumption.

65. Information provided by PEMEX, May 2002.

66. PEMEX. Cited in Reforma, Negocios 2A, 19 June 2002.

67. For instance, there are around 50 registered makers of flat solar panels.

68. Masera, O., A. D. Cerón, and A. Ordóñez. 2001. "Forestry Mitigation Options for Mexico: Finding Synergies between National Sustainable Development Priorities and Global Concerns." In *Mitigation and Adaptation Strategies for Global Change* 6: 291-312. Kluwer Academic Publishers: The Netherlands. The figure includes carbon in soils, decomposing matter and forest products. Of the 24 petagrams of carbon, 80 percent is located in forests with the remaining 20 percent in other land use categories.

69. Twenty-nine percent of mammals, 32 percent of freshwater fish, 48 percent of orchids, 51 percent of leguminosae, 52 percent of reptiles, 60 percent of amphibians, and 79 percent of cactaceae are native to Mexico. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), 2000a.

70. SEMARNAT, 2000a. Between 1976 and 1993, 3.3 million hectares of rainforest were deforested.

71. CONAPO.

72. Secretaría de Energía, 2001c, 16.

73. National Institute of Ecology, Second National Communication. 2001.

74. Secretaría de Energía, 2001d.

75. Mexico, along with Brazil and other countries, supported the adoption of targets and timetables for the global expansion of renewable energy during the 2002 World Summit on Sustainable Development in Johannesburg, South Africa.

76. Masera, O., and C. Sheinbaum. 2000. "Mitigación de Emisiones de Carbono y Prioridades de Desarrollo Nacional." Institutos de Ingeniería y Ecología, Universidad Nacional Autónoma de México (UNAM).

77. Instituto Nacional de Ecología, 2001, 263.

78. The resolution of April 25, 2002 revoked a regulatory change that the government introduced on May 22, 2001, to expand the amount of energy produced by the private sector. This is the first time the Supreme Court considered an energy issue.

79. Masera and Sheinbaum, 2000. A complex model was developed, with projections of emissions for CO_2, CH_4, CO, and NOx for 1990 to 2010. The baseline adopted is based on a GDP growth rate of 4.5 percent.

80. Sathaye, J.A. et al. 2001. "Carbon Mitigation Potential and Costs of Forestry Options in Brazil, China, India, Indonesia, Mexico, the Philippines and Tanzania." *Mitigation and Adaptation Strategies for Global Change* 6: 185-211. Kluwer Academic Publishers: The Netherlands. Brazil, China, India, Indonesia, Mexico, the Philippines, and Tanzania were compared. Each study uses the same methodology: the Comprehensive Mitigation Assessment Process (COMAP). In the case of Mexico, sustainable forest management and bioenergy through long- and short-rotation plantations, forest restoration, and agroforestry are analyzed.

81. Environmental Defense, a U.S.-based non-governmental organization, provided some technical support for the design of this internal cap-and-trade system.

82. The System of Transactions Registry (SRT) and the operating rules are available at http://www.dcsipa.pemex.com/carbono.

83. Masera and Sheinbaum, 2000.

84. The lower figure corresponds to Sathaye et al., 2001. The higher figure corresponds to Trexler, M., and C. Haugen. 1995. "Keeping It Green: Evaluating Tropical Forestry Strategies To Mitigate Global Warming." World Resources Institute: Washington, DC.

85. Masera et al., 2001. The net sequestration potential in the 30-year period would be 46x106 Mg C yr-1.

86. There are some data limitations in this study due to the lack of a centralized digital database for gaseous emissions and air quality in South Africa. The database maintained by the Department of Environmental Affairs and Tourism (DEAT) is incomplete and not available to the public.

87. See the International Energy Agency's 1996 survey, "Energy Policies of South Africa." The latest estimate of South Africa's inventory (currently unpublished) of GHG emissions is for 1994. In 1998, the South African government developed a climate change policy discussion document and circulated a national response strategy for public comment. The government has completed a draft of its First National Communication to the UNFCCC that it expects to submit in 2002.

88. DEAT, 1999. "National State of the Environment Report: South Africa." Available at http://www.ngo.grida.no/soesa/nsoer/issues/climate/index.htm.

89. Department of Minerals and Energy (DME), 1998.

90. DME, 2001. Available at http://www.dme.gov.za.

91. Winkler, H. 2002. "Sustainable Development Policies and Measures."

92. Ibid.

93. These are the product of the Environmentally Sound Low Cost Housing Task Team, led by the Department of Housing and including DME, the Department of Water Affairs and Forestry (DWAF), and DEAT.

94. DME, 2001.

95. DME. 2002. "Draft White Paper on Renewable Energy and Clean Energy." Available at http://www.dme.gov.za.

96. Turkey's membership in the OECD stems from its historical position as a participant in the Marshall Plan. This membership does not imply that the country is so thoroughly industrialized as other members. When the UNFCCC was adopted in 1992, all OECD members were included in the list of developed nations in Annexes I and II. The Turkish government objected to this arrangement, which meant that Turkey would have to assume obligations reserved for a developed nation, although its economy was far less developed. Until recently, Turkey refrained from becoming a party to the Convention and asked to be deleted from its list of developed countries. At the Seventh Conference of Parties in Marrakesh in 2001, Turkey was removed from the Annex II list in recognition of its special circumstances. Consequently, the Turkish Grand Assembly, the nation's legislature, is expected to ratify the Convention. If Turkey becomes a party to the Kyoto Protocol as well, its new position will bring opportunities for obtaining foreign investments for energy efficiency and clean technology projects through the Protocol's flexible mechanisms.

97. OECD. 2000. "OECD Environmental Data Compendium 1999." Paris.

98. Ibid.

99. OECD. 1999. "Environmental Performance Review – Turkey." Paris.

100. The Energy Charter is the pan-European agreement defining energy trade policies across the continent.

101. International Energy Agency. 2001. "Energy Policies of IEA Countries: Turkey 2001 Review." OECD/IEA: Paris.

102. Turkey's General Secretariat for the European Union. 2001. "Turkish National Programme for the Adoption of the Aquis." Ankara.

103. Chubu, and R&R Scientific and Technical Services Ltd. 2002. "Turkey Energy and Environment Review: Special Studies—Task 3: Co-generation Potential." April.

104. The Model for Analysis of Energy Demand (MAED) simulates medium- to long-term energy demand in a country. The model was developed by the International Atomic Energy Agency.

105. International Energy Agency. 2001. "Energy Policies of IEA Countries: Turkey 2001 Review." OECD/IEA: Paris.

106. SPO. 2001. “Eighth Five-Year Development Plan Special Expert Committee Report on Electric Energy.” Ankara; TUBITAK/TTGV, Science-Technology-Industry Platform. 1998. “Working Group Report on Energy Technologies Development.” Ankara; SPO. 2001. “Eighth Five-Year Development Plan Special Expert Committee Report on Mining.” Ankara; “Subcommittee Report on Renewable Energy Sources.” In *Proceedings of Turkey’s 1st Energy High Council Meeting,* MENR, 7-9 December 1998, Istanbul; MENR. 2001. “Objectives and Activities of the Ministry of Energy and Natural Resources and Affiliated and Related Institutes.” Ankara. In Turkish; Alta_, M. et al. 2000. “1998 Energy Statistics.” World Energy Council, Turkish National Committee, 8th Energy Congress. Ankara (May). In Turkish; Turkey’s General Secretariat for the European Union, 2001; Turkey Geothermal Association. 2002. “Today’s and Tomorrow’s Energy-Geothermal: Importance for Turkey and State-of-the-Art in the World.” Ankara (January). In Turkish; R&R Scientific and Technical Services Ltd. 2002. “Turkey Energy and Environment Review: Special Studies—Task 8: Landfill Gas Collection, Disposal and Utilization in Turkey.” April.

107. International Energy Agency, 2001.

108. Ibid.

109. These goals are contained in SPO, 2001. The energy-intensity changes are relative to the MAED baseline.

110. See endnote 106.

111. Ibid.

112. Reductions in annual growth documented in this report total 288 MtC and include the following: Brazil (10 MtC), China (250 MtC), India (18 MtC), Mexico (10 MtC), South Africa (NA), and Turkey (NA). The reductions amount to 18 percent of the countries’ total emissions of 1,575 MtC. For comparison to the Kyoto reduction, see endnote 1.

113. Desulfurization improves local air quality, but lowers the overall efficiency of power plants, resulting in slightly higher carbon dioxide emissions.

114. Richard Baron. 2001. “International Emissions Trading: From Concept to Reality.” International Energy Agency: Paris.

115. Chandler, op cit; PCAST II; Intergovernmental Panel on Climate Change. 2000. *Special Report on Technology Transfer.* Cambridge University Press: London.

notes

This report examines measures contributing to climate change mitigation in key developing countries—Brazil, China, India, Mexico, South Africa, and Turkey—and identifies future mitigation opportunities. The Pew Center on Global Climate Change was established by the Pew Charitable Trusts to bring a new cooperative approach and critical scientific, economic, and technological expertise to the global climate change debate. We intend to inform this debate through wide-ranging analyses that will add new facts and perspectives in four areas: policy (domestic and international), economics, environment, and solutions.

Pew Center on Global Climate Change
2101 Wilson Boulevard
Suite 550
Arlington, VA 22201
Phone (703) 516-4146
www.pewclimate.org