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LOW-CARBON DEVELOPMENT

LATIN AMERICAN RESPONSES TO CLIMATE CHANGE

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THE WORLD BANK

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Preface

A GLOBAL FINANCIAL AND ECONOMIC CRISIS of unprecedented dimensions was unfolding at the time of the writing of this book. The urgency, immediacy, and staggering magnitude of the challenges posed by such a crisis have the potential to crowd out efforts aimed at addressing the challenges of global warming that are discussed in detail in this book. The capacity of political leaders and of national and supranational institutions to deal with major global threats is, after all, not unlimited. It would be, therefore, naive to think that the world's ability to tackle simultaneously the breakdown of financial markets and the threats posed by global warming is free of tensions and trade-offs. These two global menaces have such far-reaching implications for mankind, however, that it would be imprudent to allow the shorter-term emergency of the global financial crisis and economic downturn to unduly deflect policy attention away from the longer-term dangers of climate change. The challenge clearly is to find common ground and to identify and pursue as many policies as feasible that can deliver progress on both fronts simultaneously. This is possible in principle, but not easy to achieve in practice.

In effect, the world economic slump will be associated with a fall in private investment, including climate-friendly investment. The latter may tend to suffer disproportionately in the current context, given that the price of fossil fuels has fallen dramatically relative to alternative, clean sources of energy. Not surprisingly, utilities already seem to be making significant reductions in their investments in alternative energy, and there is already a reduction in the flow of project finance devoted to low-carbon energy projects. The expectation that a low relative price of fossil fuels is here to stay might not only deter investment in low-carbon technology, it could also induce substitution in consumption in favor of cheaper but dirtier energy. For example, low gasoline prices could deflate the momentum toward hybrid vehicles, particularly in North America. With lower economic growth worldwide, furthermore, greenhouse gas (GHG) emissions could experience a cyclical decline; this might create political incentives to postpone policy efforts to bring down the emissions trend. In all, the global financial and economic crisis could lead to a shortening of policy horizons that might induce a shift toward a more carbon-intensive growth path. This shift would only increase the difficulty and raise the costs of reducing GHG emissions down the line.

Experience with previous financial crises in emerging economies suggests that trade-offs often arise between long-term environmental concerns and short-term

macroeconomic policy responses.[1] In particular, as competing claims rise on shrinking budgetary resources during a crisis, budget cuts tend to affect, to a larger extent, the provision of public services that are considered to be a "luxury"—that is, services whose immediate impact on the people or sectors affected by the emergency is perceived to be low and only indirect. In developing countries, these often include items such as forest conservation or the protection of ecosystems. According to an International Monetary Fund paper (Giambiagi and Ronci 2004), for example, in the aftermath of the Asian and Russian crises, Brazil reduced public expenditures (excluding wages, social security benefits, and interest payments) for 1999 by 11 percent in nominal terms with respect to 1998. However, some key Amazon environmental programs were reduced by much more than the average. The Brazilian Institute for the Environment and Natural Renewable Resources, for instance, experienced a budget cut of 71 percent with respect to originally approved funding, and of 46 percent compared with 1998. There are also indications that this phenomenon went beyond the federal level. Brazilian states and municipalities, faced with the need to produce "primary surpluses," were not able to compensate for the cuts in federally funded environmental programs in the Amazon (Kasa and Naess 2005).

If leaders at the national and international levels are visionary, they can avoid falling into the trap of sacrificing environmental sustainability to short-term macroeconomic necessities and can take advantage of opportunities to address climate change concerns. In particular, policies and programs to address today's pressing problems can be designed and implemented with a long-term horizon. Sometimes, these decisions can be win-win. But sometimes, there will be tradeoffs. For example, private investment in, and consumption of, clean energy will be stimulated by a relative increase in the price of fossil fuels; this can be encouraged through a combination of regulations, taxes, carbon-trading schemes, and subsidies. But making firms pay to pollute and forcing households to consume more expensive, if cleaner, energy are not popular in times of economic recession. Tilting private sector activity in a sustainable fashion toward low-carbon choices thus calls for carefully managed political compromises and sound judgment on the part of policy makers to ensure that long-term considerations are not neglected for political expediency.

Greater scope for synergies is likely to be found in the area of public investment. Massive public investment programs will have to be part of the fiscal stimulus required to deal with the global economic crisis, especially in developed countries and high-saving emerging economies. Appropriately designed and implemented, these programs can generate win-win dynamics and outcomes, simultaneously advancing the causes of supporting economic recovery while helping to encourage growth in areas that minimize or mitigate the impact on climate change. Moreover, countries that manage to effect the transition from a high-carbon to a low-carbon economy during the economic slump can enjoy "first-mover advantages," that is, a greater competitive ability to promote long-term growth beyond the cyclical downturn. As a result, the current financial crisis can actually create a unique opportunity for a new deal for the twenty-first century, focused on low-carbon growth. The declared vision of the recently elected government in the United States for environmental sustainability and energy security adds hope in this regard. A "green recovery"—that is, a virtuous interaction among job creation, growth resumption, and low-carbon-oriented public investments and policy actions—is a worthy option and arguably the only sensible option for the world community at this juncture. Such an option can be turned into reality if leaders and political systems rise to the occasion.

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Note

1. See for example, Ruta and Hamilton (2008).

Abbreviations

A/R	afforestation/reforestation
BPDPMD	barrels per day per million dollar produced
°C	degrees celsius
CAIT	Climate Analysis Indicators Tool
CARICOM	Caribbean Community
CCGT	combined cycle gas turbine
CCRIF	The Caribbean Catastrophe Risk Insurance Facility
CCT	conditional cash transfer
CDIAC	Carbon Dioxide Information Analysis Center
CDM	Clean Development Mechanism
CER	certified emission reduction
CFE	Federal Electricity Company of Mexico
CFU	carbon finance unit
CH_4	methane
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COMBO	Coral Mortality and Bleaching Output
DALY	disability adjusted life year
DSM	demand-side management
EB	Executive Board (of the CDM)
EIA	environmental impact assessment
ENSO	El Niño-Southern Oscillation
EPA	U.S. Environmental Protection Agency
EPC	Energy Performance Contracts
ERPA	Emission Reduction Purchase Agreement
EU	European Union
FCPF	Forest Carbon Partnership Facility
FHIS	Honduras Social Investment Fund
FIDE	Fideicomiso para el Ahorro de Energía Eléctrica (energy savings trust fund)
G-8	Group of Eight
GDP	gross domestic product
GHG	greenhouse gas
GMO	genetically modified organism
GTC/y	gigatons of carbon per year
GW	gigawatt
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
KWh	kilowatt hour
LCR	Latin America and the Caribbean Region
LFG	landfill gas
LNG	liquefied natural gas
LUC	land-use change
LULUCF	land use, land-use change and forestry
MM	millimeter

MW	megawatt
MWh	megawatt hour
N_2O	nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PLAC	*Programa Latino Americano del Carbono*
PPM	parts per million
R&D	research and development
REDD	reducing emissions from deforestation and forest degradation
SCC	social cost of carbon
SD-PAM	Sustainable Development Policies and Measures
SNLT	Sectoral No-Lose Target
STP	social time preference
TAR	Third Assessment Report
tCO_2e	tons of CO_2 equivalent
TOE	tons of oil equivalent
UK FRP	United Kingdom Forestry Research Program
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WBCSD	World Bank Committee on Sustainable Development
WS&S	water sanitation and safety
WTO	World Trade Organization

CHAPTER 1

Confronting the Global Challenge

Introduction

Climate change is already a reality. This is evidenced by the acceleration of global temperature increases, the melting of ice and snow covers, and rising sea levels. Latin America and the Caribbean Region (LCR) are not exempt from these trends, as illustrated by the changes in precipitation patterns that are already being reported in the region, as well as by observations of rising temperatures, the rapid melting of Andean tropical glaciers, and an increasing number of extreme weather events. The most important force behind climate change is the rising concentration of greenhouse gases (GHGs) in the Earth's atmosphere driven mainly by manmade emissions of carbon dioxide (CO_2) and other greenhouse gases. Because of inertia in the climate system, the planet is likely to continue warming over the twenty-first century, and unless emissions are significantly reduced, this process could accelerate, with potentially very serious consequences for nature and mankind. There is still, however, a high degree of uncertainty regarding the specific drivers, timing, and impact of global climate change, as well as about the costs and efficacy of actions aimed at either mitigating it or dealing with its physical and economic impacts. As a result, it is very hard, at this point, to unambiguously determine economically efficient emission pathways for which the benefits of actions to mitigate climate change would exceed the costs of those actions.

Apart from the question of the optimal path, the difficulty of agreeing on a mechanism to resolve the problem is compounded by the fact that individual countries can only capture a fraction of the global benefits arising from their efforts to mitigate climate change, which creates serious coordination challenges. Despite these problems and uncertainties, there is increasing evidence suggesting that urgent action is needed in order to alter current emission trends so as to avoid reaching GHG concentration levels that could trigger large and irreversible damages. Negotiations are under way and are scheduled to be concluded in 2012 with a new agreement on a way forward. At the same time, individual countries are also considering how to respond in their own domestic policy to the challenges of climate change. LCR governments and civil society should be well informed about the potential costs and benefits of climate change and their options for decisions that will need to be made over the next decades as well as the global context in which these decisions must be taken. At the same time, the global community needs to be better informed about the unique perspective of the LCR—problems the region will face, potential contributions the region can make to combat global warming, and how to unlock the region's full potential so as to enable it to maximize its contribution while continuing to grow and reduce poverty. This report seeks to help fill both these needs.

The Evidence on Climate Change

Inhabitants of Latin America and the Caribbean are well aware of the high costs associated with extreme weather events and climate-related natural disasters. Between 2000 and 2005, Latin American countries experienced 309 climate-related natural disasters, including 166 floods, 113 windstorms, and 30 droughts. Information on the damages caused by these natural disasters is available only for about 20 percent of the events but still

amounts to more than US$17.5 billion.[1] Central Americans, for instance, have fresh memories of Hurricane Mitch, which killed more than 10,000 people in 1998. Similarly, as a result of the heavy rainfall, floods, and landslides that hit Peru during the 1997–98 El Niño episode, the country experienced monetary losses of US$3.5 billion, or about 5 percent of gross domestic product (GDP).[2] While the concerns about the negative impact of climate-related disasters are not new, during the past three decades the region has experienced a worrisome increase in the annual frequency of those events. Between 1970–99 and 2000–05, for instance, their number increased 2.4 times.[3]

Adding to these concerns, a number of highly unusual extreme weather events have taken place during recent years. In December 1999, for example, two months after the end of República Bolivariana de Venezuela's rainy season, a record amount of rainfall led to severe floods and landslides that took the lives of 30,000 people. More recently, in March 2004, Brazil was hit by Hurricane Catarina, the first ever observed in the South Atlantic. Catarina caused severe flooding in the eastern Amazon and displaced thousands of families in southern Brazil. Other recent unusual events include flooding in the Argentinean Pampas (2000–02), severe droughts in the Amazon (2005), hailstorms in Plurinational State of Bolivia (2002) and Buenos Aires (2006), and the record 2005 Caribbean hurricane season, which included Wilma and Katrina among other major hurricanes. The damages caused by Wilma in the Yucatan Peninsula amounted to almost US$1.9 billion, whereas those of Katrina in the U.S. Gulf Coast reached more than US$81 billion. In the case of Katrina, at least 1,836 people were killed, including during the subsequent floods, making it the deadliest U.S. hurricane since the 1928 Okeechobee Hurricane.[4]

Extreme weather events and climate change

Extreme weather events are by definition unlikely: they belong to the tails of the probability distributions of the corresponding variables (for example, temperature, rainfall, wind, and so forth). Thus, for a given climate and in a given time and location, those events tend to occur with a very small probability, once in many years. However, the increasing number of extreme weather events observed during recent years raises the question of whether we are dealing with a series of unrelated random occurrences or whether we are confronted with a long-run increasing trend. In the first case, the high number of climate-related natural disasters that have recently hit LCR countries could just be the result of bad luck. There would be no reason to expect the annual number of those events to be sustained or to continue rising in the future. We would be dealing with the normal weather variability that exists within any given climate.

There is, however, a worrisome alternative hypothesis to explain the recent increase in the number of unusual weather events. If, as is increasingly believed by the scientific community, the climate of the whole planet is warming, the probability distribution of many weather variables would also be shifting. As a result, events that were previously infrequent, being located in the tails of the corresponding probability distributions, could now become more ordinary. Were these changes to be sustained, households, companies, and governments would have to reassess a large number of key decisions, including, for instance, where to locate their homes, factories, and public infrastructure; what goods and services to produce; and what prices to charge for them.

To some extent this is already happening. As an example, shortly after Katrina, U.S. risk-modeling companies raised their estimation of the probability of a similar event from once every 40 years to once every 20 years.[5] Indeed, analysts speculated that the increasing number and intensity of tropical cyclones in the North Atlantic Basin was related to a simultaneous increasing trend in sea surface temperatures in that area, with both trends being the result of global warming. The reassessment of the likelihood and severity of climatic disasters is not, however, particular to the United States. It has taken place all over the world as a result of the increasing scientific evidence suggesting that the world's climate system is indeed changing.

The evidence of ongoing global climate change

Based on the analysis of recent data on the evolution of global temperatures, snow and ice covers, and rising

sea levels, the Intergovernmental Panel on Climate Change (IPCC) has recently asserted that "warming of the climate system is unequivocal." This is one of the main conclusions of the IPCC's Fourth Assessment Report, released in September 2007, produced by more than 150 lead authors from more than 30 countries, with more than 600 expert reviewers.

Among the new evidence reported by the IPCC is the acceleration in the rate of growth of global surface temperatures, which increased by 0.13 degrees Celsius (°C) per decade between 1956 and 2005, or about twice the decadal increase observed between 1906 and 2005. Moreover, the mass of Arctic sea ice has shrunk by 2.7 percent per decade since 1978. Related to this trend, the rate of rising sea levels has recently accelerated, from an average of 1.8 mm per year from 1961–2003 to 3.1 mm per year from 1993–2003. As shown by the IPCC, the above changes in the global climate have already had noticeable impacts on precipitation patterns, the frequency of extreme weather events, and the intensity of North Atlantic tropical cyclones. Moreover, the IPCC expresses a high level of confidence that various human activities (for example, agriculture and health) and natural systems (for example, plants and animal species, marine ecosystems, and hydrological systems) have already been affected by global warming.[6]

Ongoing climate change in Latin America

Latin America has not been exempt from the global trends documented by the IPCC. Important changes in precipitation and increases in temperatures have been observed in many countries of the region.[7] In particular, increases in mean temperatures of approximately 0.1°C per decade have occurred in South America during the twentieth century. Precipitation has increased in some areas—northeast Argentina, southern Brazil, Paraguay, northwest Peru, and Uruguay—and decreased in others—southwest Argentina, southern Chile, and southern Peru. The rate of rising sea levels has also increased, reaching 2–3 mm per year during the past two decades in southeastern South America. The evidence collected by the IPCC suggests that the above changes in the region's climate are already affecting the frequency of extreme weather events. Examples of changes that are already visible include more frequent heavy rains over northeast Brazil and central Mexico, an increase in flood frequency in some parts of the Amazon, and a 50 percent rise in streamflow in the Parana, Paraguay, and Uruguay—Rivers.

Some of the changes in climate observed so far have had positive economic impacts. Examples include rising crop yields as a result of increased precipitation in the Argentinean Pampas—ranging from 12 percent in the case of sunflowers to 38 percent for soybeans—and a 7 percent increase in pasture productivity in Argentina and Uruguay. Other visible impacts, however, are definitely negative. For instance, higher mortality and morbidity rates have been recorded in Bolivia as a result of increased flooding, landslides, and storms.[8] Another worrisome consequence of the changes in climate that have already been observed in the region is the rapid retreat of the tropical glaciers that has been documented in the Andes.[9] One striking illustration of this trend is the photographic record of the Chacaltaya Glacier in Bolivia, shown in figure 1.1. Projections suggest that many of the glaciers at lower altitudes could completely disappear over the next 10 to 20 years, with far-reaching impacts on the economies and human welfare of these regions (chapter 2).[10]

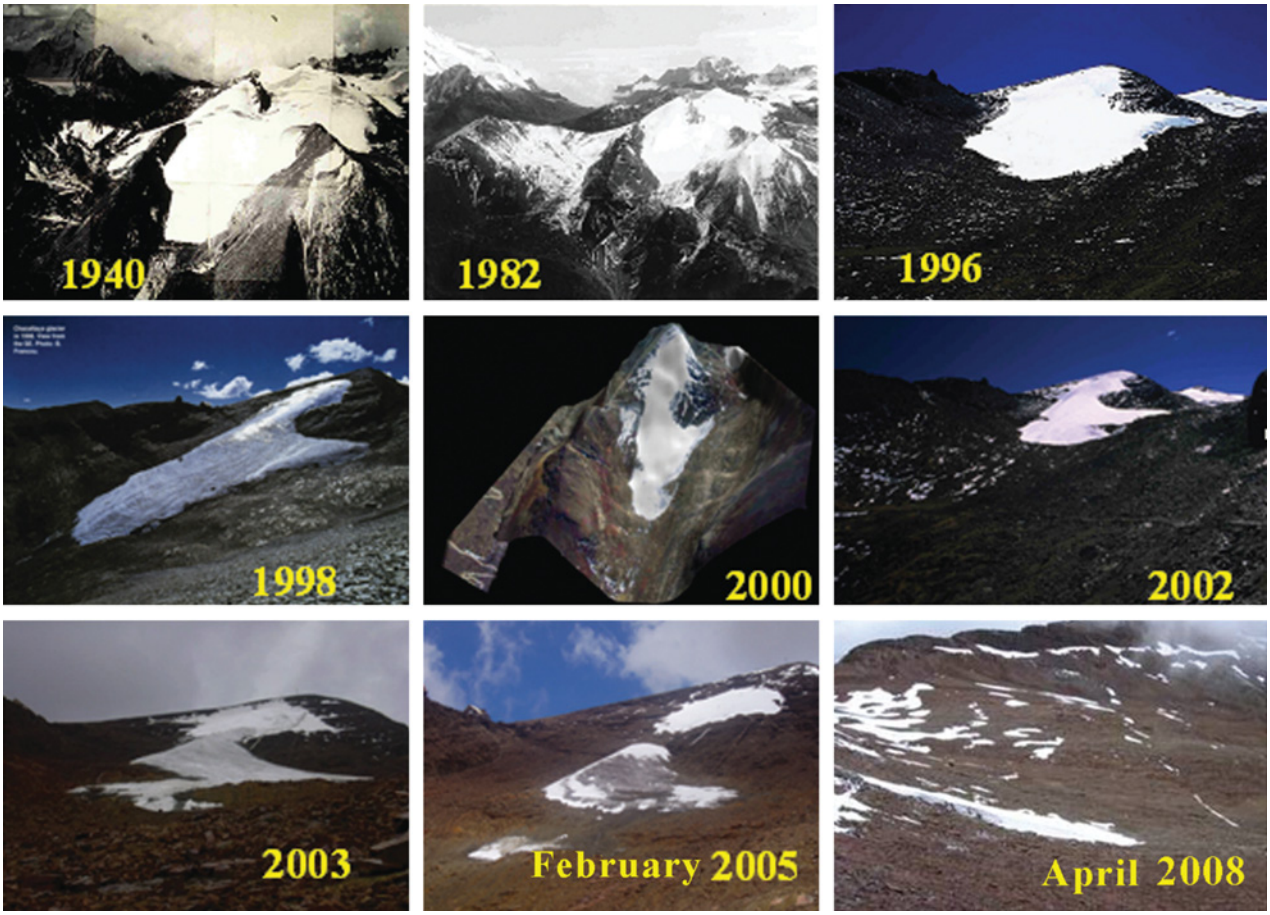
What is behind climate change?

The Earth's global mean climate is determined by the balance of incoming and outgoing energy in the atmosphere. The Earth receives energy from the sun. Most of it is absorbed by the planet but a fraction is reflected back into space. The amount of energy that is bounced back depends on the concentration of GHGs in the Earth's atmosphere. These gases trap some of the radiation received from the sun and allow the planet's temperature to be about 30°C above what it would be otherwise (Stern 2007). While the greenhouse effect is a natural process, without which the planet would probably be too cold to support life, the concentration of greenhouse gases in the atmosphere has been accelerating over the past 250 years, leading to a significant increase in average global temperatures.

A number of GHGs occur naturally. Water vapor, for instance, is a strong greenhouse gas and its concentration in the Earth's atmosphere can only be indirectly related

FIGURE 1.1

Retreat of the Chacaltaya Glacier in Bolivia



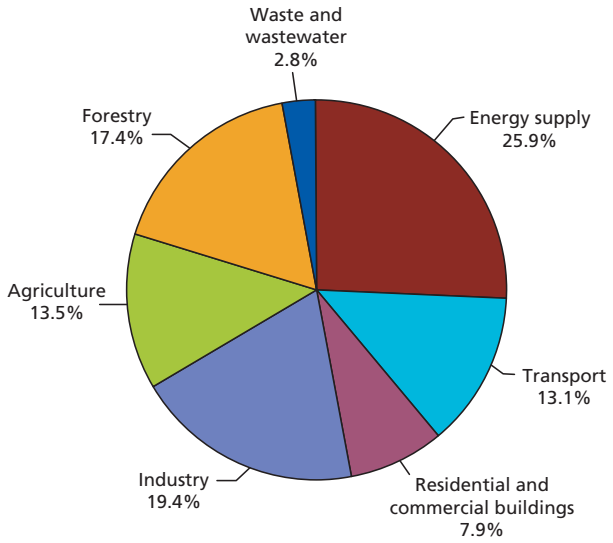
Source: Photographs by B. Francou, E. Ramirez, and W. Vergara.

to human activities. However, most of the increase in the overall concentration of GHGs observed since the industrial revolution can only be explained by taking into account human activities. In fact, the IPCC has recently concluded with 95 percent certainty that the main drivers of the observed global changes in climate have been anthropogenic—that is, manmade—increases in GHG concentrations.

The most important anthropogenic GHG is carbon dioxide which in 2004 represented 77 percent of total GHG emissions. Other important GHGs are methane (CH_4) and nitrous oxide (N_2O). Global atmospheric concentrations of CO_2 have increased by 35 percent between 1750 and 2005, while those of CH_4 and N_2O have increased by 148 percent and 18 percent, respectively, during the same period. Most of the observed increases in atmospheric concentrations of GHGs have been driven by fossil fuel burning, which leads to CO_2 and CH_4 emissions, followed by CO_2 emissions from land-use change—for example, the conversion of forests into agricultural land—and N_2O and CH_4 emissions from agriculture.[11] Taking into account the different warming effects of various GHGs, the current stock of all GHGs in the Earth's atmosphere is estimated to be equivalent to about 430 ppm (parts per million) CO_2.[12]

The sectors in which CO_2 emissions have grown at faster rates since 1970 are power (145%) and transport (120%), which in 2004 represented 26 and 13 percent, respectively, of global GHG emissions (figure 1.2). Large increases in CO_2 emissions have also been

FIGURE 1.2
Sector Composition of Global Greenhouse Gas Emissions



Source: Adapted from IPCC (2007), figure 2.1 (c). Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2 equivalent.

observed in industry (65% since 1970) and as a result of deforestation (40%). In 2004 those two sectors accounted for, respectively, 19 and 17 percent of total emissions. Other human activities that contribute to GHG emissions include agriculture, the operation of residential and commercial buildings, and the disposal of waste and wastewater.

LCR's contribution to global GHG emissions

Despite having almost 9 percent of the world's population and about 6 percent of global gross domestic product, the LCR accounts for less than 6 percent of global energy related CO_2 emissions. The LCR's share of global emissions is higher, reaching 12.5 percent, when all GHG emissions, including those coming from land-use change are considered. In addition to being a relatively low emitter from energy-related sources, LCR is also not one of the regions of highest projected growth in emissions derived from the burning of fossil fuels. According to the International Energy Agency (IEA), energy-related CO_2 emissions in Latin America are expected to grow, in per capita terms, by 10 percent between 2005 and 2015 and by 33 percent from 2005–30, compared to increases of 32 percent by 2015 and 59 percent by 2030 in the developing world (IEA 2007).

The LCR is also unique in the composition of its GHG emissions (chapter 5). First, emissions originating from land-use change and agriculture account for about two-thirds of LCR's emissions, compared to one-third at the global level and 44 percent among other developing countries. Second, emissions from energy supply and industrial activities each account for about 10 percent of LCR emissions, compared to shares of 45 percent and 37 percent, respectively, in the rest of the developing world. Finally, emissions related to the transport sector represent almost 10 percent of LCR's GHG emissions, compared to shares of 20 percent in high income countries but just 6 percent in other developing countries.

The predominance of land-use change in the LCR's GHG emission profile suggests that policies and projects aimed at reducing emissions from deforestation and forest degradation (REDD), as well as promoting afforestation and reforestation (A/R), should be featured prominently in any future significant contribution of the region to global climate change mitigation efforts. The good news is that there are considerable synergies between reducing emissions from land-use change and other sustainable development objectives, including a positive impact on water resources, biodiversity, and the long-term vulnerability of the corresponding natural and socioeconomic systems.

As for LCR's relatively low share of energy-related emissions, this results mainly from its cleaner energy mix, driven by a higher reliance on renewable energy (mainly hydroelectricity), and a much lower use of coal among other fossil fuels. The relatively high amount of emissions from the transportation sector, however, should probably be a source of concern. The IEA predicts that between 2000 and 2050, CO_2 vehicle emissions will increase by 140 percent worldwide. The vast majority of this increase will take place in developing regions, especially Latin America and Asia, as a result of increased motorization and vehicle use. These trends are not only worrisome from a climate change perspective, they also pose daunting

local challenges, including the need to deal with increasing levels of pollution and vehicle congestion.

What Climate Impacts Can be Expected in the Future?

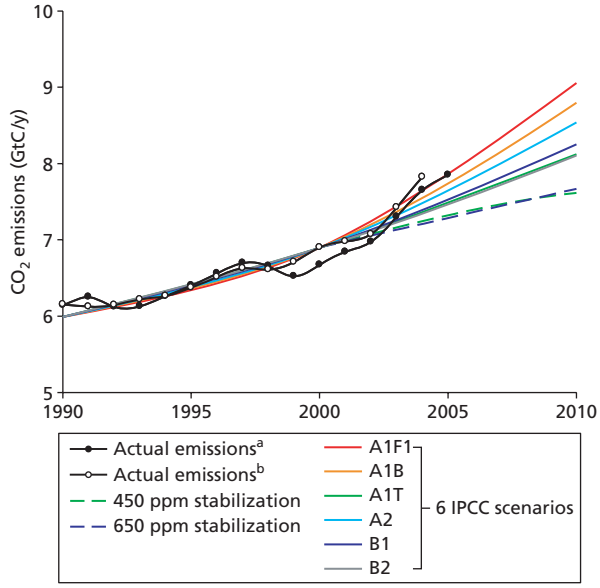
The global climate system has a long response time to changes in the concentration of greenhouse gases in the atmosphere. As a result, global warming is expected to continue in the near term even in an unrealistic scenario in which immediate measures were to be taken to maintain those GHG concentrations constant. In particular, the IPCC predicts that even with constant GHG concentrations global temperatures would increase by 0.1°C per decade over the next two decades.

GHG emissions, however, are as of yet not showing any clear signs of slowing down. Depending on the specific assumptions adopted with regard to global demographic, economic, and technological trends, the IPCC predicts that global GHG emissions will increase by 25 percent to 90 percent between 2000 and 2030 if no additional climate change mitigation policies are implemented. As a result, under most of the "business-as-usual" scenarios considered by the IPCC, global temperatures would increase at a rate of about 0.2°C per decade until 2025. By 2050, the planet would be 1.3°C to 1.7°C warmer than at the end of the twentieth century. By 2100, global temperatures would reach between 1.8°C and 4.0°C above that baseline.

The above projections, however, are probably on the conservative side. Indeed, recent observations of actual emissions are proving to be higher than those predicted by the IPCC, even in its most pessimistic scenarios (figure 1.3). Stern (2008), for instance, predicts that the current rate of increase in the stock of GHGs in the atmosphere, of about 2.5 ppm CO_2e (carbon dioxide equivalent) per year, could increase to between 3 ppm and 4 ppm per year over the current century. As a result, under current emission trends the stock of GHGs in the Earth's atmosphere could reach 750 ppm by 2100, which would imply that global warming would exceed 4°C with an 82 percent probability and it would rise above 5°C with a 47 percent probability.

FIGURE 1.3

Actual versus Projected Global Greenhouse Gas Emissions



Sources: Raupach et al. (2007) and World Bank staff calculations. Emission trajectories corresponding to the main scenarios studied by the IPCC's Special Report on Emission Scenarios (2001).
Note: The future emissions continuum is contained in four scenario families: A1, A2, B1, and B2. A1F1 (intense dependence on fossil fuel); A1B (balance energy supply between fossil fuels and alternatives); and A1T (alternative energies largely replace fossil fuels) are part of A1. GtC/y = gigatons per year; ppm = parts per million; IPCC = Intergovernmental Panel on Climate Change. Details on each scenario are in endnote 13.
a. according to Carbon Dioxide Information Analysis Center
b. according to Environmental Impact Assessment

Global impacts

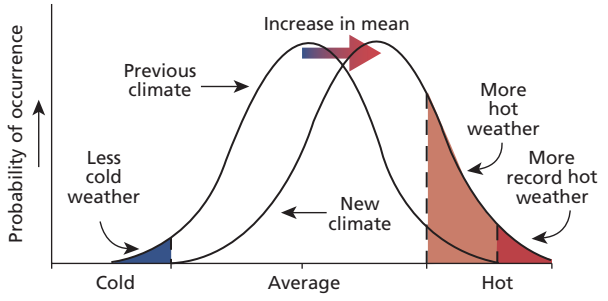
The intensity and effects of global warming are expected to vary considerably across regions of the world. Generally, more warming is expected in higher latitudes and continental regions. For instance, Stern (2007) predicts that if global warming were to attain 4°C, oceans and coasts would warm by 3°C, mid latitudes by more than 5°C, and poles by 8°C. Moreover, while the IPCC expects heat waves all over the world to become more intense, longer lasting, and more frequent, the probability of extreme warm seasons is projected to rise above 90 percent in many tropical areas, compared to about 40 percent elsewhere. Expected global changes in rainfall patterns are also differentiated across regions. For instance, more rain is expected in higher latitudes and less in the tropics, with the latter prediction being more uncertain. Tropical cyclones are likely to become more intense, for instance in the

Caribbean, with higher peak winds and heavier precipitation. More generally, to the extent that global warming leads to shifts in the distribution of weather variables, previously "extreme" events located in one of their "tails" could become more frequent—for example, an increased number of record hot weather—while the frequency of extreme events at the other end of the distribution would fall—for example, fewer extremely cold days (figure 1.4).

Depending upon the rate and magnitude of climate change, some of its impacts have the potential to be very large, abrupt, and/or irreversible. In particular, the IPCC estimates that there is 50 percent chance—"medium confidence"—that for global average temperature increases of 1°C to 4°C (1990–2000 to relative), a widespread deglaciation of West Antarctic and Greenland ice sheets could take place. This, in turn, would imply that sea levels could rise by several meters, leading to major changes in coastlines and ecosystems and the inundation of low lying areas, especially in river deltas. While this process is expected to occur over very long time scales (millennia), the IPCC does not exclude the possibility that it could take place over shorter time periods (for example, centuries), with very serious consequences on the relocation of populations, economic activity, and infrastructure. In addition, for temperature increases of 1.5°C to 2.5°C (relative to 1980–99), a large number of species—20 to 30 percent of those assessed—would be at increased risk of extinction. For higher rates of warming, above 3.5°C, as much as 40 to 70 percent of species would be at risk.

FIGURE 1.4

Impact of Climate Change on the Frequency of Extreme Weather Events



Source: Intergovernmental Panel on Climate Change.

Current climate risks in the LCR

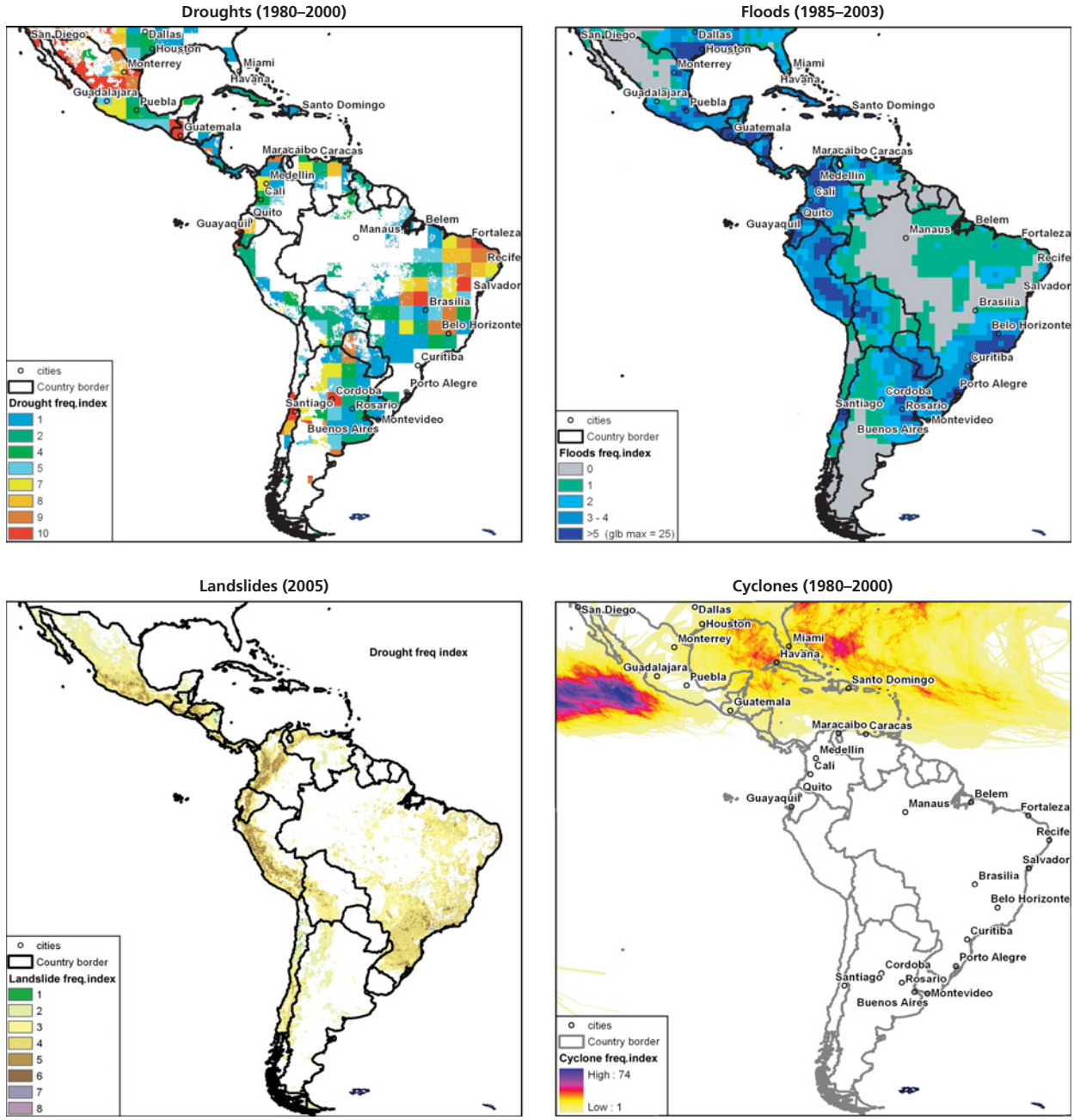
Before reviewing the expected future changes in the LCR's climate, it is useful to identify the extent and location of current climate related risks. As shown in map 1.1, even under current climate conditions relatively large portions of the LCR are exposed to various types of climate-related hazards. In Mexico and Brazil, for instance, severe droughts are common in northern regions, while in the South there is a high exposure to extreme floods, landslides, and, in the case of Mexico, also cyclones. Similarly, Central American and Caribbean countries have a high exposure to both floods and cyclones, with the former group also being prone to droughts (notably El Salvador and Guatemala). Andean countries have a high exposure to droughts (especially central Chile and Ecuador), floods, and landslides, while floods are the most important hazard in northeastern Argentina, Paraguay, and Uruguay.

It is important to note that the risks of death and economic losses associated with natural disasters depend not only on a given country's exposure to those hazards, but also to the country's level of fragility or social vulnerability, which in turn are a very complex function of social, economic, political, and cultural variables.[14] Thus, for instance, mortality rates associated with cyclones are about 10 times higher in the low and lower-middle-income countries of the region than in their upper-middle-income neighbors. However, mortality rates from floods and landslides are highest, respectively, among upper-middle-income and lower-middle-income LCR countries. Similarly, while the economic losses associated with cyclones and droughts tend to decrease with income per capita, those from floods and landslides are lowest among low income countries, probably because those affected have fewer assets at risk.

Identifying the areas that are at a higher risk of natural disasters, either because of a high probability of hazard events or due to the high losses associated with a given hazard, is important for developing government policies in the area of disaster prevention and preparedness. In particular, an accurate mapping of current and future risks could help improve the prioritization and targeting of the resources allocated to

MAP 1.1

Latin America and the Caribbean Region's Exposure to Natural Disasters under Current Climate Conditions



Source: Constructed by World Bank Staff using data from Dilley et al. (2005).

risk-reduction efforts, including for actions aimed at reducing the vulnerability and exposure of infrastructure and improving the ability of countries to manage disaster risks.[15] Especially in high-risks areas in which recurrent natural disasters create formidable obstacles for growth and poverty reduction, the improvement of countries' policy and institutional frameworks for disaster management should ideally be an integral part of development strategies.

Impacts of climate change in the LCR

As mentioned above, the disaster risks faced by the LCR under current climate conditions are likely to be amplified if current trends in GHG emissions are

maintained. The IPCC's Fourth Assessment Report predicts that under business-as-usual scenarios temperature increases in the LCR with respect to 1961–90 could range from 0.4°C to 1.8°C by 2020 and from 1°C to 4°C by 2050 (Magrín et al. 2007). Even though LCR's share in global GHG emissions is relatively small, in most of the region the expected annual mean warming is likely to be higher than the global mean, the exception being the southern part of South America (Christensen et al. 2007). These projections, derived from global circulation models, also point to changing precipitation patterns across the region, with increased winter rainfall in Tierra del Fuego, higher summer precipitation in southeastern South America, and drier conditions in Central America and the southern Andes.

Despite the high uncertainty regarding future rainfall patterns in some parts of the region, especially in northern South America, including the Amazon region, there are strong indications that climate change may magnify extremes already observed across the region. Thus, under current climate trends, some of the current climate "hot spots" could become even hotter. This can be seen through a comparison of map 1.1 with the panels of map 1.2. (on p. 10). Indeed, it appears that many areas with a current high exposure to drought or flood risks would have to deal with respectively even drier conditions and more intense rainfall in the future.

As shown in table 1.1, this would the case of all the high-risk drought areas of Chile, El Salvador, Guatemala, and Mexico, for which the predictions of at least five out of eight global climate models are that by 2030 the number of consecutive dry days will increase and heat waves will become longer. Similarly, between 47 and 100 percent of the high-risk flood areas of Argentina, Peru, and Uruguay are expected to become even more exposed to intense rainfall. True, there are still considerable differences in the specific regional projections derived from various global climate models. However, for most of the previous examples the level of model concordance is quite high, as can be seen in the panels of map 1.2. (on p. 11).

The changes in temperature and precipitation patterns that are currently projected for the LCR should have wide-ranging impacts on natural systems and human activities.[16] These impacts are examined in detail in chapter 2 of this book, including an analysis of the changes in agricultural and livestock productivity that are projected to occur in most countries of the region.

Costs and Benefits of Mitigating Climate Change

We have reviewed the large array of potentially negative impacts associated with the global and regional changes in climate that are predicted under current trends in global GHG emissions. Reversing those trends in order to mitigate the negative impacts of climate change would have nonsignificant costs associated with reducing the amount of GHG emissions derived from the production and consumption of a large array of goods and services. In order to determine how much mitigation should ideally be undertaken at the global level, those costs need to be compared to the corresponding benefits that would be derived by means of avoiding climate damages and reducing the expenditures needed for adapting to changing climate conditions.

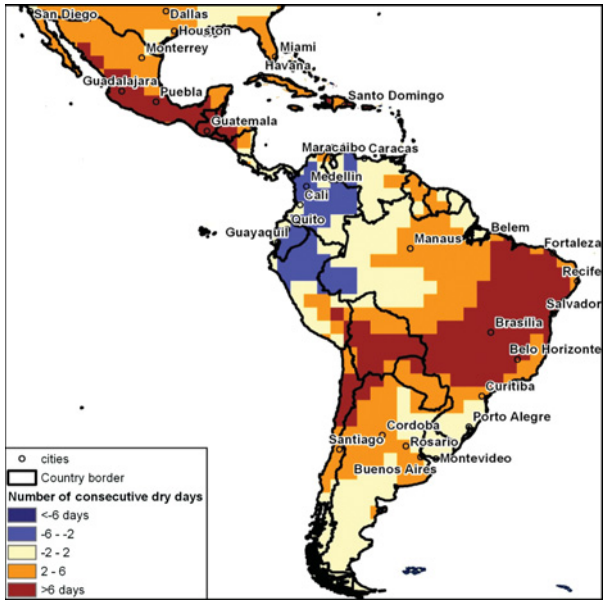
What is the optimal amount of mitigation? A simple conceptual framework

Both the marginal costs and the marginal benefits of mitigating climate change depend on the scale of the emission reductions to be undertaken. The costs of additional mitigation efforts tend to increase with the level of emission reductions that is envisaged. While some inexpensive options for reducing GHG emissions are available in some sectors—for example, some improvements in energy efficiency can actually save money while reducing GHG emissions—ambitious climate mitigation goals are likely to require the adoption of energy technologies that are less carbon intensive but also relatively more expensive than those currently in use. Similarly, in some isolated areas of the Amazon, the opportunity costs of avoiding deforestation and forest degradation is probably very small and so would be the costs of creating monetary incentives for forest conservation. However, in order to achieve more ambitious goals in terms of reduced emissions from deforestation, the corresponding programs would be forced to also cover areas with much higher land productivity, which would increase the costs of additional forest conservation efforts.

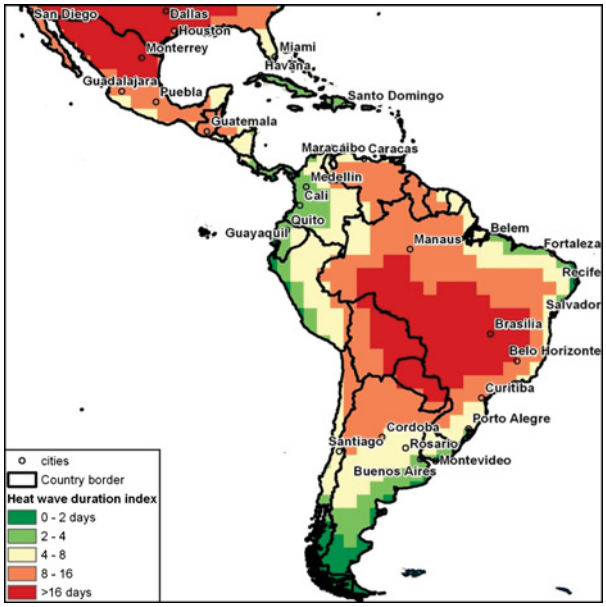
MAP 1.2

Expected Changes in Latin America and the Caribbean Region Climate Risks from 1981–2000 to 2031–50 Based on Eight Global Circulation Models (p. 10) and Levels of Model Concordance (p. 11)

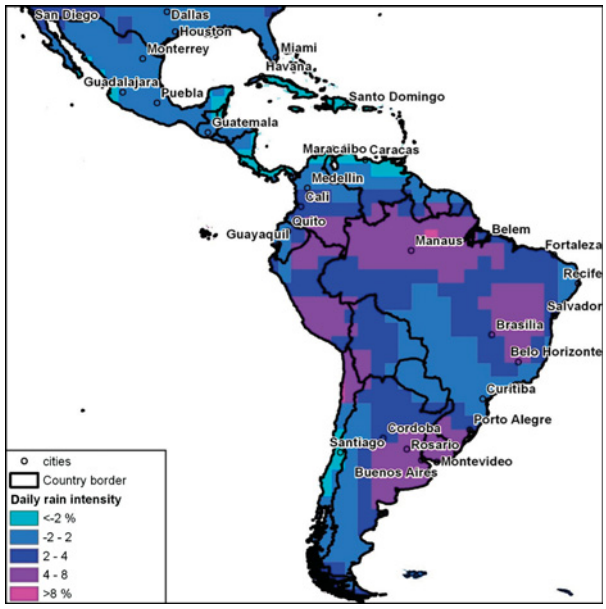
More dry days



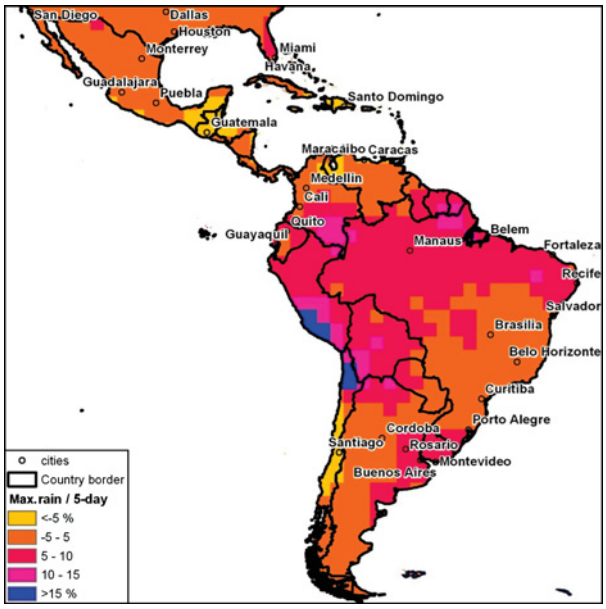
Longer heat waves



Higher rain intensity



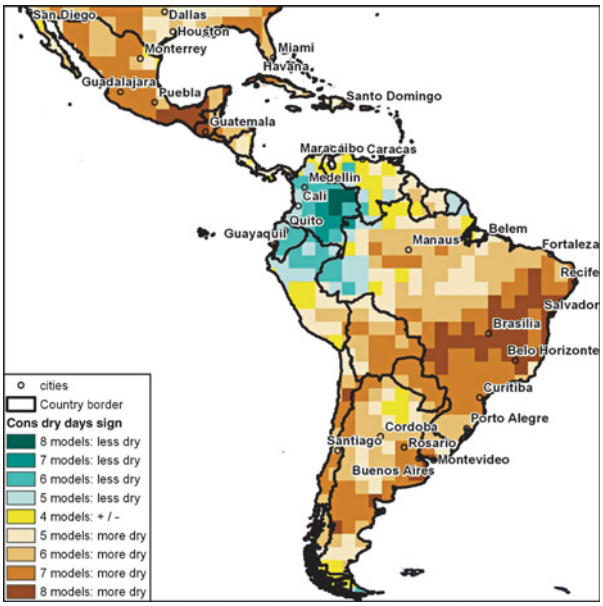
Higher maximum rainfall



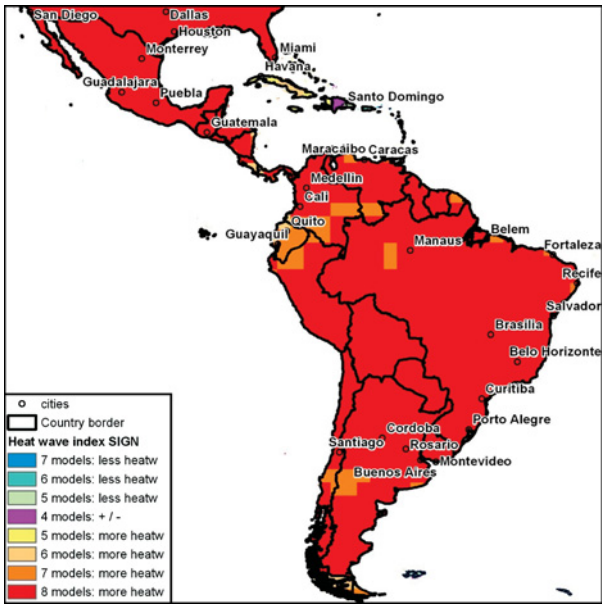
(Map continues on next page.)

MAP 1.2
(continued)

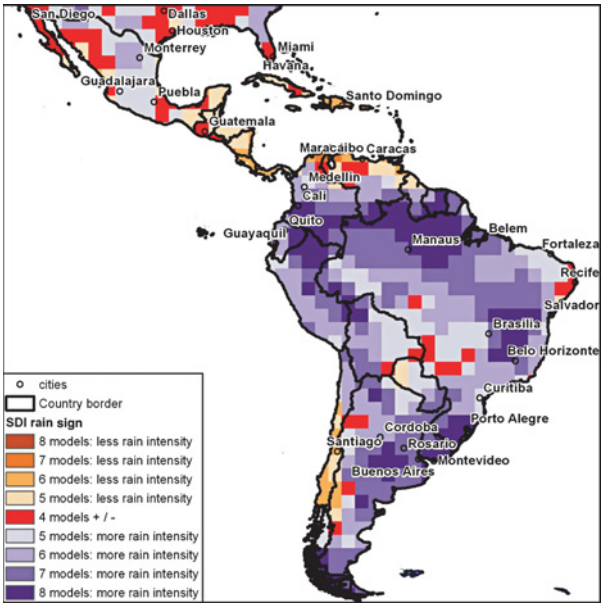
Dry days: concordance



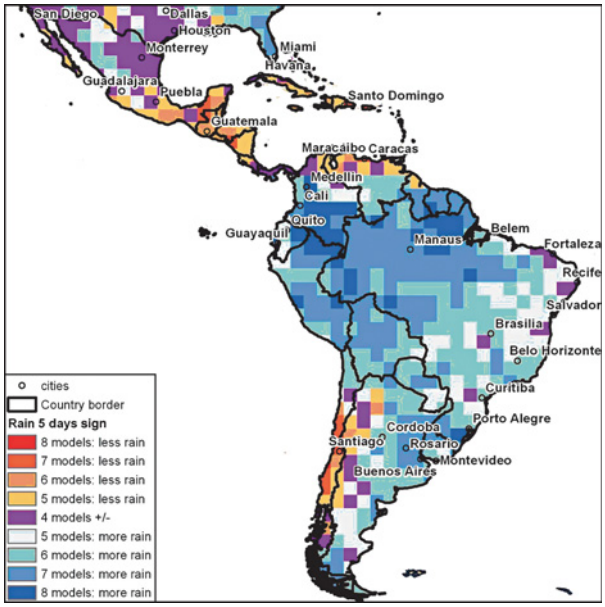
Heat waves: concordance



Rain intensity: concordance



Maximum rainfall: concordance



Source: World Bank staff calculations using eight global circulation models (see table 1.1).
Note: SDI = Simple daily intensity.

TABLE 1.1

Fraction of the Latin America and the Caribbean Region Countries' Territory with Increased Climate Risks in 2030

percent

	Increase in maximum consecutive dry days (CCR): at least 2 more days (2030)	Increase in heat-wave duration (HWD): at least 8 more days (2030)	Share of areas with high current drought probability that also have high CCR or high HWD in 2030 (%)	Increase in simple daily rainfall intensity index (SDI): at least 4% (2030)	Increase in maximum amount of rainfall in 5-day period (R5D): at least 10% (2030)	Share of areas with high current drought probability that also have high SDI or high R5D in 2030 (%)
Argentina	52	38	77	28	2	47
Belize	100	87	n.a.	0	0	0
Bolivia	93	100	100	16	16	28
Brazil	71	79	100	39	3	22
Chile	59	26	100	25	19	0
Colombia	2	4	56	26	19	21
Costa Rica	0	0	0	0	0	0
Cuba	100	0	n.a.	0	0	0
Dominican Republic	98	0	n.a.	0	0	0
Ecuador	0	0	0	12	0	14
El Salvador	100	17	100	0	0	0
Guatemala	100	96	100	0	0	0
Guyana	76	96	n.a.	0	0	n.a.
Guyane	6	6	n.a.	6	49	n.a.
Haiti	100	0	n.a.	0	0	0
Honduras	97	56	n.a.	0	0	0
Jamaica	100	0	n.a.	0	0	0
Mexico	97	87	100	0	0	0
Nicaragua	66	0	73	0	0	0
Panama	0	0	n.a.	0	0	0
Paraguay	100	100	100	0	1	2
Peru	21	10	0	62	36	68
Puerto Rico	100	0	n.a.	0	0	0
Suriname	69	80	n.a.	48	17	n.a.
Trinidad and Tobago	0	0	n.a.	0	0	0
Uruguay	0	0	n.a.	100	0	100
Venezuela, R. B. de	10	81	100	9	0	0

Source: World Bank staff calculations using the following models: cnrm: cnrm-cm3, Meteo France; gfdl: gfdl-cm2.0, Geophysical Fluid Dynamics Lab/NOAA; inmc: inm-cm3.0, Institute Numerical Math, Russia; ipsl: ipsl-cm4, Institute Pierre Simon Laplace, France; mirh: miroc3.2(hires), University of Tokyo, JAMSTEC, Japan; mirm: miroc3.2(medres), University of Tokyo, JAMSTEC, Japan; mri: mri-cgcm2.3.2, Meteorological Research Institute, Japan; ccsm: ccsm3, National Center for Atmospheric Research USA. Drought and flood frequency indexes from Dilley et al. (2005).

Note: CCR, HWD, SDI, R5D report percent of territory where climate events are predicted by 5 or more global circulation models. A high probability of drought is defined on the basis of a drought frequency index of 8 or more; a high probability of floods is defined as a flood frequency index of at least 3. n.a. = not applicable.

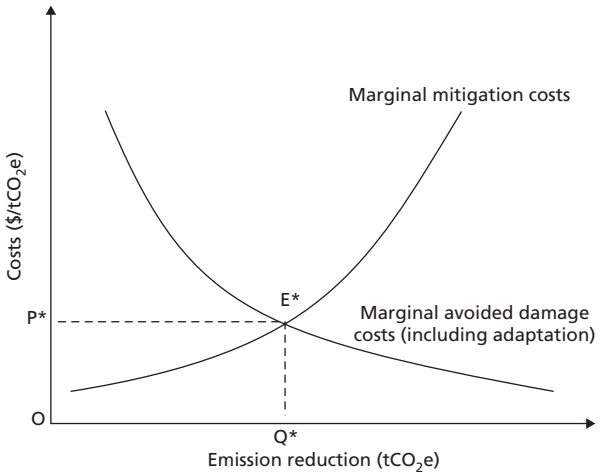
The marginal benefits of mitigating climate change, on the other hand, tend to fall with the scale of emission reduction efforts. Compare for instance a business-as-usual scenario in which very limited emission reduction are implemented, with an alternative hypothetical situation in which emissions are drastically reduced so as to maintain constant the current concentration of GHGs in the Earth's atmosphere. As mentioned previously, in the first scenario using Stern's (2008) predictions we could eventually face a 50 percent chance of global warming in excess of 5°C, which in turn would imply a large probability of catastrophic damages. The payoff of reducing emissions in this scenario would be large. In contrast, in the alternative scenario, in which the stock of GHGs is stabilized at current levels, global warming in the near term would be in the order of only 0.1°C per decade. As a result, the marginal benefit of additional emission reductions would probably be smaller.

Assuming that we know the curves representing the marginal costs and benefits (avoided damages) of mitigating climate change for different levels of emission reductions—which, as argued above and illustrated in figure 1.5, are respectively upward and downward sloping—implementing an optimal level of mitigation effort would appear to be quite straightforward. It would amount to finding the intersection between those curves and then using one of two policy alternatives to get there. The first would be a "cap-and-trade" system in which governments would distribute—or auction—permits to emit, thus putting a ceiling on total GHG emissions consistent with the optimal amount of emission reductions OQ* depicted in figure 1.5. The entities covered by the scheme—for example, firms, individuals, or countries—would be free to either reduce their own emissions up to their corresponding caps or to buy or sell permits to emit from other participants. As a result, emissions reductions would be implemented by those who face the lowest mitigation costs and trading would lead the price of carbon to converge to the level of the marginal mitigation cost OP*.

A second alternative to achieve the efficient level of mitigation OQ* would be to directly establish a price on GHG emissions by creating a "carbon tax" set at the level OP*. The objective of this tax—or that of the auctioning of emission reduction permits in a cap and trade system—would not be to increase government revenues, but rather to internalize the externality created by GHG emissions. In particular, the goal would be that of making emitters pay a price equal to the marginal damage caused to others. Indeed, implementing mitigation efforts above and beyond the point given by the intersection of the marginal mitigation and damage cost curves (E*)—either by setting a quantity control above OQ* or a carbon tax above OP*—would cost more than the value of the additional damages that would be avoided. Similarly, setting a carbon tax below OP* or a cap on emissions below OQ* would amount to wasting the opportunity of avoiding negative impacts of climate change at a cost that would have been lower than that of the corresponding climate damages.

FIGURE 1.5

Marginal Mitigation Cost and Avoided Damage (Benefit)



Source: Authors.

Carbon taxes versus "cap and trade"

In theory, in a world of perfect information well-designed carbon taxes or cap-and-trade schemes could achieve the optimal level of climate mitigation. In practice, however, policy makers need to deal with the fact that the position and slope of the marginal costs and benefits of climate mitigation are likely to vary over time, both with the level of GHG emissions and with the evolving set of available mitigation technologies. Moreover, even at a given point in time, the precise estimation of marginal mitigation and damage costs is hampered by the large degree of uncertainty associated with the drivers, timing, and impact of global climate change, as well as with the cost and efficacy of various mitigation and adaptation alternatives. For example, estimates of the so-called climate sensitivity parameter, defined as the change in average global temperatures resulting from a doubling of the stock of GHGs in the atmosphere, vary from 2°C to 4.5°C (Solomon et al. 2007). In addition, while we have a good idea of the types of climate impacts that would be associated with different levels of warming, damage estimates at the regional level are still quite imprecise as is our knowledge of the timing of some of the global impacts of warming. For instance, in the case of the catastrophic events associated with high

rates of global warming, we know that they could occur within a time scale of centuries or millennia. Finally, there is still considerable uncertainty regarding the costs of some of the energy technologies that would need to be deployed in order to achieve large-scale emission reductions.

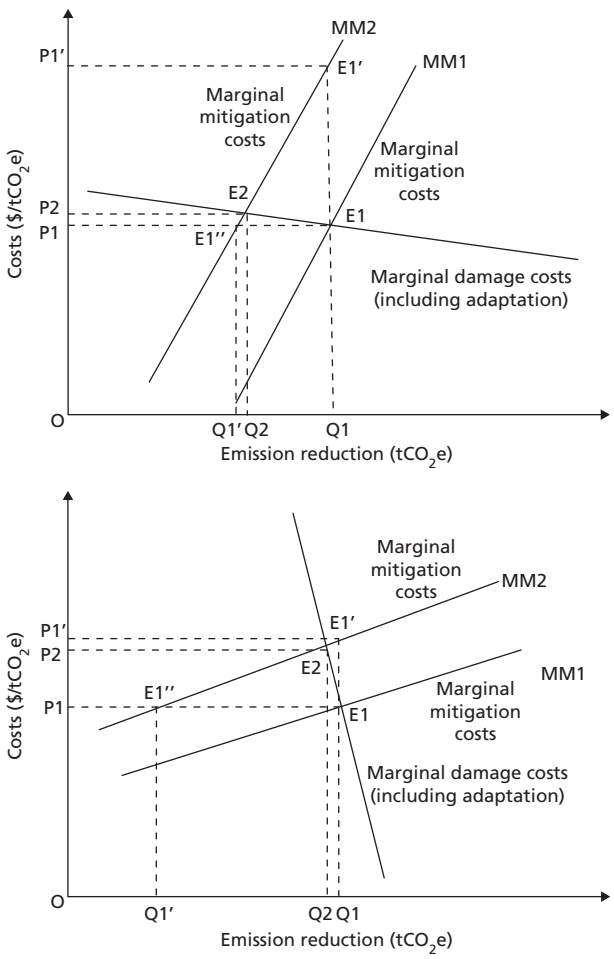
The presence of imperfect information has important implications on the choice of carbon taxes versus cap-and-trade schemes. Indeed, policy makers need to choose whether they prefer to deal with surprises in the levels of GHG emission reductions when using a carbon tax or with volatile carbon prices when opting for using quantity controls on emissions rather than a carbon tax. Indeed, in a cap-and-trade (carbon tax) scheme, policy makers control the quantity (price) of emissions reductions, but the market determines the corresponding price (quantity). As suggested by Weitzman (1974), carbon taxes are preferable to quantity controls when the slope of the marginal costs curve is larger than that of the marginal damage curve because in this situation the cost of incorrectly estimating the position of the mitigation cost curve is lower using a tax than when using a cap. This is illustrated in figure 1.6, in which policy makers believe the cost curve to be MM1 and the optimal mitigation level to be at point E1, but they later find out that the true mitigation cost curve is MM2 instead of MM1, so that efficient mitigation would occur at point E2. Had they chosen to fix a cap OQ1, they would actually end up at point E1′. If instead they had chosen a carbon tax OP1, they would end up at point E1″. In the upper panel, the slope of the damage cost curve is relatively smaller and the carbon tax is preferable, as shown by the fact that E2 is much closer to E1″ than to E1′. The reverse occurs in the lower panel, where the cost of the mistake is much higher when using a tax than a cap-and-trade scheme, which is illustrated by the fact that E1″ is now much farther away from E2 than is E1′.[17]

Marginal mitigation cost curves are likely to be steeper when decisions are made with a shorter time horizon, whereas the opposite is true for the marginal damage cost curve (Stern 2007). Indeed, because in the short term capital stocks and the set of available technologies are fixed, mitigation costs can increase quickly as larger emission reductions are envisioned. These restrictions, however, are relaxed in the long run, which would make the corresponding curves flatter. In contrast, while in the long-term policy makers can envision altering the *stock* of GHGs in the atmosphere, their short-run policy lever is only the *flow* of GHG emissions, which has only a limited and indirect influence on marginal damages. As a result, changes in long-run policy targets for emission reductions can have a much larger impact on expected marginal damages, thus making the corresponding curve steeper when longer time horizons are considered.

In this context, as argued by Stern (2007), policy makers should ideally consider combining long-term

FIGURE 1.6

Impact on Optimal Policies of Unexpected Changes in Marginal Mitigation Costs



Source: World Bank staff.

quantity controls—for example, GHG stabilization targets—with short-term flexible policy instruments. The latter should ideally not be rigid with respect to short-term emission reductions, but they should generate a carbon price that is consistent with long-term policy goals. In our simplified conceptual framework, the main option in this respect would be the use of a carbon tax. As discussed later, however, other possible alternatives include flexible cap-and-trade schemes and, to a lesser extent, regulations that implicitly price carbon at the desired level. As suggested by Stern (2007), an analogy can be made in this respect with inflation targeting frameworks, in which short-term adjustments are made in short-term policy levers, namely interest rates, in order to ensure convergence with long-term inflation goals.

Several caveats need to be mentioned, however, which may nuance the aformentioned conclusions. First, in a hypothetical situation in which the scientific evidence suggested that the world is close to a "tipping point"—that is, a critical concentration of GHGs in the atmosphere that sets in motion sudden and catastrophic climate change—policy makers would have good reasons to prioritize quantity controls over taxes, even in the short run. In that case, the bottom panel of figure 1.6 could in fact be a better representation of the short than of the long term.

Second, as mentioned previously, a flexible cap-and-trade system could in theory be used instead of a carbon tax in order to generate a common carbon price across sectors and/or countries without abdication of the necessary short-term flexibility with respect to the quantity of emission reductions and to minimize the extent of price volatility naturally associated with a policy that focuses on generating certainty on quantities rather than prices. Allowing for intertemporal trade in allowances, for example, could help smooth carbon prices. Allowing caps to be adjusted periodically as new information arises on the level of mitigation costs could also help provide the necessary policy flexibility and reduce price volatility, although revisions should not be too frequent because this could also discourage investment. Alternatively, it would be possible to deal with the inevitable price volatility associated with cap-and-trade systems through the creation of a "Climate Fed," which would intervene in the allowances market in order to stabilize their price (Aldy et al. 2008). Automatic price ceilings and floors could also be introduced, respectively, by increasing quota allocations when carbon prices surpass a certain predetermined level and by means of a hybrid mechanism in which a carbon tax would kick in if prices fall below a certain floor. It is worth noting, however, that several of these schemes would also create additional difficulties for achieving international policy synchronization (Stern 2007).

Third, depending on how each system is implemented, carbon taxes may generate fewer economic distortions than cap-and-trade schemes. In particular, if emission permits are distributed freely—as opposed to being auctioned—they can generate the same level of pricing on carbon without generating any revenues for governments. Thus, while in both cases carbon prices are likely to be passed on to consumers, with a negative economic impact derived from lower returns to labor and capital, that effect can be partially compensated in the case of carbon taxes. For that to happen carbon taxes need to be revenue-neutral and their proceeds need to be recycled into the economy in a way that reduces other tax distortions—for example, by lowering tax rates on personal or capital income (Aldy et al. 2008). This disadvantage of cap-and-trade schemes can, of course, be reduced if auctions of emission permits are implemented and the revenues are also used "judiciously."

Fourth, it is important to note that taxes—or for that matter any other mechanism that gives rise to a price on carbon—can only lead to efficient levels of emission reductions when the same price on carbon applies to all emitters. This is the only way to ensure that the least expensive mitigation alternatives, with marginal costs below the common carbon price, are implemented. Achieving a common carbon price within national boundaries implies harmonizing various domestic government policies across sectors, so that the combined impact of emission caps, carbon taxes, and regulations are the same for all emitters. While this is certainly not trivial, achieving the same goal at the global level is much more challenging, especially if one expects the agreement to both generate efficient emission reductions and satisfy equity considerations.

In this context, carbon taxes and cap-and-trade systems both have advantages and disadvantages. If carbon taxes are widely adopted, for example, efficiency would call for a common tax rate (adjusted for implicit effects of other policies) across countries. Simulations using computable general equilibrium models can be used to evaluate the global costs of achieving a given emission reduction under two scenarios, one in which a uniform tax is levied in all countries, and another in which a tax in each country is levied at a rate that would achieve the same percentage reduction in each. The global costs of the former policy would be only a fraction of the cost of the latter policy. However, in order to be seen as equitable, the agreement would also have to include a set of resource transfers across countries—for example, from industrialized to developing countries—if the former agree to a higher contribution to global climate change mitigation efforts, at least in the short term. In contrast, if an international cap-and-trade scheme is adopted, a common price on carbon would emerge even if countries agree on different levels of contributions to global efforts—that is, different caps on emissions. In this context, resources would flow automatically to countries that offer the lowest cost-mitigation opportunities, thus potentially funding mitigation efforts that could go above and beyond the commitments of the corresponding countries. As argued by Aldy et al. (2008), however, the flip side of the coin is that it may be more difficult to negotiate country-level emission reduction targets and baselines than to focus simply on negotiating tax rates.[18] Moreover, most developing countries may find it easier to implement carbon taxes through their finance ministries—for example, using the experience accumulated with energy taxes—than to put in place the infrastructure needed for implementing a cap-and-trade scheme, including building the capacity of their environment ministries to establish, monitor, and enforce emission reduction targets.

Complementary approaches to mitigation: technology policy and regulations[19]

By pricing the negative externalities generated by GHG emissions, carbon taxes and cap-and-trade schemes can create the monetary incentives needed by private firms to invest in the development of low-carbon technologies. This process can be further accelerated if current fossil fuel–based technologies are made increasingly costly as a result of rising oil prices and/or the reduction of energy subsidies. There are, however, a number of motivations for using complementary technology policy instruments and regulatory measures to promote the development and, perhaps more important in the case of developing countries, the widespread deployment of new or improved low-emission technologies.

First, it may take some time for carbon pricing policies to gain the credibility needed for having an impact on the strategic technology decisions of private investors. In other words, given the high uncertainty surrounding long-run expectations on carbon prices, private firms may not as of yet use them as the basis for significant increases in their investments in the research and development (R&D) of new low-carbon technologies. To the extent that these technologies are needed with urgency in order to effectively ramp up global climate mitigation efforts, additional monetary incentives for R&D could be warranted. These R&D subsidies could thus be motivated, in a risk-management perspective, by the need to minimize the potentially catastrophic downside risks associated with uncontrolled climate change.

Second, to the extent that R&D investments in new low-carbon technologies generate positive externalities—for example, through knowledge spillovers to other firms and sectors—their returns could be higher from a social rather than from a private perspective. This would strengthen the case for public support, especially at the initial phases of the R&D process—for example, to a larger extent in basic than in applied research—where knowledge spillovers are more likely to be found. In the case of new types of low-carbon energy technologies, however, there could also be an economic rationale for government subsidies during the stage of commercial deployment, provided that there are significant dynamic economies to scale. In particular, even if the new technologies are initially not competitive, production costs may tend to diminish over time with cumulative production. It may thus be socially desirable to invest in the deployment

of these new technologies even if the private sector would not by itself do so.

It is important to note that governments should ideally strike a balance between the risk of "picking winners"—which would call for technology-neutral policy instruments—and the need to maintain a sufficiently diversified portfolio of low-carbon technology options. Indeed, technology-neutral subsidies run the risk of failing to support some of the most promising technologies if they are still too far from being commercially competitive. Moreover, special support may be targeted at transformational technologies that can be considered critical for achieving sizable emission reductions in strategic sectors. One important example is the development and deployment of carbon capture and storage technologies, which is generally seen as the main alternative for reconciling large reductions in emission reductions in the power sector, with the continued use of fossil fuels in the medium to long term.

Third, the presence, in the area of energy efficiency, of a large number of untapped opportunities for reducing emissions at very low or even negative costs suggests that a number of market failures may limit the diffusion of the corresponding low-carbon technologies. These market failures include lack of information among consumers about some of the benefits of energy conservation, credit constraints, or the presence of "split incentives" when those who would have to pay for the cost of increased energy efficiency (for example, home builders) are not able to fully capture the returns of their investments (for example, from tenants). Options for dealing with these problems include the issuance of mandatory energy efficiency standards for buildings, appliances, or vehicles; information campaigns or other policies aimed at raising awareness about best practices in energy conservation; monetary incentives to facilitate selected investments in energy efficiency by firms or individuals; and improvements in energy conservation within public sector agencies. Ideally, governments should assess the price of carbon that is implicit in the aforementioned policies, calculated as the additional costs associated with complying with each new regulation divided by the expected reduction in GHG emissions that it should generate.

Estimates of the global cost of reducing emissions

Global climate models can be used to estimate the macroeconomic costs of mitigating climate change. Estimates are generally produced for different GHG stabilization scenarios, which are, in turn, associated with different emission reduction trajectories and with a range of probable levels of associated warming. For example, the most stringent targets considered by the IPCC call for stabilization of GHG concentrations within a range of 445 ppm to 535 ppm CO_2e. These targets would imply that emissions would have to peak by at most 2015–20. By 2050 they would have to drop to between 30 percent and 85 percent of the 2000 level, which would imply massive reductions in the rate of emissions per unit of GDP. Thus, for instance, following Stern's assumption of a tripling of world GDP by 2050, a 50 percent reduction in global emissions would imply that emissions per unit of output would have to be reduced by about 85 percent. The likely equilibrium temperature increases that would correspond to these targets would be between 2°C and 2.8°C with respect to preindustrial levels.[20] The average cost of achieving these mitigation goals, based on 15 climate models considered by the IPCC, would be a reduction of up to 3 percent of global GDP in 2030 and up to 5.5 percent by 2050.

A slightly less stringent target of 535 ppm to 590 ppm CO_2e would require emissions to peak by at most 2030 and to fall, by 2050, to between 5 percent above their 2000 level and a 30 percent reduction below 2000. In this scenario, temperature increases would be between 2.8°C and 3.2°C.[21] This target would imply a median estimate of aggregate mitigation costs of 1.3 percent of global GDP in 2050, with maximum costs of 4 percent of global GDP in that year and 2.5 percent in 2030. A similar stabilization target of 550 ppm CO_2e has been proposed by Stern (2007), who calculates that the corresponding climate mitigation costs would be of about 1 percent of world GDP, which is very close to the median estimate reported by IPCC for the 535ppm to 590 ppm CO_2e target. Stern warns that even if this target is met there would still be a 7 percent probability of temperature increases above 5°C. While this is a relatively unlikely

event, it is worth recalling that this level of global warming could possibly lead to the melting of most of the world's ice and snow, as well as to rising sea levels of 10 meters or more, and losses of more than 50 percent of current species.

What carbon prices would be needed to stabilize GHG emissions?

Carbon prices associated with different levels of emission reductions can be calculated using either "top-down" or "bottom-up" approaches. Within the first approach, a number of carbon price estimates have been generated using global climate models, so as to achieve different GHG stabilization targets. In this approach, as reported by the IPCC, the carbon prices that would be needed in 2030 in order to stabilize GHG concentrations in the range of 445 ppm to 535 ppm CO_2e would be close to 100 US\$/tCO_2e. For the less stringent target of stabilization at 535 ppm to 590 ppm CO_2e, the IPCC reports a median carbon price of 45 US\$/tCO_2e in 2030, with model estimates ranging from 18 to 79 US\$/tCO_2e in that year, and from 30 to 155 US\$/tCO_2e in 2050.

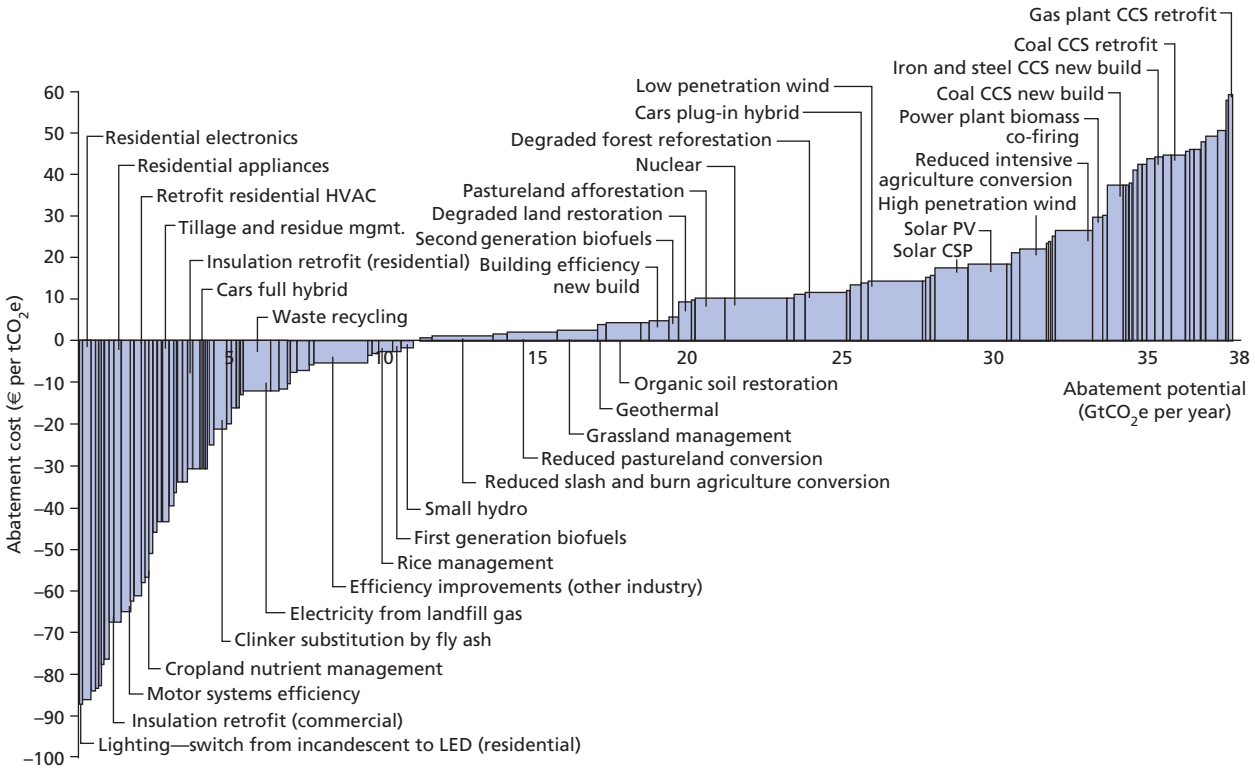
Bottom-up studies generate estimates of the aggregate mitigation potential associated with different carbon prices that are very similar to those obtained using the top-down approach. For example, both types of studies predict that carbon prices of up to 100 US\$/tCO_2e would yield reductions of about 30 percent to 50 percent of 2030 emissions. However, bottom-up studies produce relatively more detailed estimates of the mitigation opportunities that could be economically feasible at different carbon prices. Indeed, those studies start from the analysis of the various alternative technologies for reducing GHG emissions that are available in each sector and region of the world and compute the respective mitigation potential and costs per ton of avoided GHG emissions. The results can conveniently be presented through a curve that ranks the various mitigation alternatives ordered by their average mitigation costs, thus approximating the world's marginal mitigation cost curve. An example of such a GHG emissions cost-abatement curve, produced by the *McKinsey Quarterly*, is reported in figure 1.7.

As illustrated in figure 1.7, in order to attain ambitious stabilization targets—for example, 550 ppm, CO_2e—mitigation efforts should be spread across a large number of sectors. Increases in energy efficiency in buildings offer some of the largest mitigation potential at lower costs. According to the IPCC, those measures account for between one-fifth and one-third of global mitigation potentials at carbon prices below US\$100/tCO_2e. In addition, energy supply, industry, and agriculture would each account for between 15 percent and 20 percent of the total potential, while forestry would contribute 8 percent to 14 percent depending on the scenario. Emission reductions in the transport sector would account for less than 10 percent and waste for about 3 percent of the total global mitigation potential.[22] In almost all sectors, the only exception being transport, more than 50 percent of global mitigation potentials would be located in developing countries. In particular, these countries would account for almost 70 percent of the potential for reducing emissions in industry, agriculture, and forestry.

Figure 1.7 also illustrates the fact that a sizable amount of emission reductions—about 7 Gt CO_2e or about 25 percent of the total mitigation potential for carbon prices of up to US\$100/tCO_2e—could be achieved at negative costs, that is, saving money. This estimate is shared with other bottom-up studies as well as with the top-down studies reviewed by the IPCC. About 80 percent of these no-regrets mitigation alternatives would be associated with increases in energy efficiency in commercial and residential buildings. However, if oil prices were to continue rising above what is envisaged in most IPCC scenarios, large mitigation opportunities at negative costs could also arise in the transport sector. Indeed, fuel savings could more than compensate for the cost of implementing a wider array of low-carbon transportation technologies. As previosly discussed, taking advantage of these "low hanging fruits" may require dealing with market failures that retard the development and deployment of many energy-efficient technologies. This, in turn, calls for combining carbon pricing policies—for example, carbon taxes or cap-and-trade schemes—with the use of regulatory standards and various technology policy instruments.

FIGURE 1.7

McKinsey's Global Greenhouse Gas Abatement Cost Curve Beyond Business-as-Usual, 2030



Source: Reprinted with permission from *McKinsey Quarterly* (2007).
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play. CCS = carbon capture and storage.

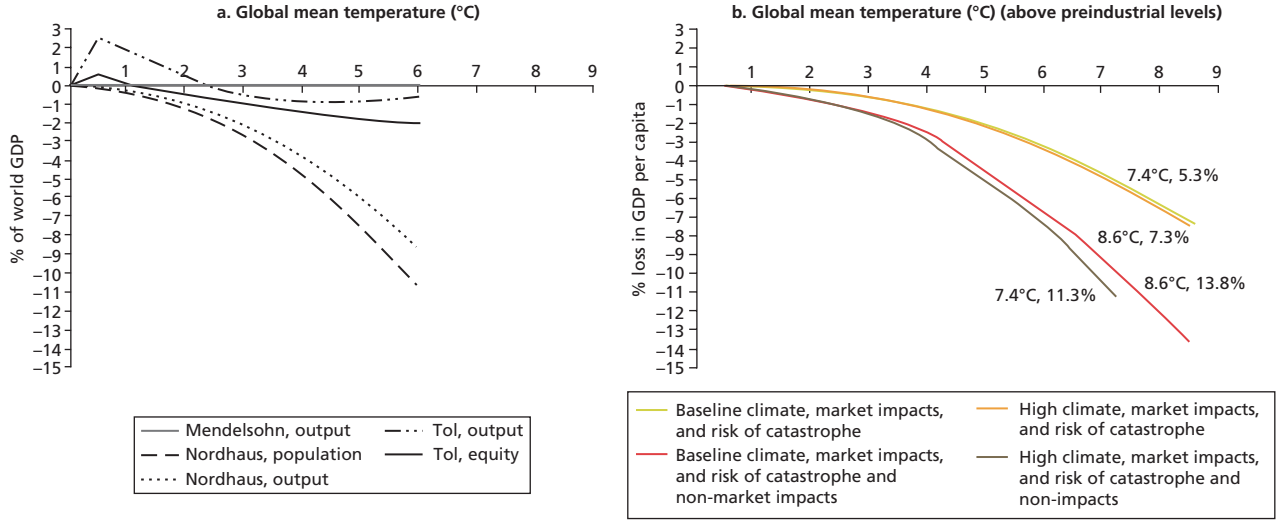
Current estimates of the damage costs of climate change

Estimates of the damage costs of climate change need to take into account the large differences existing across regions, both in the level of warming expected for given increases in GHG concentration and in the vulnerability of different natural and human systems to given levels of climate change. For instance, the IPCC predicts that for warming of 1°C to 3°C some regions and sectors may suffer while others may benefit from. The IPCC Third Assessment report (2001) estimated that the likely damage that would be caused by a doubling of GHG concentrations—which could lead to warming in the range of 2°C to 4.5°C above preindustrial levels—could reach 1 percent of GDP in developed countries but a much larger percentage in developing countries. As a result, it estimated that global costs would be between 1.5 percent and 3.5 percent of world GDP. Similarly, using the latest scientific evidence, the IPCC's Fourth Assessment Report predicts that the global mean losses associated with warming of 4°C could be of 1 percent to 5 percent of world GDP but losses in some regions could be substantially higher.

Higher global damage costs have been obtained by Stern (2007) who estimates that warming of 4°C above preindustrial levels could imply costs of up to 3 percent of world GDP, while warming of 5°C would cost about 5 percent of global output. Stern estimates that over the next two centuries the costs of unmitigated climate change would reach between 5 percent and 11 percent of global GDP now and forever (including the cost of catastrophic climate events). The higher estimates of damage costs result from incorporating the computation of nonmarket impacts on human health and the environment. Even larger estimates of up to

FIGURE 1.8

Damage Costs of Different Levels of Global Warming



Source: Adapted from "Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change," figure SPM.4. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Source: Stern (2007).

20 percent of global consumption are obtained by Stern when using alternative assumptions on the sensitivity of climate to GHG, as well as equity weights to account for the fact that poor countries and people are likely to be disproportionately affected by climate change. As illustrated in figure 1.8, Stern's estimates are slightly lower than those of Nordhaus and Boyer (2000), respectively, about 5 and 7 percent of GDP for warming of 5°C, for example. Stern's estimates, however, are much higher than those reported by Mendelsohn et al. (1998) and Tol (2002), who predict damages of up to 2.5 percent of global GDP for temperature increases as high as 6°C, even when using population-based equity weights to compute damages. These lower estimates, however, do not incorporate the cost of catastrophes nor do they compute the cost of nonmarket impacts.

An alternative approach to the costing of the impacts of climate change is the calculation of the social cost of carbon (SCC), defined as the change in the discounted value of the utility of future consumption caused by an additional ton of GHG emissions. SCC estimates, however, vary widely across studies, depending on the treatment of uncertainties, the discount rates that are used to calculate the present value of future damages, as well as on the types of damages that are taken into account—for example, nonmarket impacts and catastrophes—and the treatment that is given to risk and equity. Tol (2005) has reviewed more than 100 SCC estimates and found a median value of US$11.80 per ton of CO_2 among peer-reviewed studies. He argues that the social cost of carbon is unlikely to exceed US$14/t$CO_2$ using standard assumptions on discounting and aggregation. Similarly, Nordhaus (2007) estimates that the optimal global price of carbon—which should ideally be equal to the SCC—will be at US$9.50/t$CO_2$ in 2015, rising to $23 in 2050, and $56 by 2100. In contrast, Stern (2007) reports a SCC estimate of US$85/t$CO_2$. This is above the 95th percentile of the estimates reviewed by Tol and almost 10 times the value of Nordhaus's estimate.

The debate about discount rates

The relatively high estimates obtained by Stern for the potential damages of climate change have been criticized as being driven by his use of very low social discount rates to value future monetary flows. Stern uses a standard conceptual framework for calculating rates of Social Time Preference (STP). Nordhaus

(2007) and Weitzman (2007), however, argue that Stern makes nonstandard assumptions to derive that rate and that a reasonable STP should be between 5.5 and 6.[23] Using this higher social discount rate drastically weakens Stern's case for the need to sharply and immediately reduce GHG emissions. In particular, Nordhaus shows that Stern's very high estimate of \$310/tC for the social cost of carbon is entirely driven by his assumptions regarding a low STP. Indeed, using Nordhaus's Dynamic Integrated Model of Climate and the Economy (DICE-2007) to calculate the social cost of carbon under Stern's, and under alternative more standard assumptions for the STP rate, yields estimates of the social cost of carbon of respectively US\$99/tCO_2e and \$10/tCO_2e. The second estimate is much closer to the average of the estimates reported by Tol (2005).

Weitzman (2007), on the other hand, has argued that Stern may have "gotten it right for the wrong reasons." Weitzman coincides with Nordhaus in his critique of Stern's nonconventional parameter assumptions for calculating the STP rate. But he argues that the expected growth rate (σ) is a random variable with a distribution that has a thick left tail (that is, relatively high probability of extremely low growth) because of some of the possible catastrophic events that could be triggered by climate change. This creates structural uncertainty, of the sort described by Knight (1921) or Keynes, in the sense that the scale and probability of the corresponding rare events cannot be calculated on the basis of past observations or computer simulations, especially since the underlying distribution tends to evolve with climate.

In Weitzman's approach, the uncertainty associated with climate change, combined with the very serious consequences associated with some of its possible catastrophic impacts, implies that the use of relatively low discount rates for assessing the future costs of GHG emissions could be justified on the basis of risk-aversion assumptions, and the idea that one tends to be disproportionately afraid of rare disasters on which existing time series are unable to shed light. In particular, Weitzman proposes that the fear of "thick tail events"—which he argues would also explain the "equity-premium puzzle," namely, the fact that people tend to pay high premiums for safe stores of value—would justify a middle course policy approach in which increasingly stringent targets for emission reductions would be combined with devoting additional resources to improving our understanding of the nature, likelihood and consequences of "runaway-climate disasters."

Can optimal mitigation pathways be established?

The evidence presented so far suggests that the climate mitigation costs of implementing the GHG stabilization target of 550 ppm CO_2e recently proposed by Stern (2008) could be well below the cost of the corresponding avoided damages. In particular, mitigation costs for that target are of about 1.3 percent of global GDP according to the IPCC's median estimate. In contrast, achieving that target could allow for a sizable decline in the amount of expected global warming, arguably from more than 4°C—for example, if GHG concentrations reach 750 ppm CO_2e under business-as-usual trends—to about 3°C above preindustrial levels. As shown in the right panel of figure 1.8, this could reduce damage costs from 4 percent to less than 2 percent of global GDP, according to estimates by Stern (2007), and from about 5 percent to 3 percent of world output, according to estimates by Nordhaus and Boyer (2000).

Nevertheless, as previously illustrated, estimates of both climate change mitigation and damage costs are still quite imprecise due to the various types of uncertainties involved. As a result, whereas it appears that some degree of climate mitigation is certainly warranted, the IPCC argues that it is probably not yet possible to unambiguously determine economically efficient emission pathways, or stabilization levels, for which marginal mitigation benefits would always exceed the corresponding marginal costs. Thus, in practice, decision making regarding the optimal trajectory of emission reductions is likely to require an iterative process of risk management, driven by the evolving scientific evidence regarding climate sensitivity to GHG concentrations, damage costs from climate change, and technological options for mitigation. In any case, as argued by Aldy et al. (2008), given the current evidence, from the perspective of the industrialized world,

at least a moderately scaled emissions program appears to be warranted in the short term.

Strategic aspects of mitigating climate change

Many economic analyses treat climate change as a single-agent problem. Implicitly or explicitly, these studies take the perspective of a global social planner and try to determine what, ideally, should be done to mitigate climate change and its consequences. Such a single-agent approach is useful to find a "first-best" reference point against which actual policies can be compared. However, by construction, a single-agent model has nothing to say about what is realistically feasible and probably *will* happen (as opposed to what *should* happen) in the fight against global warming. To address this question, one must explicitly take into account that the world comprises many independent and heterogeneous countries, whose interests do not coincide—neither with each other nor with those of an imaginary global social planner.

Naturally, the outcome of the global climate change "game" crucially depends on whether countries cooperate to find and implement a joint mitigation strategy. But even if all countries are sincerely committed to reaching a negotiated settlement, it remains essential to understand what would happen in its absence. The reason is that the noncooperative outcome, describing what happens if the negotiations fail, very much determines what a joint strategy is actually going to look like. In particular, in the absence of a joint strategy, countries have to unilaterally decide how much to spend on mitigation. In that case, the total mitigation effort will be (1) too little, (2) too late, and (3) undertaken by the wrong countries.[24]

The intuition for the first effect, that is, insufficient effort, is straightforward: GHG reductions are a public good and, hence, countries face a classic free-rider problem. This inaction is reinforced and complemented by a second effect, namely, inefficient delay. That is, even if a country recognizes that it should act to mitigate climate change, it has a strong incentive to wait. If countries are unsure about each other's vulnerabilities and costs of mitigation, they may, sometimes falsely, believe that another country will "step up to the plate," and they may avoid doing so themselves. From the perspective of individual countries, this creates an option value of waiting. By the time countries come to the realization that it really is up to them to act, it may already be too late or, at the very least, precious time has been lost. Finally, the reason that mitigation effort, if any, tends to be undertaken by the wrong country is the following: in the absence of coordination and cooperation, it is the country with the lowest "cost-to-vulnerability" ratio that ends up taking action. But, generally, this is not the country with the lowest cost per se, as the countries' vulnerabilities to climate change may differ quite a bit. Hence, resources end up not being expended in the most cost-effective way.

Is a global deal feasible?

Taken together, these dynamics will lead to a significant under supply of mitigation effort. Clearly, what is needed to escape from this inefficient and rather dismal outcome is a joint, coordinated strategy. This raises the question of whether such a joint strategy can be agreed upon, and if so, what it would look like. In this respect, as suggested by Stern (2007), there are several conditions that need to be met in order to successfully implement a coordinated international approach to mitigating climate change.

First, it is critical that countries share a common understanding of long-term goals. The extent to which this condition is met in the case of climate change mitigation has arguably increased significantly over the past two decades. This is illustrated by the results of the successive IPCC reports which, starting in 1990, have produced an increasing amount of evidence on the gravity of the climate change challenge as well as on the potential for addressing it through drastic reductions in manmade GHG emissions. Moreover, the 1992 agreement on the United Nations Framework Convention on Climate Change (UNFCCC), which has been ratified by 189 countries, explicitly recognized as its overarching objective the stabilization of GHG concentrations at a level that avoids dangerous anthropogenic climate change. In addition, the Kyoto Protocol, agreed to in 1997 under the UNFCCC and subsequently ratified by 162 countries, established a binding commitment by industrialized countries, to reduce GHG emissions during the 2008–2012 period

by 5 percent with respect to their 1990 level. Stern (2008) suggests that the UNFCCC objective of avoiding dangerous climate change could be given further specificity by setting a more ambitious quantitative target for the stabilization of GHG concentrations in the atmosphere. In particular, he suggests a target of at most 550 ppm CO_2e, which would require cuts in emissions of at least 30 percent and perhaps 50 percent by 2050, with respect to 2000.

A second condition for a coordinated approach to be successfully implemented is that participants should view the agreement as equitable. This requirement needs to be assessed in the context of the incontrovertible fact that industrialized countries carry a larger historical responsibility for the accelerated increase in GHG concentrations, while developing countries are the most vulnerable to the adverse effects of climate change, and the least able to cope with the necessary adaptation. This asymmetry is the source of the principle of common but differentiated responsibilities established by the UNFCCC. The principle includes two elements: first the common responsibility of states for the protection of the global environment, and, second, the need to take into account the different circumstances, particularly each state's contribution to the evolution of the problem and its ability to prevent, reduce, or control the threat. From the perspective of global equity, industrialized countries would have not only to attain radical emission reductions within their own boundaries, but also to provide technological and financial resources that could enable developing countries to reduce the carbon intensity of their economies.

It is clear, however, that industrialized countries cannot stabilize the climate system exclusively through their own emission reductions. Developing countries are expected to surpass the high-income countries in the Organisation for Economic Co-operation and Development as the leading contributor to global CO_2 fossil fuel emissions by the beginning of the next decade (IPCC 2007).[25] Moreover, while under a business-as-usual scenario, per capita CO_2 emissions in developing countries are expected to continue to be about three times lower than in the developed world by 2030; between two-thirds and three-quarters of the increase in CO_2 emissions with respect to 2000 are expected to come from developing countries. In this context, in order to uphold the principle of common but differentiated responsibilities while at the same time fostering a smooth transition toward increasing responsibility by the developing world, a gradual incorporation approach could be applied.

In particular, some developing countries could gradually move over time, based on demonstrated capability, from having no mitigation commitments, to the adoption of climate-friendly policies, to limiting emission growth, and, finally, to some of them adopting emission reduction or at least emission intensity targets. In the meantime, developing countries could benefit from international financial flows to support the adoption of low-carbon technologies (see chapter 4). To that end, as discussed below, the current international climate framework could be allowed to incorporate mechanisms to support a wider set of emission reductions, including for instance those associated with reduced deforestation and those derived from the implementation of climate-friendly government policies and measures—as opposed to a focus on emission reductions from individual projects, as in the current version of the Clean Development Mechanism (CDM) of the Kyoto Protocol.

Third, for a cooperative approach to be effective, broad-based country participation is required, which, in turn, implies that the arrangement must be compatible with the underlying incentives of participants. This is probably the most challenging aspect of reaching a global deal on climate change. Incentives for countries to participate in a given agreement include the medium- and long-term benefits derived from efficiently mitigating the damages associated with climate change, as well as potential short-term co-benefits derived from participation in the agreement. The latter are particularly important, given the potential for free-riding on the former. Co-benefits may include access to financial support and technology transfer from other participating countries, as well as some by-products of countries' own mitigation measures, including enhanced environmental protection and energy security and increased levels of competitiveness associated with increasing energy efficiency and transitioning out of increasingly obsolete carbon intensive technologies.

A credible global agreement would also have to be flexible with respect to the different sets of domestic policy instruments that countries are likely to employ—for example, including carbon taxes, emission caps, technology programs, and regulations—and that should ideally be compared and benchmarked across countries in order to assess their contributions to global goals. As mentioned above, efficiency in climate change mitigation calls for a framework in which emitters from all over the world face the same price for carbon. This goal could be achieved even if the domestic policies that lead to the pricing of carbon take different forms in different countries—for example, explicit carbon taxes, emission caps and trade, or implicit carbon prices related to the cost of regulatory compliance—and if cross-country resource transfers are agreed upon in order to allow for an equitable distribution of the burden of climate mitigation. Finally, flexibility would also be required in terms of the need to accommodate evolving country circumstances in cases of noncompliance with previously agreed country targets, as opposed to employing harsh but noncredible punishment threats.

Minimizing trade-offs between climate change mitigation and development

Economic growth has historically been accompanied by increasing GHG emissions driven by growing fossil fuel energy consumption and the conversion of forest land into agriculture and other productive activities. While economic growth in developing countries must continue and, in fact, accelerate in order to eradicate poverty in the world, the risks associated with climate change introduce an additional development challenge, namely, that of increasingly decoupling growth from GHG emissions. To the extent that low-carbon technologies are relatively more expensive—for example, renewable sources of energy tend to cost more than their fossil fuel counterparts—there are clear trade-offs between pursuing higher rates of economic growth and contributing to climate change mitigation.

These trade-offs, however, can to some extent be alleviated by focusing, at least initially, on climate mitigation opportunities that involve sizable development co-benefits (chapter 6). In fact, in a number of cases the corresponding projects can be described as "no-regrets" opportunities, in the sense that they would be socially profitable based on their development co-benefits alone, without taking into account their impact on the reduction of GHG emissions. In Brazil, for example, tax incentives to increase employment in the production of small and inexpensive automobiles (fewer than 1,000 cubic centimeters), together with improvements in the management of electricity supply and demand aimed at energy savings, were responsible in 2000 for an 11 percent reduction in the country's energy-related CO_2 emissions (Szklo et al. 2005). Similarly, while the creation of 23 million hectares of public forest reserves in the Amazon between 2004 and 2006 was motivated mainly by sustainable development objectives, it greatly contributed to the 50 percent reduction in deforestation rates that was observed during that period (Nepstad et al. 2007). Incorporating climate change considerations when assessing the costs and benefits of alternative development patterns in such sectors as energy, industry, transportation, and agriculture can help take advantage of these type of opportunities, which involve relatively small trade-offs between development and climate change mitigation objectives. Candidates include all the technologies with negative marginal mitigation costs (figure 1.7).

Beyond "no-regret" cases, however, low-carbon technologies are not likely to become dominant in developing countries unless they are either (1) subsidized or made more competitive through (2) the reduction of subsidies for fossil fuels or (3) the establishment of explicit or implicit carbon prices (for example, through taxes, emission caps, or regulations). Due to equity considerations in global climate negotiations, alternative 3 is less likely to be implemented in a large-scale in the developing world, at least in the near term. In contrast, the second alternative is akin to a no-regret opportunity which should be seriously considered by most countries. Indeed, reducing the large subsidies that currently favor the consumption of fossil fuels in developing countries could produce considerable fiscal savings and have a positive impact on reducing local pollution and congestion problems while at the same time encouraging the deployment of low-carbon energy sources. As for the

first alternative, it could be implemented without creating an additional burden on developing economies through the sale of emission reduction credits in the context of the CDM. In this respect, an expanded CDM could play an important role in ensuring that global mitigation efforts are both efficient and equitable.

Expanding the Clean Development Mechanism

As discussed in chapter 4, there are a number of concerns with the current functioning of the CDM, which focuses on project-level emission reductions, relative to baseline scenarios. First, as argued by Figueres, Haites, and Hoyt (2005), the CDM's single project approach makes it unlikely to "catalyze the profound and lasting changes that are necessary in the overall GHG intensities of developing countries' economies." A more effective approach would entail transforming the baselines themselves so as to make development pathways more carbon friendly (Heller and Shukla 2003). In this context, rather than focusing on actions at the project level, mitigation efforts in developing countries would have to shift toward promoting reforms across entire sectors—for example, energy, transport, agriculture, and forestry. Some initial steps in this direction were taken in the agreement in December 2005 in Montreal to include "programs of activities" in the CDM. But this approach could be explored further.

As noted, the LCR is particularly intensive in emissions from deforestation and forest degradation. Reductions in these emissions were not included in the first commitment period of the Kyoto Protocol due in part to concerns over technical issues, including baseline setting and monitoring—that is, to ensure the additionality and permanence of emission reductions—and with respect to leakages—that is, the risk that avoided deforestation in some places could be compensated by increases in others (Schlamadinger et al. (2007). There were also concerns with a possible trade-off between the use of this potentially low-cost mitigation option and the implementation of domestic emission reductions in industrialized countries (Sawyer et al. 2008). More recent international negotiations, however, have moved toward recognizing decreases in deforestation from a pre-established baseline as generating credits and or compensations in a post-2012 regime. In particular, the Bali Action Plan adopted in December 2007 by the parties of the Kyoto Protocol explicitly calls for addressing "policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries." Several types of proposals have emerged in this regard during recent years, and it is critically important for the LCR that a workable plan be adopted for fully incorporating REDD in the CDM.

On the one hand, Costa Rica and Papua New Guinea have proposed to incorporate REDD into the climate change architecture, thus allowing for the possibility of issuing credits to projects or programs that reduce deforestation with respect to some established baseline. Brazil, on the other hand, has proposed establishing a specific "nonmarket" fund dedicated to REDD. This "Tropical Forest Fund" would potentially receive contributions from industrialized countries but the contributions would not count toward the mitigation commitments of those countries. The fund would award financial incentives for reductions in deforestation rates below established baselines. There would be no penalties for not meeting the corresponding targets, although failing to do so could count against future reductions below the baseline (Sawyer et al. 2008). Other proposals have combined aspects of both market-oriented and fund-based alternatives, while also establishing financial incentives per avoided ton of CO_2. As noted by Strassburg et al. (2008), however, in order for those financial incentives to be effective in addressing the local drivers of deforestation, and because of sovereignty issues, the intranational distribution of the resources to be allocated to reducing deforestation may need to be decided at the country level and is unlikely to be included in international REDD mechanisms.

Adapting to Climate Change

Just as they have adapted to past climatic shifts, humans and ecosystems will autonomously respond to the forthcoming changes in ways that will mitigate the negative effects and enhance the positive, to the extent they are able to do so. In contrast to measures to reduce emissions of GHGs, for most actions to

adapt to climate change the individual taking the action incurs the bulk of the costs and receives the bulk of the benefits. That is, these measures generate few externalities. For this reason, adaptation is much less vulnerable than is mitigation to collective action problems that would cause a suboptimal response. This does not mean that public policy is not needed in this area, but rather implies that the kinds of necessary policies, institutions, and investments will have much in common with those that are needed to provide the kinds of "public goods" that government should normally provide. Good adaptation policy is in general good development policy.

The timing of adaptation policy and investments is important. While some harbingers of major climate change are already having an impact, the bulk of the change will occur over long time horizons—decades and centuries. Climate change may manifest itself as changes in long-term trends in average temperatures and precipitation, increased variability in these and/or more extreme events. There is much uncertainty regarding exactly how climate in particular locations will change, and therefore what kind of adaptation will be needed. There is more agreement among models regarding the degree of warming than regarding the changes in precipitation patterns, but the latter are at least as important in planning for adaptation. Here, Latin America and the Caribbean stands out, along with Africa, as the region with the greatest uncertainties, as measured by consistency of predictions by different models. The long planning horizons and uncertainty may lead one to question whether policy makers in developing countries should consider undertaking adaptation policy at all in the short term given their other development priorities.

This intuition is correct to a point. Undertaking major investments or policy responses in anticipation of specific climatic impacts runs a high risk of wasting resources or even increasing adverse impacts if the changes do not materialize as expected, or if future technological advances allow a more cost-effective response. Weighed against that is the risk that failure to take timely actions may incur preventable damages, and some investments and policies may take a long time to bear fruit. As noted above, however, this kind of trade-off is not so stark, since many—if not most—of the things that governments can do to help their citizens adapt to climate change are first and foremost good development policy. For these kinds of actions, the specter of climate change may not be the most important motivation, but may nonetheless change the political calculus. Yet, there are clearly some areas in which urgent action is warranted to prevent irreversible damages, especially to ecosystems that are currently under climate-related stress. As argued in chapter 3, what is needed is a kind of triage or prioritization of actions to identify what has to be done in the short term and what should be postponed.

Outline of the Report

Chapter 2 of this report will explore the nature of the physical impacts that climate change is likely to have in the LCR and quantify some of the economic effects. Both human and natural systems will need to adapt to the new climatic conditions. Chapter 3 will consider the evidence regarding how this is likely to occur autonomously in the LCR, and how international policies and institutions, as well as those in the LCR countries, can facilitate this process so as to reduce the pain and optimize any possible gains. We will then revisit the challenges associated with mitigating global climate change, focusing on the kinds of domestic and international government policies that could help achieve that goal (chapter 4). The report will then review the pattern of Latin America's GHG emissions and discuss the underlying economic factors that have produced this pattern (chapter 5). Finally, we will attempt to identify concrete options that LCR countries have to reduce emissions in the most cost-effective ways, while in a number of cases enjoying various ancillary benefits from doing so (chapter 6).

Notes

1. Nagy et al. (2006).
2. Mata and Nobre (2006).
3. Nagy et al. (2006).
4. Magrín et al. (2007).
5. Raddatz (2008).
6. In the terminology of the IPCC, a high level of confidence in a given statement amounts to a belief, based on expert judgment of the underlying evidence (data, models, or analyses)

that the chance of the corresponding finding being correct is at least 8 out of 10.

7. Parry et al. (2007).

8. Magrín et al. (2007).

9. Francou et al. (2005).

10. Bradley et al. (2006) and Ramírez et al. (2001).

11. In 2004, CO_2 emissions from fossil fuel use represented 56.6 percent of total GHG emissions, while CO_2 emissions from land-use change were 17.3 percent. Agriculture was responsible for 13.5 percent of total GHG emissions, accounting for almost 90 percent of N_2O emissions (which, in turn, were 8 percent of total GHG emissions) and for more than 40 percent of CH_4 emissions (which were 14 percent of total GHG emissions). Other sources of CH_4 include emissions from landfill waste, wastewater, and the production and use of bio energy. IPCC (2007).

12. Hereafter this is referred to as CO_2 equivalent or CO_2e.

13. See Raupach et al. (2007). The figure depicts observed global CO_2 emissions including all terms in Equation (1), from both the EIA (1980-2004) and global Carbon Dioxide Information Analysis Center (CDIAC) (1751–2005) data, compared with emissions scenarios (8) and stabilization trajectories (10, 11, 12). See Marland et al. (2007). EIA emissions data are normalized to same mean as CDIAC data for 1990–1999, to account for omission of F_{Cement} in EIA data. The 2004 and 2005 points in the CDIAC dataset are provisional. The six IPCC scenarios (8) are spline fits to projections (initialized with observations for 1990) of possible future emissions for four scenario families, A1, A2, B1, and B2, which emphasize globalized versus regionalized development on the A, B axis and economic growth versus environmental stewardship on the 1, 2 axis. Three variants of the A1 (globalized, economically oriented) scenario lead to different emissions trajectories: A1FI (intensive dependence on fossil fuels), A1T (alternative technologies largely replace fossil fuels), and A1B (balanced energy supply between fossil fuels and alternatives). The curves shown for scenarios are averages over available individual scenarios in each of the six scenario families, and differ slightly from "marker" scenarios. The stabilization trajectories are spline fits approximating the average from two models (11, 12), which give similar results. They include uncertainty because the emissions pathway to a given stabilization target is not unique.

14. Dilley et al. (2005).

15. As argued by Dilley et al. (2005), improvements in the management of disaster risks may require a wide range of policy and institutional reforms, capacity building activities, and advance planning for postdisaster emergency financing.

16. Vergara (2005) and Magrín et al. (2007).

17. See Stern (2007) or Philibert (2006) for a more detailed computation of the deadweight losses associated with choosing the wrong tax versus the wrong cap. Given new information on marginal mitigation costs, larger losses would occur when using a cap and trade scheme in the left panel and from a carbon tax in the right panel. Note also that if abatement costs are known with certainty, uncertainty over marginal mitigation benefits does not matter in the *choice* of policy instruments—it would only affect the *level* of taxes or quotas—unless of course that uncertainty also affects the slope of the marginal benefit curve. See Philibert (2006).

18. As argued by Aldy et al. (2008), however, once international agreements on carbon taxes are reached, an adequate monitoring system would have to be estabished so as to make sure that countries do not adopt compensating fiscal measures—for example, additional energy subsidies—to cushion or reduce the burden of the carbon tax.

19. This section relies heavily on Stern (2007).

20. This is based on the best estimate (the mode) reported by the IPCC for the aforementioned climate sensitivity parameter. However, if the more pessimistic estimates for this parameter are used instead, the temperature increases for a stabilization target of 445 ppm to 535 ppm CO_2e could be as high as 4.2°C.

21. The increase could be of up to 4.9°C; high estimates for the climate sensitivity parameter are used instead of the mode.

22. It is worth noting, however, that these estimates rely on the allocation of electricity savings to the corresponding end-use sectors. If instead the corresponding emissions reductions were to be allocated to the energy supply sector, its share in the total mitigation potential would increase to about 35 percent and that of energy efficiency in buildings would fall to about 12 percent. Moreover, the mitigation potential of the transportation sector is underestimated as freight transport and public transport are excluded from the analysis.

23. The framework can be summarized using the Ramsey formula: $STP = \beta + \varepsilon * \sigma$ where β is the pure time discount rate, σ is the expected rate of long run growth in per capita output, and ε is the elasticity of marginal utility of consumption. Stern assumes that β is 0.1, on the basis of the philosophical principle that all generations should be treated equally, that σ is 1.3, and ε is equal to 1, which implies an STP of 1.4. As argued by Nordhaus and Weitzman the pure time discount rate (β) is generally believed to be between 1.5 and 2; growth (σ) could be safely assumed to be 2 percent per year based on past experience; and the elasticity of marginal utility of consumption (ε) is usually thought to be close to 2.

24. See Vardy (2008) for details.

25. It must be noted, however, that the historical accumulated emissions of developing countries will continue to be below those of the industrialized countries until the end of the century (Figueres 2007).

CHAPTER 2

Climate Change Impacts in Latin America and the Caribbean

How Is the Climate in the LCR Changing?

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change—released in September 2007—states that "warming of the climate system is unequivocal." The IPCC expresses a "high level of confidence" that various human activities (for example, agriculture and health) and natural systems (for example, plants and animal species, marine ecosystems, and hydrological systems) have already been affected by global warming.[1]

Latin America has not been exempt from the global trend.[2] In particular, increases in mean temperatures of approximately 0.1°C per decade have occurred in South America during the twentieth century, with higher rates of warming in the Andean region, consistent with predictions of models of climate change. Precipitation has increased in some areas—northeast Argentina, southern Brazil, Paraguay, northwest Peru, and Uruguay—and decreased in others—southwest Argentina, southern Chile, and southern Peru. The rate of of rising sea levels has also increased, reaching 2 to 3 millimeters per year during the past two decades in southeastern South America. The evidence collected by the IPCC suggests that these climatic changes are already affecting the frequency of extreme weather events. Prominent examples include more frequent heavy rains over northeast Brazil and central Mexico, an increase in flood frequency in some parts of the Amazon, and a 50 percent rise in streamflow in the Parana, Paraguay, and Uruguay Rivers. Recent years have also seen increased hurricane activity in the Caribbean region.

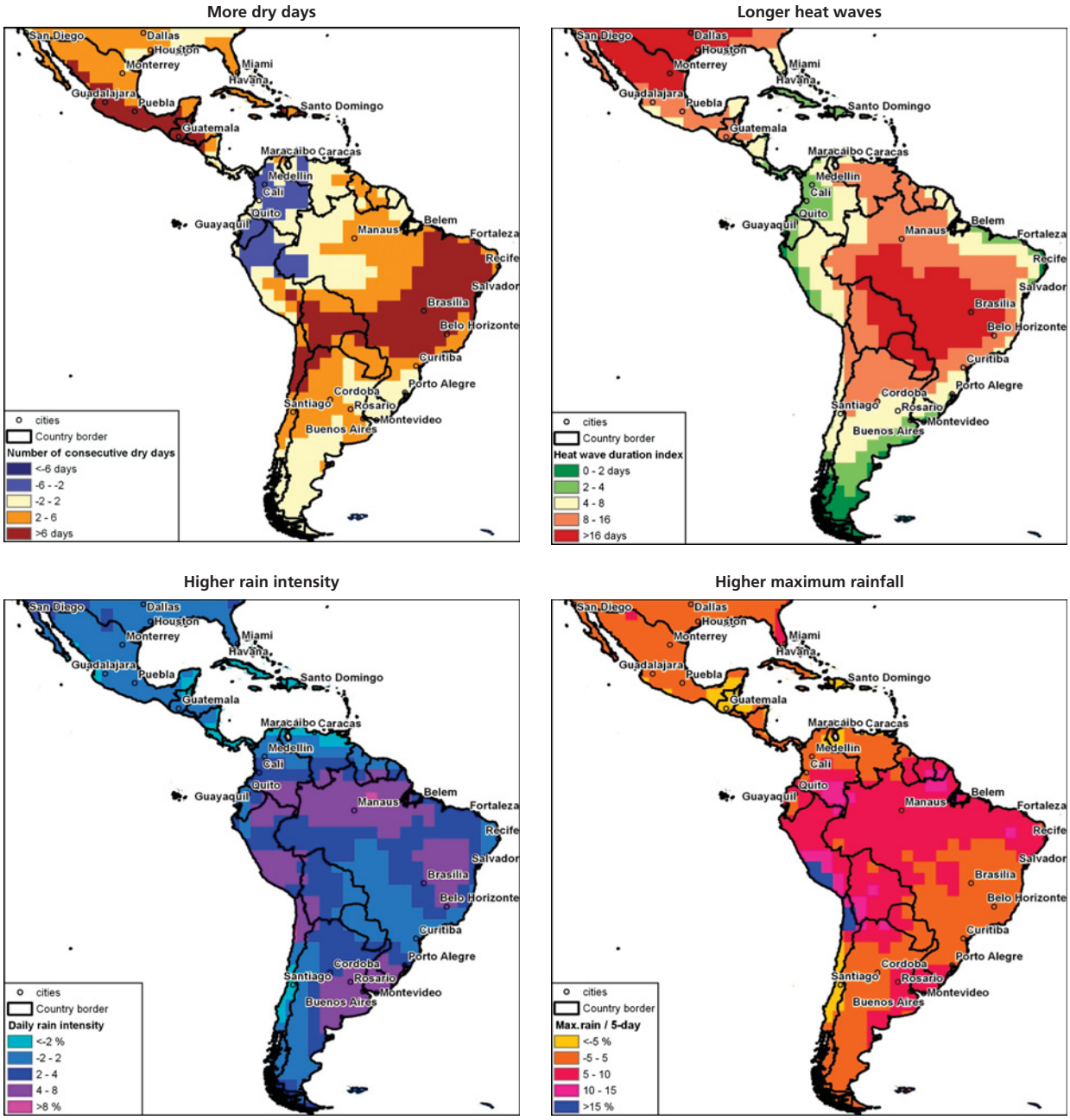
As the warming accelerates in the years ahead, much more widespread and serious consequences are forecast for the LCR. Recent UNFCCC studies and future climate change scenarios derived from global climate models predict that warming in most areas of LCR will be greater than the global mean, the exception being the southern part of South America (Christensen et al. 2007).[3] The IPCC's Fourth Assessment Report predicts that under business-as-usual scenarios temperature increases in the LCR with respect to 1961–90 could range from 0.4°C to 1.8°C by 2020 and from 1°C to 4°C by 2050 (Magrín et al. 2007). More recent data indicate that the current rate of emissions is faster than that in the most extreme scenario considered in Magrín et al. (2007), implying that the anticipated warming may exceed current forecasts. Work undertaken using the Earth Simulator in Japan generally confirms these projections and indicate a likelihood of fast warming in the Andes cordillera.[4]

These projections also point to changing precipitation patterns across the region, with increased rainfall in Tierra del Fuego and southeastern South America and drier conditions in Central America and the southern Andes (map 2.1). Despite considerable uncertainty about rainfall patterns in particular countries, there are indications that climate change may lead to more frequent extreme events, with some areas receiving less precipitation, and, as such, arid and semi-arid areas may be more vulnerable (UNFCCC 2006a).

An accurate mapping of both current and future hazards is important for informing disaster prevention

MAP 2.1

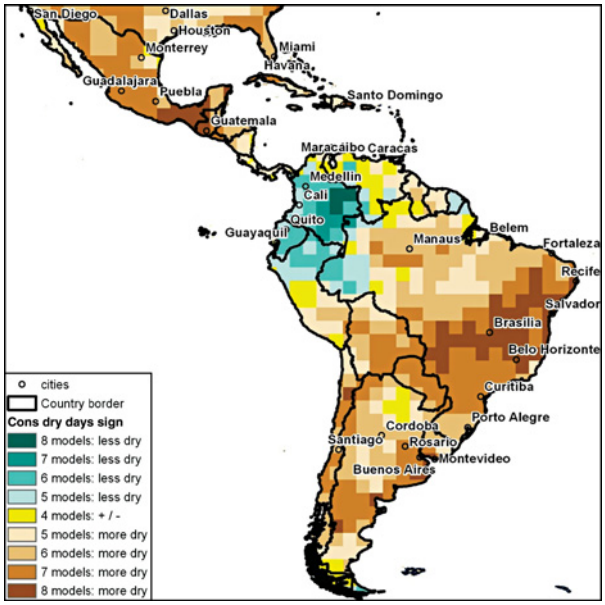
Expected Changes in Latin America and the Caribbean Region Climate Risks from 1981–2000 to 2031–50 Based on Eight Global Circulation Models (p. 30) and Levels of Model Concordance (p. 31)



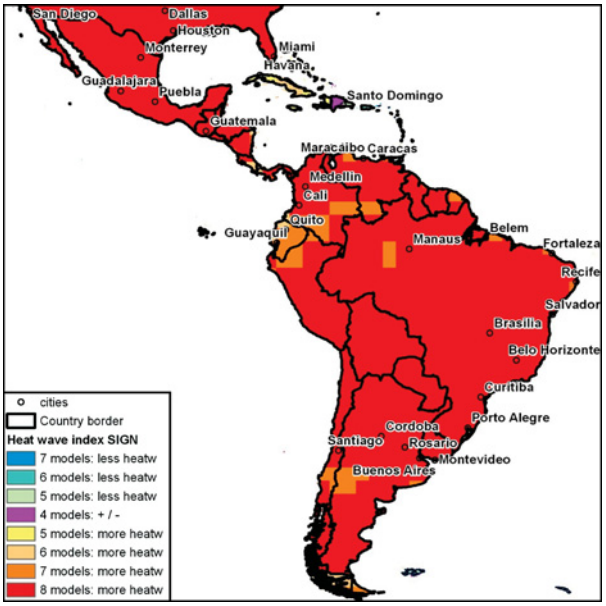
(Map continues on next page.)

MAP 2.1
(continued)

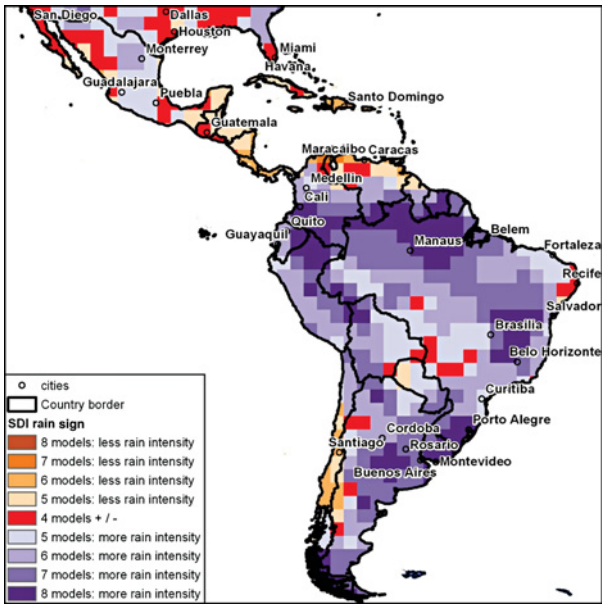
Dry days: concordance



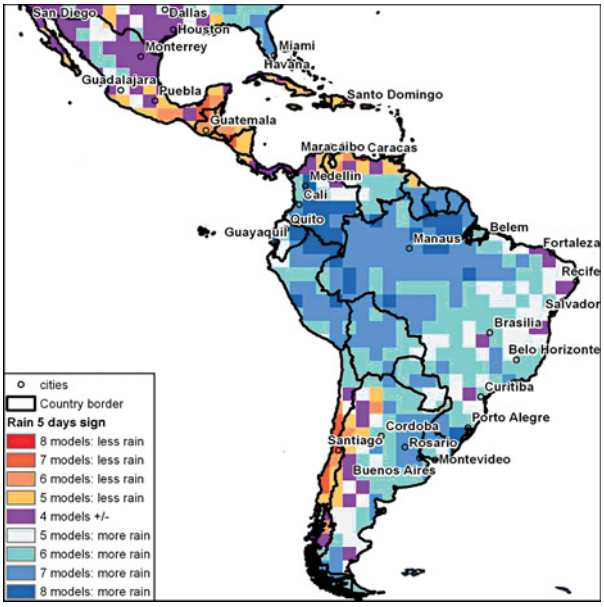
Heat waves: concordance



Rain intensity: concordance



Maximum rainfall: concordance



Source: World Bank staff calculations using eight global circulation models (see table 2.1).
Note: SDI = Simple daily intensity.

and preparedness. As shown in table 2.1, under current climate conditions, some regions of Central America, the Andean countries, Brazil, and Mexico are at highest risk for being hit by droughts. Similarly, large areas with high risk of floods can be found in the Andean countries, Argentina, Brazil, the Caribbean, Central America, Paraguay, and Uruguay. Indeed, as illustrated in the top four panels of map 2.1, it appears that a number of areas with a current high exposure risk for droughts or floods would, in the future, have to deal with even drier conditions and more intense rainfall, respectively. In particular, this would be the case for all of the high-risk drought areas of Chile, El Salvador, Guatemala, and Mexico, for which the predictions of at least five out of eight global climate models indicate that by 2030 the number of consecutive dry days will increase and heat waves will become longer. Similarly, between 47 and 100 percent of the high-risk flood areas of Argentina, Peru, and Uruguay are expected to become even more exposed to intense rainfall. The bottom panels of map 2.1 indicate that there is considerable disagreement with respect to specific regional projections derived from various global climate models. However, for most of the previous examples, the level of model concordance is relatively high.

Damage from tropical storms is a major economic risk for many countries in the Caribbean Basin. Table 2.2 indicates the cumulative economic cost and loss of life for countries in this region from 1979 to 2006. The estimated costs of hurricane impacts in the region are estimated to have increased by two orders of magnitude since the 1970s, although this is partially a result of increased development, rather than changes in weather patterns. The year 2005 saw the number of hurricanes in the North Atlantic hit 14, a historic high. And in 2004, for the first time ever, a hurricane formed in the South Atlantic and hit Brazil. Of particular significance is the recent increase in Mesoamerican landfalls since 1995 after an extended quiet regime of nearly 40 years. Four of the 10 most active years for hurricane landfalls have occurred in the past 10 years. In 2008 Cuba, Haiti, and other islands were particularly affected by multiple hurricanes. This raises the question of whether we are already seeing the impacts of climate change and if the damages will be greater than expected (e.g., due to a possible increase in frequency). In fact, following hurricane Katrina, U.S. risk-modeling companies raised their estimation of the probability of a similar event from once every 40 years to once every 20 years as a result of the warming of water temperatures in the North Atlantic Basin. Similarly, historical data are very suggestive of a trend toward intensification in the strength of hurricanes with landfalls in the North Atlantic, including the Caribbean Basin.

Correlation between the frequency of tropical cyclones and sea surface temperatures can be seen in figure 2.1. The evidence seems to imply that these storms are likely to become more common as the Earth heats up. A recent study (Curry et al. 2009) estimates that each increase in sea surface temperatures of 1 degree Fahrenheit (0.6 degree Celsius) could increase the frequency of tropical storm activity in the North Atlantic by up to five storms per year. However, there is still not a scientific consensus on this, partially because of the difficulties in isolating the effects of temperature from those of other natural cycles. On the other hand, there is greater consensus that global warming is likely to cause their intensification. Certainly, recent reviews of major hurricane activity over time (Hoyos et al. 2006; Curry et al. 2009) point to trends in the intensification of hurricanes in the Caribbean Basin. In fact, Curry et al. (2009) indicate that it is likely that this is indeed attributable to increasing sea surface temperatures caused by anthropogenic global warming. They find that for each 1 degree Fahrenheit (0.6 degree Celsius) warming of the sea, hurricane intensity increases by somewhere between 2 and 5 percent. This corresponds to an increase in the range of 10 to 26 percent in damages. Even with no increase in frequency, this intensification could have major implications for regional ecosystems and human activities.

Taking all kinds of climate-related disasters (including droughts, extreme temperatures, windstorms, and floods) together, there appears to be a positive trend over the past few decades, although less marked in the LCR than in the rest of the world (figure 2.2). Raddatz (2008) likewise confirms statistically that the incidence of climatic disasters has increased worldwide

TABLE 2.1

Fraction of National Territory of Latin America and the Caribbean Region Countries with Current High Risks of Drought, Floods, or High Expected Increase (by 2030) in Dry Days, Heat Waves, or Rainfall Intensity

	High probability of droughts (current climate)	Increase in maximum consecutive dry days (CCR): at least 2 more days (2030)	Increase in heatwave duration (HWD): at least 8 more days (2030)	Area with high current drought risk and high CCR or high HWD in 2030 (%)	High probability of floods (current climate)	Increase in simple daily rainfall intensity index (SDI): at least 4% (2030)	Increase in maximum amount of rainfall in 5-day period (R5D): at least 10% (2030)	Area with high current flood risk and high SDI or high R5D in 2030 (%)
Argentina	12	52	38	77	25	28	2	47
Belice		100	87		14	0	0	0
Bolivia	1	93	100	100	30	16	16	28
Brasil	27	71	79	100	13	39	3	22
Chile	62	59	26	100	9	25	19	0
Colombia	8	2	4	56	75	26	19	21
Costa Rica	20	0	0	0	63	0	0	0
Cuba	0	100	0		79	0	0	0
Ecuador	65	0	0	0	85	12	0	14
El Salvador	100	100	17	100	99	0	0	0
Guatemala	100	100	96	100	73	0	0	0
Guyana	0	76	96		0	0	0	
Guyane		6	6		0	6	49	
Haiti	0	100	0		94	0	0	0
Honduras	0	97	56		100	0	0	0
Jamaica	0	100	0		100	0	0	0
Mexico	43	97	87	100	33	0	0	0
Nicaragua	17	66	0	73	81	0	0	0
Panama	0	0	0		30	0	0	0
Paraguay	23	100	100	100	63	0	1	2
Peru	4	21	10	0	82	62	36	68
Puerto Rico		100	0		66	0	0	0
Republica Dominicana	0	98	0		89	0	0	0
Suriname	0	69	80		0	48	17	
Trinidad Y Tobago		0	0		97	0	0	0
Uruguay	0	0	0		68	100	0	100
Venezuela	19	10	81	100	26	9	0	0

Source: World Bank staff calculations using the following models: cnrm: cnrm-cm3, Meteo France; gfdl: gfdl-cm2.0, Geophysical Fluid Dynamics Lab/NOAA; inmc: inm-cm3.0, Inst. Numerical Math, Russia; ipsl: ipsl-cm4, Inst Pierre Simon Laplace, France; mirh: miroc3.2(hires), University of Tokyo, JAMSTEC, Japan; mirm: miroc3.2(medres), University of Tokyo, JAMSTEC, Japan; mri: mri-cgcm2.3.2, Meteorological Research Institute, Japan; ccsm: ccsm3, National Center for Atmospheric Research USA.
Note: CCR, HWD, SDI, R5D report % of territory where climate events are predicted by 5 or more Global Circulation Models.

TABLE 2.2

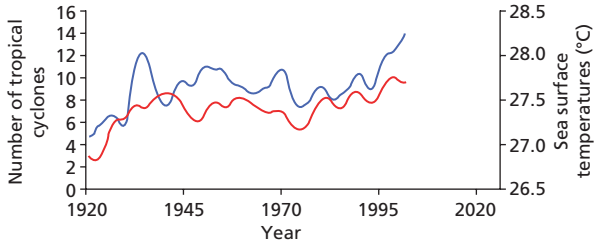
Cumulative Losses for Each Country, 1979–2006

Country	Total cyclones	Damage (2007 US$M)	Avg. damage % of GDP	Total lives lost	Avg. lives lost per 100,000 pop.
Mexico					
Gulf Coast	16	47,315	5.29	380	2.39
Central America					
Belize	3	469	11.71	69	9.81
Costa Rica	4	168	0.37	42	0.33
El Salvador	2	370	2.00	253	2.21
Guatemala	1	1,159	3.86	68	0.60
Honduras	3	5,196	32.69	7,042	39.84
Nicaragua	6	5,176	25.29	3,957	16.22
Greater Antilles					
Cuba	14	8,042	2.35	38	0.03
Dominican Republic	7	9,439	5.30	2,418	5.58
Haiti	7	2,495	22.87	4,721	8.46
Jamaica	7	4,675	12.17	72	0.45
Puerto Rico	12	11,365	0.94	48	0.14
Lesser Antilles					
Antigua and Barbuda	6	1,753	55.53	4	2.88
Barbados	5	11	0.09	1	0.35
British Virgin Islands	6	607	179.34	6	37.55
Dominica	3	71	21.46	1	1.45
Grenada	4	1,040	105.37	40	12.39
St. Kitts and Nevis	3	1,436	110.05	6	7.19
St. Lucia	5	14	0.52	22	5.81
St. Vincent and Grenadines	4	64	6.96	5	1.43
Bahamas	11	2,648	7.60	6	0.42

Source: Curry et al. (2009).
Note: Estimated normalized damage is given in millions of 2007-equivalent U.S. dollars. The lives lost in the storms are expressed by 100,000 individuals.

FIGURE 2.1

Time Series of North Atlantic Tropical Cyclones (blue) and Sea Surface Temperature (red)



Source: Adapted from Curry et al. (2009).

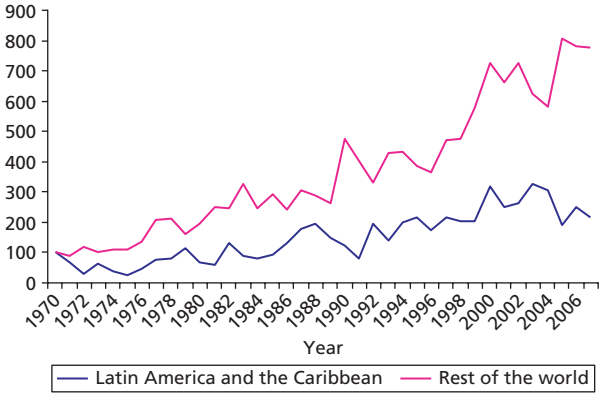
over the past four decades. Disaggregating by type of disaster and by subregion, it appears that windstorms disproportionately affect the Caribbean, Central America, Chile, and Mexico; floods hit Andean countries, Central America, and the Southern Cone; while droughts hit some Andean countries, Central America, and Brazil.

What Are the Consequences of Climate Change for Economies and Ecosystems in the LCR?

The changes in temperature and precipitation patterns that are currently projected for the LCR would have diverse impacts on natural systems and human activities. But the economic sector likely to suffer the most direct and largest impact is agriculture, and the impact on this sector dominates the overall picture of quantifiable economic effects in all current models. Studies that have quantified sector-by-sector damages for the LCR estimate agricultural losses ranging from US$35.1 billion per year (out of US$49 billion total, 0.23 percent of GDP),[5] to US$120 billion per year

FIGURE 2.2

Climate-Related Disasters in Latin America and the Caribbean Region versus the Rest of the World Index (1970 = 100)



Source: World Bank staff calculations (based on EM-DAT: The OFDA/CRED International Disaster Database, Catholic University of Louvain).
Note: Countries represented: Anguilla; Antigua and Barbuda; Argentina; The Bahamas; Barbados; Belize; Bolivia; Brazil; Cayman Islands; Chile; Colombia; Costa Rica; Cuba; Dominica; the Dominican Republic; Ecuador; El Salvador; French Guiana; Grenada; Guadeloupe; Guatemala; Guyana; Haiti; Honduras; Jamaica; Martinique; Mexico; Montserrat; Netherlands Antilles; Nicaragua; Panama; Paraguay; Peru; Puerto Rico; St. Kitts and Nevis; St. Lucia; St. Vincent and the Grenadines; Suriname; Trinidad and Tobago; Turks and Caicos; Uruguay; República Bolivariana de Venezuela, Virgin Islands. The disasters charted meet at least one of the following criteria: (1) 10 or more people reported dead, (2) 100 people reported affected, (3) declaration of a state of emergency, (4) call for international assistance.

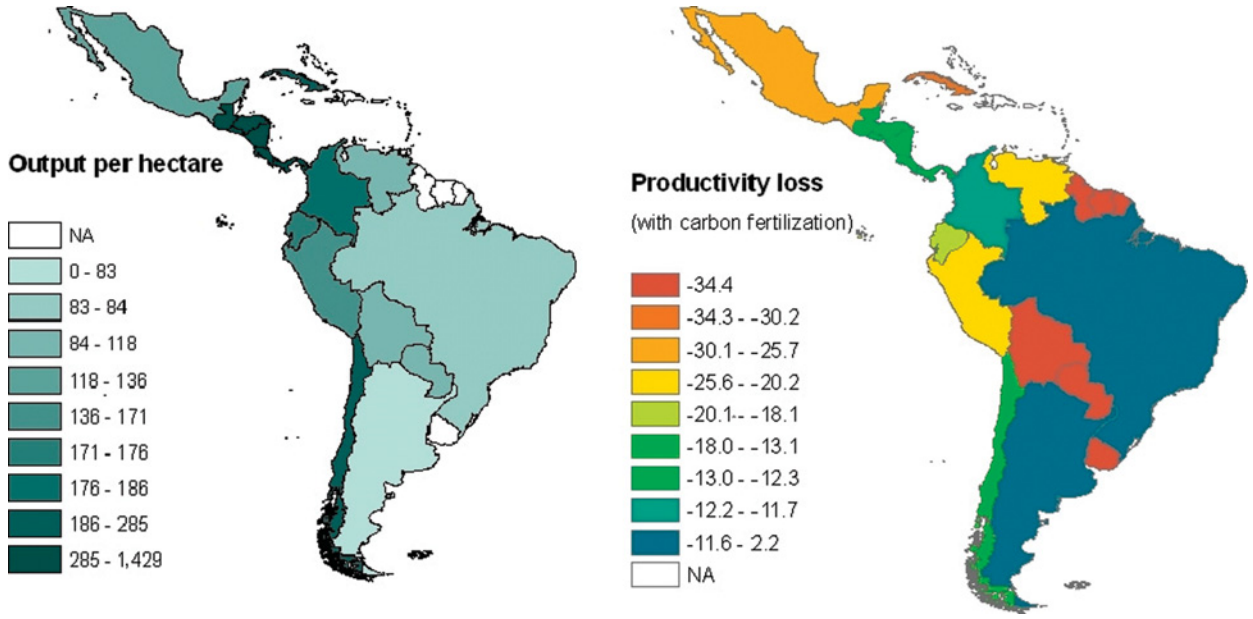
(out of US$122 billion total, 0.56 percent of GDP)[6] by 2100. A recent study based on a global general equilibrium model with endogenously determined emissions levels projects total losses in the LCR of about $111 billion (1 percent of GDP) by 2050 if warming reaches about 1.79°C relative to 1900. Except for studies by Toba (2008). on Caribbean regions, discussed later, none of these studies include damages to noneconomic sectors, for example, to ecosystems, nor do they take into account the effects of natural disasters or the possibility of catastrophic events, such the collapse of major ice sheets or melting permafrost. But because the loss estimates are based on observations of how farmers behave in different climates, they do implicitly take into account private adaptive responses.

Cline (2007) applied a consistent methodology to recalculate the data in a crop model-based study of the effects of climate change on world food supply by Rosenzweig and Iglesias (2006). His results project that yields in the LCR (averaged across the four different climate models) will decline 19 percent for higher income "calorie exporting" countries, 13.5 percent in higher income "calorie importing" countries, and 17 percent in middle- and low-income countries. Cline also reports his own estimates, based mostly on existing studies adjusted to make them more realistic in his view, for example, by allowing for the yield-augmenting effects of carbon fertilization. Even under this optimistic carbon-fertilizer scenario, yields are projected to increase in only two countries: Argentina (by 2 percent) and Brazil (by 7 percent, but with considerable regional variation). In all other countries yields are projected to decline: by 12–13 percent in Central America, Chile, and Colombia; 18–25 percent in Ecuador, Mexico, and Peru; 30 percent in Cuba; and 34 percent elsewhere in South America. This compares to a median global decline of 4 percent (see map 2.2).

Applying a Ricardian methodology to a sample of farm households in seven South American countries, average potential revenue losses from climate change in 2100 were estimated to range from 12 percent for a mild climate change scenario to 50 percent in a more severe scenario, even after farmers undertake adaptive reactions to minimize the damage (Seo and Mendelsohn 2008). In a country feeling sever impacts, like Mexico, the forecast fall in value of the land (as a measure of the decline in productivity) is larger than the actual value of the land itself for 30–85 percent of all farms, depending on the model and the severity of warming (Mendelsohn et al. 2008). Yet it is worth noting that across countries and even within the same country, the impacts are likely to vary substantially from one region to the next. Even in hard-hit Mexico, some regions are forecast to benefit. Across the continent of South America, losses are generally forecast to be higher nearer the equator, with some areas on the Pacific and in the south of the continent showing possible gains. These studies also find that small farms do not feel more severe impacts than large, perhaps because the larger farms tend to be more specialized in temperate (heat-intolerant) crops and livestock, and therefore less adaptable.

MAP 2.2

Current Agricultural Productivity and Expected Changes by 2080

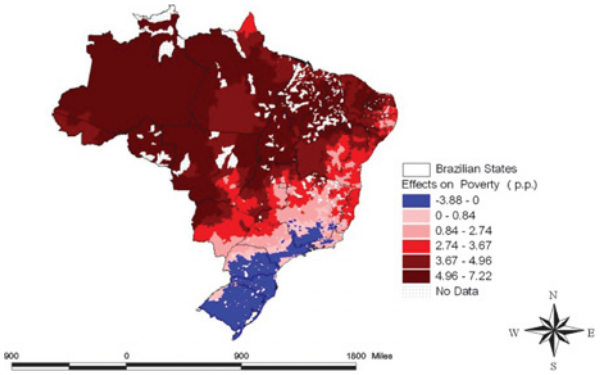


Source: Constructed on the basis of estimates by Cline (2007).
Note: Cline (2007) estimates one value for Central American countries and one value for "Other South American countries." We applied the value of Central American countries to Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, and the value of "Other South American countries" to Bolivia, French Guiana, Guyana, Paraguay, Suriname, and Uruguay.

What would be the impact of these kinds of changes in productivity on rural poverty? Answering this question requires both good household data and good modeling of the way in which households would respond. One recent study of this issue in Brazil (Assuncao and Feres 2008) concludes that there would be big differences in impact, depending on the degree of households' economic mobility. If labor mobility is constrained, overall rural poverty would increase by 3.2 percentage points. If households are allowed to migrate, the impact falls to 2 percentage points. In either case, the effect of climate change is highly region-specific, depending on the regional changes in the climate per se, as well as the variation in productivity responses and off-farm economic opportunities (figure 2.3).

FIGURE 2.3

Effects of Climate Change on Poverty, Brazilian Municipalities



Source: Assunçao and Feres (2008).

The full economic and social costs of climate change go beyond the kinds of costs included in these estimates. One type of incremental cost is the damage potentially caused by increasing frequency or intensity of extreme events (climatic disasters) that may result from global warming. Certainly, extreme weather events already take a high toll in the region. In 1999, for example, 45,000 people were killed in floods and mudslides in República Bolivariana de Venezuela, while 10,000 people lost their lives due to the devastating impact of hurricane Mitch in 1998 (UNFCCC 2007b).

A series of four storms and hurricanes—Fay, Gustav, Hanna, and Ike—swept across parts of Haiti during August–September 2008, and hit other islands as well, with devastating impact. Already the poorest place in the Western Hemisphere, Haiti, has become even more destitute. These events also displace large populations, as demonstrated by the large numbers of "environmental refugees" in Central America from Hurricane Mitch (Glantz and Jamieson 2000). There is, as we noted, some uncertainty as to whether warming will make these kinds of disasters more frequent—though recent trends seem to indicate it will—but it is likely to at least make them more intense.

Worldwide, Raddatz (2008) quantifies the impacts from different types of disasters, finding that climatic disasters reduce per capita GDP by 0.6 percent on average. Droughts and extreme temperatures show the only significant effects in his analysis[7] (and the latter based on a small sample), suggesting again that agriculture is a major channel through which the effects are transmitted to the economy at large. He concludes that if the trend continues, the increased incidence of disasters found in the data over the past four decades could reduce per capita GDP by 2 percent over a decade. This would represent a permanent drop in the level (not the growth rate) of GDP.

LCR-specific research quantifying the economic impacts of increasing frequency and virulence of climatic disasters is relatively scarce. One of the few forecasts of this kind indicates that if climate change goes unabated, climate-related disasters could cost the LCR US$300 billion per year in the next decades (CEPAL 2002; Swiss Re 2002). In another more recent study, Curry et al. (2009), estimate the economic losses from tropical storms in the Caribbean Basin for four scenarios. These range from a "low" scenario (A1) corresponding to no increase in frequency and a 2 percent increase in intensity of storms to a "high" scenario (B2) with an increase in frequency of 35 percent and an increase in intensity of 5 percent. The cumulative damages for the five-year period of 2020–25 are shown in table 2.3. Losses to the Gulf Coast of Mexico, for example, range from US$80 billion to US$103 billion in 2007. The column MCE indicates the damages of the "maximum covered event," a measure of the greatest damage expected from a single storm. Toba (2008) estimated that annual GDP loss of Caribbean Community countries due to climate change–related disasters would be US$5 billion circa 2080 in 2007 prices in more conservative estimates (see table 2.8).

Ecosystem impacts

The effects of significant warming and consequent climatic changes would, however, extend far beyond agriculture and far beyond the macroeconomic impacts. Some of the LCR's most unique features and subregions are threatened by climate change, including Andean glaciers, other high mountain habitats, the coral reef biome in the Caribbean, the Amazon, and regions that are particularly vulnerable to extreme climatic events, such as the El Niño Southern Oscillation phenomenon (UNFCCC 2007a; Vergara 2005). Some of the major regional vulnerabilities are summarized by the IPCC (Magrín et al. 2007) in map 2.3.

Based on their irreversibility, their importance to the ecosystem, and their economic cost, four impacts related to ecosystems stand out as being of special concern (see table 2.4). These are (a) the warming and eventual disabling of mountain ecosystems in the Andes; (b) the bleaching of coral reefs leading to an anticipated total collapse of the coral biome in the Caribbean Basin; (c) the subsidence of vast stretches of wetlands and associated coastal systems in the Gulf of Mexico; and (d) the risk of forest dieback in the Amazon Basin. The first three of these are ongoing processes, whereas the fourth is a future threat.

Andean glacier retreat

Global circulation models project that the Andes will experience much greater temperature increases than neighboring lowlands and a rate of warming at least two times greater than the average. The most immediate impacts of this warming will be on tropical glaciers and high mountain ecosystems. Field observations and historical records already document rapid glacier retreat in the Andes (Francou et al. 2005). One striking illustration of this trend is the photographic record of the Chacaltaya Glacier in Bolivia, shown in figure 2.4. Projections suggest that many of the glaciers at lower

TABLE 2.3

Projected Damage for Five-Year Period Circa 2020–25 for the Four Scenarios
(in millions of 2007 US$)

			A1		A2		B1		B2	
Country	HDI	ELP	MCE	CL	MCE	CL	MCE	CL	MCE	CL
Mexico			(1.10)	(1.24)	(1.26)	(1.42)	(1.10)	(1.60)	(1.26)	(1.84)
Gulf Coast	0.792	1.49	15316	79665	15767	79665	15316	102930	15767	102930
Central America			(1.10)	(1.07)	(1.26)	(1.22)	(1.10)	(1.39)	(1.26)	(1.58)
Belize	0.737	1.67	665	209	762	239	665	272	762	309
Costa Rica	0.834	1.39	228	63	261	71	228	81	261	92
El Salvador	0.720	1.33	541	132	620	150	541	171	620	194
Guatemala	0.649	1.33	1696	412	1942	470	1696	535	1942	609
Honduras	0.672	1.25	7123	1737	8159	1981	7123	2257	8159	2566
Nicaragua	0.667	1.86	6015	2575	6890	2936	6015	3345	6890	3803
Greater Antilles			(1.10)	(1.74)	(1.26)	(1.99)	(1.10)	(2.26)	(1.26)	(2.58)
Cuba	0.809	1.35	3845	4723	4404	5401	3845	6134	4404	7003
Dominican Republic	0.738	1.65	13153	6775	15067	7748	13153	8799	15067	10046
Haiti	0.463	1.23	1936	1335	2218	1527	1936	1734	2218	1979
Jamaica	0.764	1.24	5747	2522	6582	2884	5747	3275	6582	3739
Puerto Rico	0.942	1.50	9083	7416	10405	8481	9083	9632	10405	10996
Lesser Antilles			(1.10)	(1.19)	(1.26)	(1.36)	(1.10)	(1.53)	(1.26)	(1.75)
Antigua and Barbuda	0.800	1.33	2003	694	2294	793	2003	892	2294	1020
Barbados	0.888	1.34	16	4	19	5	16	6	19	7
Dominica	0.743	1.19	93	25	107	29	93	33	107	37
Grenada	0.745	1.39	1407	430	1611	492	1407	554	1611	632
St. Kitts and Nevis	0.844	1.46	1036	624	1187	713	1036	802	1187	917
St. Lucia	0.777	1.56	15	7	18	8	15	9	18	10
St. Vincent and Grenadines	0.751	1.54	78	29	89	33	78	37	89	43
Bahamas			(1.10)	(1.31)	(1.26)	(1.50)	(1.10)	(1.68)	(1.26)	(1.93)
Bahamas	0.815	1.25	923	985	1057	1241	923	1263	1056	1597

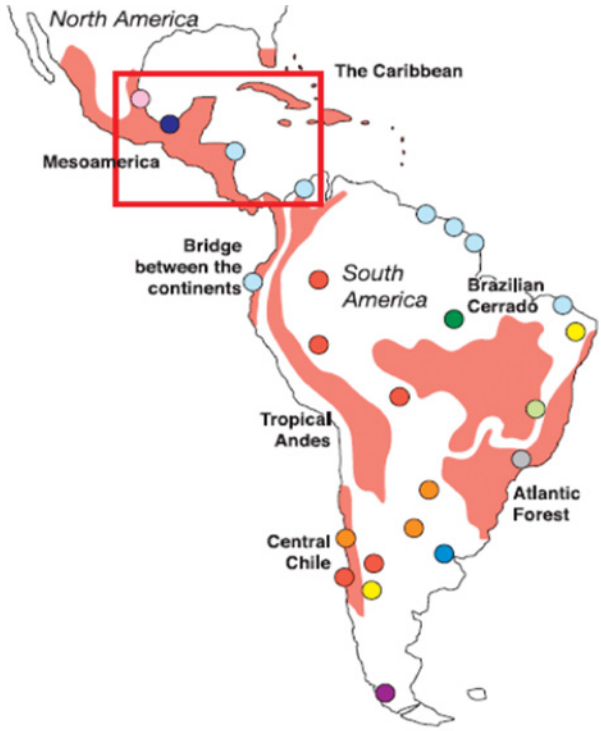
Source: Curry et al. (2009).
Note: Parenthetical values for each region are the projected hurricane risk factors. MCE = maximum covered event; CL = cumulative loss; ELP = economic loss potential; HDI = human development index.

altitudes could completely disappear over the next 10 to 20 years (Bradley et al. 2006; Ramírez et al. 2001).

The disappearance of important glaciers in Bolivia,[8] Colombia, Ecuador, Peru, and República Bolivariana de Venezuela could seriously affect seasonal water flows and the availability of water for human consumption, hydropower, agriculture, sanitation, and ecosystem integrity, possibly resulting in severe economic impacts and environmental degradation. Reduced glacial runoff in the Andes is likely to cause severe water stress for up to 77 million people by 2020 (Magrín et al. 2007). Andean countries are highly dependent on hydropower (more than 50 percent of electricity supply in Ecuador, 70 percent in Bolivia, and 80 percent in Peru), which is a major reason for the LCR's clean energy profile. However, much of this hydropower is dependent on water from glacial runoff. In Peru there are 15 power plants, with a total installed capacity of 2,480 megawatts, located in glacier-fed water basins. Although the disappearance of the glaciers might not affect total water supply, seasonal flow patterns would certainly change. This, in turn, would require significant investments to maintain generation capacity. Vergara et al. (2007) estimate annual incremental costs to Peru's power sector from US$212 million if gradual adaptation is used, up to US$1.5 billion under rationing. This is in addition to the impacts on water supply for urban areas, agriculture, and ecosystem integrity. Watersheds in arid and semi-arid areas are particularly vulnerable (UNFCCC 2007b).

MAP 2.3

Major Regional Vulnerabilities



- Coral reefs and mangroves seriously threatened with warmer sea surface temperature
- Under the worst sea-level rise scenario, mangroves are very likely to disappear from low-lying coastlines
- Amazonia: loss of 43% of 69 tree species by the end of the twenty-first century; savannization of the eastern part
- Cerrados: loss of 24% of 138 tree species for a temperature increase of 2°C
- Reduction of suitable land for coffee
- Increase in aridity and scarcity of water resources
- Sharp increase in extinction of mammals, birds, butterflies, frogs, and reptiles by 2050
- Water availability and hydro-electric generation seriously reduced due to reduction in glaciers
- Ozone depletion and skin cancer
- Severe land degradation and desertification
- Rio de la Plata coast threatened by increasing storm surges and rise of sea level
- Increased vulnerability to extreme events

Areas in red correspond to sites where biodiversity is currently severely threatened and this trend is very likely to continue in the future.

Source: IPCC (2007).

Damage to the environment in the Andes may also be significant. High mountain ecosystems, including *páramos* (a unique type of wetland found in the northern Andes) and snowcapped terrain, are among the environments most sensitive to climate change. These ecosystems have unique endemic flora and provide numerous and valuable environmental goods and services. Prospects of damage to these ecosystems are all the more alarming because major population centers, including the cities of Bogotá and Quito, depend on páramos for their water supply.

Loss of coral reefs

Under conditions anticipated by the IPCC (IPCC 2007), temperatures in the Caribbean may reach, during the current century, threshold values that would lead to collapse of the coral biome (Christensen et al. 2007). These economic losses are inherently difficult to monetize, but based on the most recent available data on various direct use, indirect use, and nonuse values, attempts have been made to illustrate indicative values of coral reefs that may be lost (Toba 2008).[9] Table 2.5 present such estimates, based on the Coral Mortality and Bleaching Output model.[10] The A1B with the 2°C temperature sensitivity scenario suggests that, under the assumptions made, the effects of both warm seas and severe high-temperature episodes could likely lead to the mortality of all corals in the area between 2060 and 2070. Although these estimate are based on available data from the Caribbean region, due to the current limitations of scientific knowledge of complicated direct and indirect linkages of coral reefs vis-á-vis other species and the integrity of ecosystems and of economic evaluation of coral reefs, the estimated results should be regarded as only an illustrative purpose.

Loss of wetlands around the Gulf of Mexico and elsewhere

Wetlands provide many environmental services, including regulation of the hydrological regime; human settlement protection through flood control, protection of the coastal region, and help in mitigating storm impacts; control of erosion; conservation and replenishing of coastal groundwater tables; reduction of pollutants; regulation and protection of water quality; retention of nutrients, sediments, and polluting agents; providing sustenance for many human communities settled along the coast; and habitats for waterfowl and wildlife.

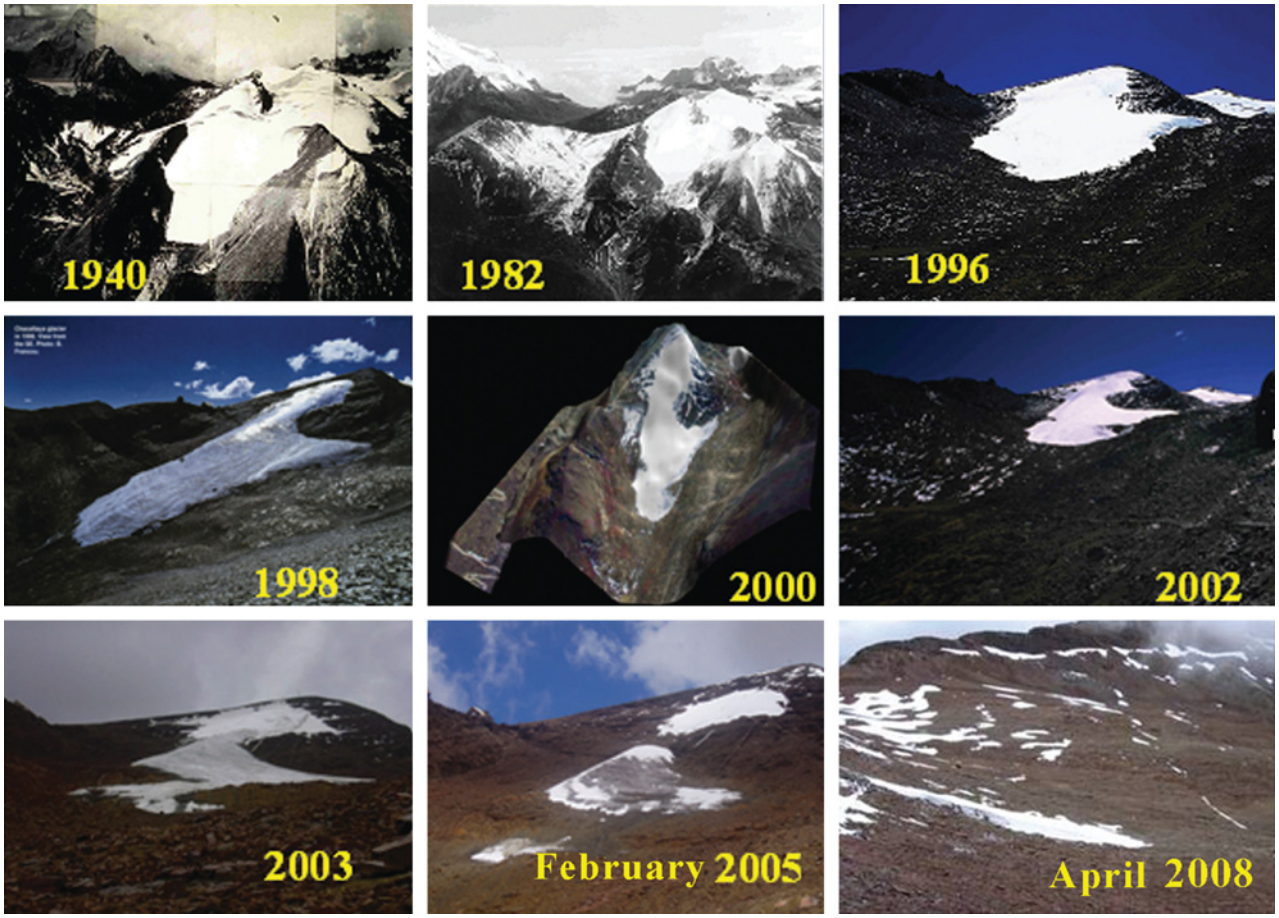
TABLE 2.4

Ecosystem Hotspots

Climate hotspot	Direct effect	Immediacy	Irreversibility	Magnitude of physical impacts	Economic consequence
Mountain ecosystems in the Andes	Warming	Now	The thermal momentum in mountain habitats will result in significant increases in temperature leading to major uni-directional changes in mountain ecology	Disappearance of glaciers, drying up of mountain wetlands, extinction of cold-climate endemic species	Impact on water and power supply, dislocation of current agriculture
Coral biome in the Caribbean	Bleaching and mass mortality of corals	Now	Once temperatures pass the threshold for thermal tolerance, corals will be gone	Total collapse of ecosystem and wide-ranging extinction of associated species	Impacts on fisheries, tourism, increased vulnerability of coastal areas
Wetlands in the Gulf of Mexico	Subsidence and salinization; increased exposure to extreme weather	Ongoing; this century	Irreversible rises in sea levels will submerge coastal wetlands affecting their ecology	Disappearance of coastal wetlands, dislocation and extinction of local and migratory species	Impacts on coastal infrastructure, fisheries, and agriculture
Amazon Basin	Forest dieback	Ongoing; this century	If rainfall decreases in the basin, biomass densities would also decrease	Drastic change to the ecosystem leading to potential savannah	Impacts on the global water circulation patterns; impacts on agriculture, water, and power supply on a continental scale

Source: Vergara (2009).

FIGURE 2.4
Retreat of the Chacaltaya Glacier in Bolivia



Source: Photographs by B. Francou, E. Ramirez, and W.Vergara.

Wetlands in many countries of the region would be severely affected by rising sea levels, with 1.35 percent of the total wetland area feeling an impact on average by a 1-meter rise and 6.57 percent by a 5-meter rise (Dasgupta et al. 2007). For some countries, the overall impact of a 5-meter rise would be catastrophic. The problem in some areas could be exacerbated by reduced rainfall. Data published as part of IPCC assessments (Milly et al. 2005) indicate that Mexico may experience significant decreases in runoffs, of the order of –10 to –20 percent nationally, and up to –40 percent over the Gulf Coast wetlands, as a result of global climate change. Mexico's third national communication[11] and other studies have documented ongoing changes in the wetlands of the Gulf and have raised urgent concerns about their integrity. Other studies have indicated that the wetlands in this region are particularly vulnerable to subsidence and saline intrusion, both forced by climate change. The threat is particularly worrisome as the Gulf of Mexico possesses one of the richest ecosystems on Earth and the most productive ecosystem in the country (Caso et al. 2004).

Amazon dieback

One of the most disastrous ecosystem impacts, if it occurs, will be a *dramatic dieback of the Amazon rainforest, with large areas converted to savannah*. Most Dynamic

TABLE 2.5

Potential Value of Lost Economic Services of Coral Reefs circa 2040–60 Based on the Results of the COMBO Model
(in millions of 2008 US$)

50 percent of corals in the Caribbean are lost		
	Low estimates	High estimates
Coastal protection	438	1,376
Tourism	541	1,313
Fisheries	195	319
Biodiversity	14	19
Pharmaceutical uses	3,651	3,651
Total	4,838	6,678
90 percent of corals in the Caribbean are lost		
	Low estimates	High estimates
Coastal protection	788	2,476
Tourism	973	2,363
Fisheries	351	574
Biodiversity	24	35
Pharmaceutical uses	6,571	6,571
Total	8,708	12,020

Source: Vergara et al. (2009).

Global Vegetation Models based on the IPCC emission scenarios show a significant risk of climate-induced forest dieback toward the end of the twenty first century in tropical, boreal, and mountain areas, and some General Circulation Models predict a drastic reduction in rainfall in the western Amazon.[12] There is as yet no consensus in the scientific community regarding the possibility of Amazon dieback because modeling results differ due to different assumptions and uncertainties. Nonetheless, the Technical Summary of the Fourth Assessment Report of the UNFCC indicates a potential Amazon loss of between 20 percent to 80 percent as a result of climate impacts induced by a temperature increase in the basin of between 2° and 3°C. The credibility of these predictions was reinforced in 2005, when large sections of southwestern Amazonia experienced one of the most intense droughts of the past 100 years. The drought severely affected humans along the main channel of the Amazon River and its western and southwestern tributaries.

The Amazon Basin is a key component of the global carbon cycle. The old-growth rainforests in the basin store about 120 billion metric tons of carbon (petagrams of carbon or Pg C) in their biomass. Annually, tropical forests process approximately 18 Pg C through respiration and photosynthesis. Despite the large CO_2 efflux from recent deforestation, the Amazon rainforest is still considered to be a net carbon sink of 0.8–1.1 Pg C per year, because growth on average exceeds mortality.

The basin is the home of about 20 million people, including several unique indigenous cultures, and is the largest repository of global biodiversity. In size it is larger than the European Union or the continental United States (about 8 million square kilometers) and produces about 20 percent of the world's flow of freshwater into the ocean.

Current climate trends may be unbalancing this well-regulated system and, in association with land-use changes, may be shifting the region from a carbon sink to a carbon source. Changing forest structure and behavior would have significant implications for the local, regional, and global carbon and water cycles. Increasing temperatures may accelerate respiration rates and, consequently, carbon emissions from soils. Decreasing precipitation and prolonged drought stress may lead to reductions in biomass density. Resulting changes in evapo-transpiration and, consequently, convective precipitation would further accelerate drought conditions and destabilize the tropical ecosystem as a whole, causing a reduction in both standing biomass and carbon carrying capacity.

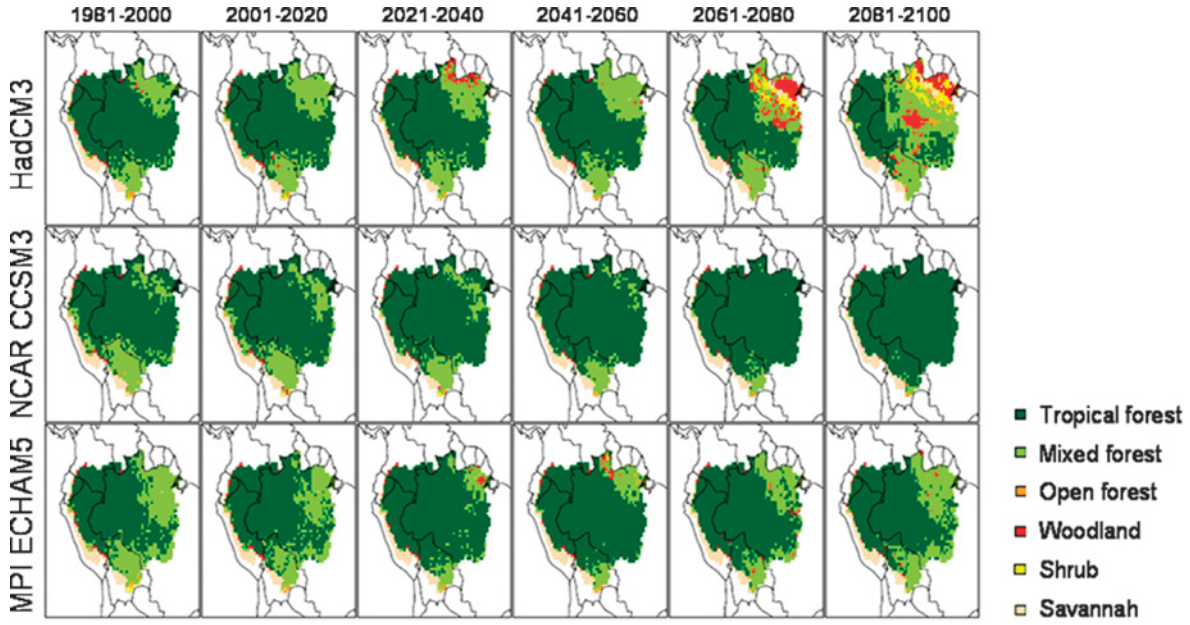
Changes in the structure of Amazon land cover and its associated water cycle would adversely impact many endemic species as well as critical economic and environmental services. Amazonian forest dieback would be a massive *high-impact* event, affecting all life forms that rely on this diverse ecosystem, including humans, and producing ramifications for the entire planet's climate and carbon cycle (map 2.4).

Other indirect impacts of climate change

In addition to the direct effects of changes in temperatures and precipitation patterns on the economic sectors and specific ecosystems, a number of other indirect impacts are also important for the LCR, including rising sea levels, general loss of biodiversity, water shortages, and health-related damages.

MAP 2.4

Modelled Natural Vegetation in the Amazon Basin under Current and Future Climate Conditions



Source: Special Report on Emission Scenarios (SRES)-A2 scenario as simulated by the Lund-Potsdam-Jena Dynamic Global Vegetation Model for managed land (LPJmL) from the outputs of three Global Circulation Models.
Note: Land-use patterns are not included.

Effects of rising sea levels

Large populations in Latin America live in coastal zones, although some live in locations that are more vulnerable than others due to land conditions, housing structures, and in particular, elevation. Examples of countries with more than 50 percent of the population living at elevations of 50 meters or less include: Argentina (50 percent), Uruguay (52 percent), and Guyana (about 70 percent) (CIESIN 2007). In addition, in most Caribbean islands more than 50 percent of the population live within 2 km of the coast (IPCC 2001). These populations are vulnerable to the effects of rising sea levels on coastal flooding and fresh water supplies, as well as possible intensification of tropical storms and their impacts.

Research on rising sea levels has typically predicted a 0–1 meter rise over the next century (Church and Gregory 2001; IPCC 2001). The rise is mainly due to ocean thermal expansion (the most important contributor); melting of ice sheets in Greenland and Antarctica (plus a smaller contribution from other ice sheets); and change in terrestrial storage. However, new data on rates of deglaciation in Greenland and Antarctica suggest greater significance for glacial melt, and a possible revision of the upper-bound estimate for rising sea levels in this century (Dasgupta et al. 2007). Since the Greenland and Antarctic ice sheets contain enough water to raise the sea level by about 68 meters (of which 7 meters is due to the Greenland sheet), small changes in their volume would have a significant effect.

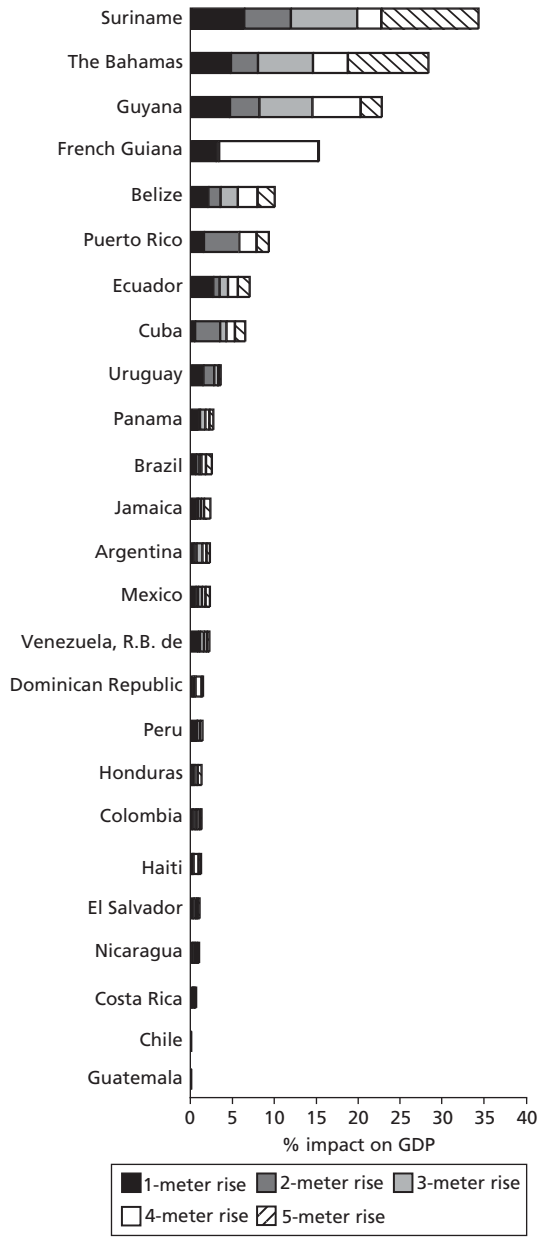
Rising sea levels would damage coastal areas in numerous ways. Erosion or submersion of arable land, along with increased soil salinity, could lead to losses in agriculture, forest products, and perennial crops, such as bananas, with lasting consequences for the income-generating ability of communities throughout the region's coastal zones (UNFCCC 2007b). The long-term health and survival of the area's mangrove forests could also be threatened by rising temperatures and acidification of the sea and increased hurricane intensity (Magrín et al. 2007; UNFCCC 2007b). Loss of forests and perennial crops, such as banana trees,

caused by the washing out of arable land and increased soil salinity, is likely to have lasting consequences for the income-generating ability of communities across the region's coastal zones (UNFCCC 2007b).

The only study to quantify total economic damages from rising sea levels in the LCR as a whole estimates these would range from 0.54 percent of GDP for a 1-meter rise to 2.38 percent for a 5-meter rise (Dasgupta et al. 2007), with the magnitude of losses differing greatly among the region's countries (figure 2.5). For CARICOM, based on the A1B scenario for the Caribbean, an increase in sea levels of 0.35 meters circa 2080 is estimated to cost an annual US$1.8 billion in 2007 prices (Toba 2008). A recent analysis completed under the Mainstreaming Adaptation to Climate Impacts in the Caribbean project, indicate that in Guyana more than 80 percent of the population and two-thirds of economic activity would be displaced by 1 meter in rising sea levels.[13]

FIGURE 2.5

Projected Sea Level Rise and Its Impact on GDP in Latin America and the Caribbean Region



Source: Dasgupta et al. (2007).

Reductions in rainfall in some regions will create water shortages, with wide-ranging effects

Even without accounting for climate change, the number of persons in Latin America living in water-stressed watersheds is forecast to increase from 22 million in 1995 to between 36 and 56 million by 2025 and between 60 and 150 million by 2055 (Arnell 2004). Using four Special Report on Emission Scenarios, by 2055, climate change would increase the number of people living in water-stressed areas under three of the four scenarios, by between 6 and 20 million persons. Particularly in arid and semiarid regions of Argentina, northeast Brazil, Chile, and northern Mexico, climate change would exacerbate water shortages. Some coastal areas would experience adverse effects on water supply, not because of a reduction in rainfall but from saltwater intrusion into aquifers as a result of rising sea levels.

Health impacts

Climate change is also likely to have multiple impacts on health, but the relationship is complex. Worldwide, the single most significant impact identified by the IPCC is an increase in malnutrition, particularly in low-income countries (Confalonieri et al. 2007), with mortality and morbidity from extreme events in second place. Other impacts identified include increases in cardiorespiratory diseases from reduction in air quality, changes in temperature-related health impacts (increasing heat stress, but reduction in cold-related illness, depending on the region), and changes in prevalence of various infectious diseases, including malaria.

Of special concern in the LCR will be the effects on malaria—mainly in rural areas—and dengue in urban areas. Vectors and parasites have optimal temperature ranges, and because mosquitoes require standing water to breed, changes in precipitation are also expected to have an effect on the prevalence of the two diseases. In areas that are now too cool, higher temperatures could allow expansion of both the range and the seasonal window of transmission. In areas where temperatures are now close to the upper threshold of tolerance, the range could contract. Areas with higher precipitation will have an increased risk. In Colombia, there is evidence that temperature is important for dengue transmission, while increased precipitation is a significant variable contributing to malaria transmission. Using statistical models of the incidence of both diseases, and forecasts of change in precipitation and temperatures (derived from eight global circulation models of the Fourth Assessment of the IPCC), the total number of victims is forecast to increase by about 76,641 by mid-century and 228,553 by the end of the century (table 2.6), at an economic cost of US$2.5 million for the period 2055–60, and US$7.5 million for a five-year period beginning in 2105.[14] These economic costs do not seem large, although an important caveat in interpreting these results is that the additional cases were calculated only in the municipalities in which the corresponding disease was present in the 2000–05 period; the estimate of the costs does not consider the potential spread to new municipalities.

Yet areas receiving less rainfall may experience a reduction in malaria risk, as forecast for Central America and the Amazon.[15] But—underscoring the complexities in forecasting the net health impact of drier weather—the seasonal pattern of cholera outbreaks in the Amazon Basin has been associated with lower river flow in the drier season.[16] No overall assessment has been carried out of the net health effects for the LCR as a whole, but recent national health impact assessments in both Bolivia and Panama, for example, have concluded that on balance there is likely to be an increased risk of infectious disease in those countries.

Toba (2008) estimated the annual costs of malaria due to climate change based on the Disability-Adjusted Life Year circa 2080 in 2007 prices for CARICOM at US$2.6 thousand, and the increased cost to health due to climate change, including acute respiratory infections, acute diarrheal diseases, viral hepatitis, varicella and meningococcal meningitis at

TABLE 2.6

Additional Numbers of Cases of Malaria and Dengue for 50- and 100-Year Future Scenarios

Vector-borne disease	Historic total number during the 2000–05 period	Additional number of cases for a six-year period: 50-year scenario	Additional number of cases for a six-year period: 100-year scenario
p.falciparum malaria	184,350	19,098	56,901
p. vivax malaria	274,513	16,247	48,207
Dengue	194,330	41,296	123,445
Total	653,193	76,641	228,553

Source: Blanco and Hernández (2009).

TABLE 2.7

Climate Change Costs Relative to the 2000–05 Period in Colombia

(in millions of US$)

Scenarios	Indirect costs of malaria and dengue	Direct cost of *p. falciparum* malaria	Direct cost of *p. vivax* malaria	Direct cost of dengue	Total costs for both diseases
50 years (2055–60)	1.1	0.2	0.05	1.1	2.5
100 years (2105–10)	3.3	0.7	0.1	3.3	7.5

Source: Blanco and Hernández (2009).

US$7.1 million per year circa 2080 (in 2007 prices), under an assumption of a 2°C increase in temperature from 1999–2080 of A1B scenario for the Caribbean region.

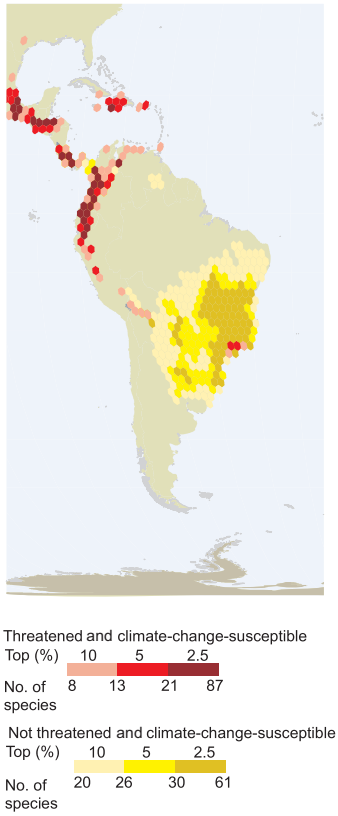
Species extinction and biodiversity loss

Even apart from the huge loss of biodiversity from such cataclysmic changes as Amazon dieback, climate change will threaten the rich biodiversity of the LCR more generally. Some of the major impacts on ecosystems have been mentioned already: loss of coral reefs, subsidence of wetlands, and the likelihood of major extinctions as a consequence of Amazon dieback. All of these would have important implications for provision of environmental services for society. Other rainforests outside of Amazonia would also be made more vulnerable to forest fires. Scholze (2005) estimates that an increase of 3°C would increase the frequency of forest fires by 60 percent in much of South America, with a somewhat smaller increased risk in Central America.

All of these impacts are likely to drastically affect the survival of species, as breeding times and distributions of some species shift.[17] Arid regions of Argentina, Bolivia, and Chile, along with central Brazil and Mexico, are likely to experience severe species loss by 2050 using mid-range climate forecasts (Thomas et al. 2004). Mexico, for example, could lose 8–26 percent of its mammal species, 5–8 percent of its birds, and 7–19 percent of its butterflies. Species living in cloud forests will become vulnerable, as the warming causes the cloud base to rise in altitude. In the cloud forest of Montverde in Costa Rica, this kind of change is already being observed, as reductions in the number of mist days has been associated with a decrease in populations of amphibians, and probably also birds and reptiles (Pounds et al. 1999). Amphibians are especially susceptible to climate change. Species that are both threatened (according to the Red List of the IUCN) and climate change–susceptible inhabit areas of southeastern Brazil, various Caribbean Islands, Mesoamerica, and northwestern South America (map 2.5). Among birds, the families that are highly susceptible and are endemic to Latin America are *Turdidae* (thrushes, 60 percent of which are classified as highly susceptible), *Thamnophilidae* (antbirds, 69 percent highly susceptible), *Scolopacidae* (sandpipers and allies, 70 percent highly suceptible), *Formicariidae* (antbirds, 78 percent highly susceptible), and *Pipridae* (manakins, 81 percent highly susceptible).[18]

MAP 2.5

Areas of High Concentration of Amphibians according to Levels of Threat and Climate Change Susceptibility



Source: Foden et al. (2009).

Although economic techniques to value biodiversity are currently underdeveloped, one approach uses "willingness to pay," thereby including only nonuse values of biodiversity (for example, eliminating potential fishery and/or tourism income). Using this approach, Toba (2008) estimated the loss of biodiversity value of coral reefs in the Caribbean at US$14–$19 million if 50 percent of corals are lost, and at US$24–$35 million if 90 percent of coral reefs are lost, in 2007 prices (see table 2.8).

TABLE 2.8

Potential Annual Economic Impact of Climate Change in CARICOM Countries circa 2080[1]

(in millions of 2007 US$)

	Presubtotal[2]	Subtotal	Total
Total GDP loss due to climate change–related disasters			4,939.9
Tourist expenditure		447.0	
Employment loss		58.1	
Government loss due to hurricane		81.3	
Flood damage		363.2	
of which is agricultural damage	1.7		
Drought damage		3.8	
of which is agricultural damage	0.5		
Wind storm damage		2,612.2	
of which is agricultural damage	1.9		
Death (GDP/capita) due to increased hurricane-related disasters (wind storm, flood, and slides)		0.1	
Floods DALY (GDP/capita)		0.8	
Sea level rise			
Loss of land			20.2
Loss of fish export (rising temperatures, hurricanes, and sea level)			93.8
Loss of coral reefs (rising temperatures, hurricanes, and sea level)			941.6
Hotel room replacement cost			46.1
Loss of tourists and sea-related tourism entertainment expenditures			88.2
Housing replacement			567.0
Electricity infrastructure loss			33.1
Telephone line infrastructure loss			3.9
Water connection infrastructure loss			6.7
Sanitation connection infrastructure loss			9.0
Road infrastructure loss			76.1
Rail infrastructure loss			2.7
Temperature rise			
Loss of tourist expenditures			4,027.4
General climate changes			
Agricultural loss			220.5
Loss of maize production		2.7	
Agricultural export loss		74.4	
Water stress and cost of additional water supply			104.0
Health			
Malaria DALY (GDP/capita)			0.003
Other disease costs			7.1

Source: Toba (2008).
Note: 1. A total of 20 CARICOM countries are included.
2. Of which is agricultural damage.

Impacts on the Caribbean

Small islands in the Caribbean region are particularly vulnerable to climate change. Toba (2008) estimated potential annual economic impacts of climate change on Caribbean community member countries, including climate change related disasters, rising sea levels, temperature rise, and general climate change (that is, arising from synthesis of various climate change impacts).[19] Table 2.8 presents the aggregated estimates for 15 CARICOM member countries and 5 associate member countries. Secondary data are adjusted to be consistent under the A1B scenario for the Caribbean region. The economic impacts are adjusted and expressed as impacts on the 2007 economy

even though the climate change will not reach its full potential for some decades, as is the standard practice in the literature. Conservative values are chosen in making estimates. The estimated total annual impacts of potential climate change on CARICOM countries circa 2080 are US$11.2 billion. For all 20 CARICOM countries, the total GDP (in 2007 prices) is US$99.3 billion. Therefore, the estimated total annual impacts are about 11.3 percent of all 20 CARICOM countries' total annual GDP. Sensitivity analyses are conducted applying the lowest and the highest under the A1B scenario for the Caribbean region projected by IPPC Fourth Assessment Report. This results in estimated annual impacts of about US$7.2 billion (7.3 percent of the 20 CARICOM countries' total annual GDP) and the highest estimate of about US$18 billion (18 percent of the 20 CARICOM countries' total annual GDP). Although these estimates are based on the use of secondary data, they still provide an indication of the magnitude of climate change damages to CARICOM countries, which is useful for decision makers in addressing climate change impacts.

Notes

1. In the terminology of the IPCC, a high level of confidence in a given statement amounts to a belief, based on expert judgment of the underlying evidence (data, models, or analyses) that the chance of the corresponding finding being correct is at least 8 out of 10.

2. Parry et al. (2007).

3. The Third Assessment Report of the Intergovernmental Panel on Climate Change predicts that global mean surface temperature will rise by as much as 6°C by 2100 (UNFCCC 2007b).

4. World Bank. 2007b. "Visualizing Future Climate in Latin America: Results from the Application of the Earth Simulator." Sustainable Development Working Paper 30.

5. Mendelsohn and Williams (2004).

6. Tol (2002).

7. Windstorms (hurricanes and cyclones) and floods did not show a statistically significant impact in the whole sample, although windstorms did show a high impact on small states, such as the Caribbean Islands.

8. The Chacaltaya Glacier is expected to completely disappear within the next 15 years. Yet, according to observations, the accelerating rate of glacier retreat is even larger for small glaciers (Francou and Coundrain 2005).

9. These values are much larger than those illustrated in table 2.8, which used different data sources and assumptions to avoid double counting.

10. The Coral Mortality and Bleaching Output (COMBO) model developed by Buddemeier and coworkers (Buddemeier et al. 2008) models the response of coral growth to changes in sea surface temperature, atmospheric CO_2 concentrations, and high-temperature–related bleaching events. COMBO estimates the growth and mortality of the coral over time based on future climate predictions and on the probability and effects of short-timed, high-temperature–related bleaching events taking place in the area.

11. National Communications to the UNFCCC (2001, 2004, 2007).

12. There are estimates of up to a 90 percent reduction in rainfall by the end of the century (Cox et al. 2004, 2008). However, some estimates suggest that 40 percent reductions in rainfall would suffice to initiate a dieback process.

13. Theo Velloza and Mark Bynoe, National Adaptation Strategy for the Agricultural Sector of Guyana to Address Climate Change.

14. Blanco and Hernández (forthcoming).

15. Van Lieshout et al. (2004).

16. Gerolomo and Penna (1999).

17. IPCC (2007), Thomas et al. (2004).

18. The antbirds are a large family of passerine birds found across subtropical and tropical Central and South America, from Mexico to Argentina. The formicariids, or ground antbirds, are small passerine birds of subtropical and tropical Central and South America. Manakins are found in southern Mexico to northern Argentina, Paraguay, southern Brazil, and on Trinidad and Tobago. Most species live in humid tropical lowlands, with a few in dry forests, river forests, and the subtropical Andes.

19. Toba (2008).

CHAPTER 3

Adapting to a Changing Climate in the LCR

Introduction

Because humans as well as the Earth's ecosystems have evolved characteristics and behaviors that optimize their well-being under current climate conditions, significant changes will inevitably cause stress. Even in areas where warming will eventually produce some beneficial effects, there will be adjustment costs. Humans and ecosystems will respond on their own in ways that will reduce the costs and enhance the benefits, to the extent they are able to do so. But a major challenge for governments and the international community will be to provide the policies, institutional infrastructure, and public goods that will facilitate this process of adaptation.

Adaptation theory defines climate adaptation as the changes in behavior in response to or in anticipation of climate change (IPCC 1996, IPCC 2001). Although the idea that people will adapt is simple, adaptation itself is complex. It is an endogenous response to climate change. As climate changes, adaptive responses must change with it. Further, adaptation is not uniform. The best response for one farmer, for example, will depend not only on his external environment, but on his own situation—his constraints and assets—financial, physical, and human—and so is not necessarily the best response for another farmer even in the same region. Adaptation is likely to be a quilt across the landscape, with very different responses in each location. Efforts to directly assist adaptation need to be sensitive to these dynamic and local qualities, with the implication that they should be aimed mainly at increasing options, rather than imposing a one-size-fits-all solution.

Efforts to plan for adaptation on both the individual and governmental levels are further bedeviled by the tremendous uncertainties involved in climate projections. There is more agreement among models regarding the degree of warming than regarding the changes in precipitation patterns, but the latter are at least as important in planning for adaptation. Here, Latin America and the Caribbean stands out, along with Africa, as the regions with the greatest uncertainties, as measured by consistency of predictions by different models (table 3.1).

Comparing the forecasts from different models for the "cells" (areas) in the LCR, there are 15 percent of the cells where less than half the models agree on the direction of change of precipitation and only 18 percent where there is a fairly high degree of consensus. Within the LCR, the subregions that show the least consistency in predictions of precipitation changes are the arid areas of Brazil and the southern equatorial region (see table 3.2). Planning for adaptation must take into account this high degree of uncertainty as well as the "average" forecast.

Adaptive Responses to Climate Change

For the most part, changes in climate will occur gradually over decades and even centuries, although there remains the possibility that certain tipping points could be reached, triggering sudden and catastrophic changes. The gradual nature of the changes combined with the normal variations and uncertainties in weather patterns means that people will be required to adjust their behavior based on very unclear signals as to what

TABLE 3.1

Projected Future Changes in Runoff

	Projected[a] change in average runoff (mid-twenty-first century)				Model agreement[c]	
		Portion[b] of region for which change is projected to:				
Region	Mean change (% of current average annual runoff)	Decrease by more than 10%	Remain within +/– 10%	Increase more than 10%	% of cells where 50% or fewer of models agree	% of cells where 80% or more of models agree
LCR	–3%	27%	56%	17%	15%	18%
AFR	–1%	25%	60%	14%	15%	16%
MNA	–30%	58%	40%	2%	8%	37%
ECA	14%	11%	25%	64%	3%	79%
SAR	11%	18%	22%	60%	4%	31%
EAP	9%	0%	47%	53%	9%	33%

Source: Adapted from World Bank Water Anchor "Water and Climate Change: Hydrologic Drivers and Potential Impacts," December 17, 2007.

a. Estimates of projected change in runoff were determined by averaging the results of Milly et al. 2005 (an analysis of the runoff output of 12 climate models run under the IPCC's SRESA1B emissions scenario, provided as gridded output at the 2.5° longitude x 2.0° latitude scale) over the grid cells that comprise each region.

b. The projected changes in runoff were divided into three categories. The percent of grid cells within a particular region that fall into each category is reported.

c. Model agreement refers to whether or not multiple models project a change in the same direction (that is, increase or decrease in runoff). Twelve different climate models were included in the analysis by Milly et al. (2005). For each grid cell, as few as 6 models may agree on the direction of change (that is, half the models project an increase and half project a decrease), and as many as 12 models may agree (that is, all models show an increase or all models show a decrease). Presented here is the percent of grid cells within a region that have poor model agreement (6 out of 12 agree) and that have moderate to good agreement (10 or more models agree).

the future may hold. One implication of this is that adjustment costs could be much reduced if there were some way of reducing the uncertainty. Another is that there will be a very high premium on flexibility.

Adaptation through changes in agricultural practices

Agriculture not only is the sector of the economy that will experience the most direct and largest impacts of climate change, it is also the source of livelihood for about 75 percent of the world's poor and a source of food for all. In the LCR about 21 percent of the rural population is poor. To support objectives of poverty reduction, development, and maintenance of the world's food supply, it is critical that the agricultural sector adapt as well as possible to climate change.

Over time, farm-level adaptations have been made in planting and harvesting dates, crop rotations, selection of crops and crop varieties, use of different management practices, and adoption of new technologies, among others (Adams et al. 1998). Such adaptation practices involve actual adjustments or changes in decision environments to reduce vulnerability to observed or expected changes in climate (Adger et al. 2002). They can be autonomous, driven by self-interest, or facilitated by governments through the development of new crop varieties that can withstand biotic stresses, investments in water management and irrigation infrastructure, and incentive mechanisms to spread risk and improve knowledge.

Four complementary approaches have been applied to study agricultural adaptation: (1) crop models; (2) Ricardian analysis; (3) stakeholder consultation/expert opinion; and (4) case studies of behavior in response to weather-related events. Crop simulation models have been used to assess crop responses to environmental and management factors. They also indicate the potential for adapting to different climates through the use of different varieties. Crop models in Latin America have been developed for a few important agricultural regions within selected countries (Argentina, Brazil, Mexico,

and Uruguay) focusing primarily on grains. The studies generally point to reductions in yields and increased variability in crop productivity in the region with rising temperatures (Adams et al. 1998). The magnitude of these changes depends on the biophysical simulation parameters used in the models but generally highlights the adverse productivity implications of warming climate.

Another commonly used approach focuses on estimating the effects of climate change on agriculture based on observed differences in agricultural production and among regions with different climates (Adams et al. 1998). Although they are limited to consideration of adaptation through changes in production strategies, Ricardian studies in South America (with focus on land values) have more systematically examined how farmers adapt to climate in a number of dimensions. One adaptation decision is the choice of farm type. Mendelsohn and Seo (2007) considered five farm types—a crop-only rainfed farm, a crop-only irrigated farm, a mixed (livestock and crop) rainfed farm, a mixed irrigated farm, and a livestock only farm—and found significant and predictable effects of climate. Higher temperatures encourage farmers to move away from crop-only farms to mixed farms and livestock farms. This is consistent with the findings of Wehbe et al. (2006) in Cordoba, Argentina. Higher precipitation pushes farmers to adopt rainfed farming and avoid expensive irrigation investments. The second adaptation decision explored is the choice of livestock species. While considering the effects of nonclimate factors, Seo and Mendelsohn (2007) find that there is a significant climate variable explaining every choice. A third adaptation decision is the choice of crop species for farmers who have chosen to grow crops (Seo and Mendelsohn 2008). The study focuses on the seven major crops grown in South America: fruits and vegetables, maize, wheat, squash, rice, potatoes, and soybeans. Maize did not appear to be as sensitive to climate as other crops, given its many varieties that can effectively grow in diverse climate zones in South America. The crop seems to be a "generalist" in the sense that it is grown throughout South America. In contrast, the other crops are more specialized and grow in narrower temperature or precipitation ranges. As temperatures warm, farmers tend to choose maize and wheat less often, while they choose potatoes, rice, soybeans, and fruits and vegetables more often. If precipitation increases, farmers move away from maize, wheat, and fruits and vegetables to potatoes, rice, and squash. Symmetrically, if precipitation falls, farmers move away from potatoes, rice, and squash to maize, wheat, and fruits and vegetables. The models attempt to draw inferences on spatial adaptation as an initial response to climate change, that is, how cooler regions might adopt practices of warmer regions if the climate warmed (Adams et al. 1998). This kind of information can guide governments in deciding how to direct long-term research or technology transfer to give farmers appropriate options.

Many adaptations can be implemented at low cost, and in fact many have high co-benefits, but comprehensive estimates of adaptation costs and benefits are currently lacking (Adger et al. 2002). Top-down modeling approaches (crop models or Ricardian analyses) adopt a narrow perspective that underestimates adjustment costs. Under bottom-up approaches (such as the National Adaptation Plans of Action, or NAPAs), costs of adaptation are estimated through a stakeholder approach, where priority adaptation activities are identified by communities (OECD 2008). The total national cost of all priority projects identified by Haiti, for example, is US$24.5 million, where the agricultural sector represents the highest adaptation cost of almost 50 percent of the total cost of adaptation. Prioritization approaches, based on stakeholder and expert consultations, for identifying responses to reducing vulnerability of agricultural systems have been undertaken in several production environments in Latin America (the dry region of Yaqui Valley in Sonora, Mexico; the high altitude production region of Mantaro Valley in Peru; and the Western region of Uruguay).

Case studies illustrate specific strategies used by Latin American agricultural producers to adapt to changes in weather, some of which have their origins in time-honored practices (box 3.1). Among them are changing sowing dates; changing varieties or crops; relying on irrigation or changing patterns of water application as Vasquez-Leon et al. (2003) and Conde

BOX 3.1

Local Coping Strategies: Learning from Long Experience

In Latin America, local coping strategies include a variety of agricultural practices, ecosystem protection, and methods to adapt to extreme events.

Farmers in Peru have been using an ancient irrigation and drainage system, "waru waru," or raised field agriculture, which makes it possible to bring into production the low-lying, flood-prone, poorly drained lands found all over the Altiplano. The shallow canals provide moisture during droughts and drainage during the rainy season. When filled with water they also create a microclimate that acts as a buffer against nighttime frosts. The waru waru system provides farmers with greater harvest security and reduces the risks associated with frosts and drought.

In Mexico, the Cajete Terrace agro-ecosystems have been in place for 3,000 years in hillside regions in Tlaxcala. In these rain-fed, corn-bean-squash agro-ecosystems, food is grown on steep, erosion-prone slopes. Rainfall is concentrated between May and September and often occurs in sudden downpours. Sloping terraces feed excess water into tanks (cajetes). The water, which would otherwise not be absorbed into the soil, is collected inside the cajetes and slowly percolates into the surrounding soil after the rain has ended. Eroded soil also trapped inside the cajetes, preventing soil loss down the slope. Nutrient rich soil inside the cajetes is later gathered and distributed into the fields.

The Aymaran indigenous people of Bolivia have been coping with droughts through the construction of small dams called "qhuthañas." These dams collect and store from 50 to 10,000 cubic meters of rainwater. Predictions on the intensity of the droughts are based on the knowledge and observations of the "yatiris" (wise men or advisers).

In El Salvador communities employ a number of soil conservation measures to cope with recurrent droughts, for example, building barriers consisting of stone and pine suckers, which provide edible fruits and additional income.

Source: UNFCCC 2007.

and Eakin (2003) found in Mexico: changing input use; changing production technology (for example, low- or no-tillage production and different grain drying techniques); increasing reliance on livestock; or improving forestry and other natural resource management (Reilly and Schimmelpfenning 1999; FAO 2005). Through changes in the use of irrigation technology, farmers located on the U.S.-Mexico border have been able to cope with more persistent droughts and continue with their activities. Similarly, small rural households in Nicaragua have adopted different approaches to land management (for example, contour barriers, crop rotation, and diversification) that have allowed them to better deal with the effects of Hurricane Mitch in Nicaragua in 1998 and possibly cope with future structural changes in rainfall patterns. The introductions of higher-yielding crop varieties, adequate use of fertilizers, and recycling of rainwater and wastewater have also helped farmers in Ecuador and Guyana to diminish the impacts of the continued change in climate (IPCC 2007).

Spatial distribution of risk is another strategy used by farmers in the region, with mixed results. Geographic separation of plots for cropping and grazing has proven to be effective for diversifying exposure of farmers in parts of Argentina and Bolivia. Yet spatial adaptation strategies can have limitations. In southern Peru, field scattering, a common risk-buffering strategy of having small and dispersed plots, has contributed to the net reduction of average yields by 7 percent (Goland 1993).

Relatively modest (low-cost) adaptation measures, such as farm-level adjustments, can significantly offset declines in projected yield as a result of climate change (OECD 2008). However, the adaptation benefits of farm-level adjustments do not translate equally to all regions or crops. For many countries located in tropical regions, the potential benefits of low-cost adaptation

measures, such as changes in planting dates, crop mixes, and cultivars, are not expected to be sufficient to offset the significant climate change damages (Adger et al. 2002). According to IPCC projections, the low latitude regions in the LCR would be among those most affected by climate change. Yields are expected to decline in low latitudes for any increase in temperature—even moderate warming, for example, 1ºC for wheat and maize and 2°C for rice, can significantly reduce yields (Easterling et al. 1993; Schneider et al. 2007). The impact will be strongly felt considering that a quarter of the LCR's population (138 million people) lives in these regions. Many among them are poor (about 24 million) (that is, living on less than US$1 a day) and a large number (about 13 million) derive their income from agriculture.

Migration as an adaptation strategy

Migration or other means of reducing reliance on agricultural income may also help some families adapt to climate change. Eakin (2005) found this to be an important strategy in Central Mexico. Many rural families already encourage some of their children to migrate to cities, who then send back remittances (Adger et al. 2002). As most urban activities are less climate sensitive, this provides important sources of independent income.[1] Studies carried out for this report comparing migration flows in different localities in Brazil and Mexico find that migratory behavior is influenced by climate conditions. However, though migration is sensitive to climate factors, the effect is generally small. The role of climate characteristics, such as motivating factors appears to be much more important for long-distance migration (for example, across municipalities, in the case of Brazil, and international, in the case of Mexico), though effects are localized and differ across regions. Because the data for these studies were collected in a long-term equilibrium, the results do not tell us much about the transition from one equilibrium to another, nor about the impact of sudden changes. Observations of movements of refugees after hurricanes in Central America and the Caribbean indicate the potential for extreme events to trigger large-scale migrations. Their repetitive occurrence can also lead to permanent displacement of populations. For example, northeast Brazil, a region impacted by the El Niño-Southern Oscillation (ENSO)[2] phenomenon, has seen reductions of agricultural GDP of up to 25 percent for years of severe drought, which resulted in displacements of up to several million low-income rural people (Mata and Nobre 2006).

Adapting to shocks versus trends

Many of the adaptations farmers use are more or less responses that minimize the risk in yields of year-to-year variance in weather. Learning to cope with interannual variations in weather makes sense. Some changes one would make to cope with annual weather may also resemble changes one would make in response to climate shifts. Some authors have suggested that the best way to prepare for climate change is simply to adapt to climate variance, that is, the changes in weather from year to year (Burton 1997; Leary et al. 2007; Smit et al. 1996). They argue that adaptation is a stock. Building up that stock to address changes in weather prepares the system to address changes in climate. For example, if farmers can choose crops and livestock that are productive in years that are abnormally hot and dry now, they will be prepared to make these choices to protect themselves against hot and dry climates.

However, there is not a perfect parallel between adapting to weather and climate. Some adaptations that make sense for a year do not make sense if the change is permanent. For example, selling off livestock in a bad year is not a good long-run strategy for climate change although it may work well to smooth consumption against weather shocks. Formal insurance is a good policy for coping with variance in weather and may be considered an adaptation to higher volatility produced by global warming. But it cannot help in coping with long-term trends produced by climate change. It can even interfere with adaptation; if subsidized insurance compensates farmers for a bad crop year after year, they have no incentive to adapt. Changing capital and long-run investments makes sense for climate change but not for short-run weather shocks. Clearly, learning how to adapt to climate variance that is part of the current climate will provide immediate benefits. These

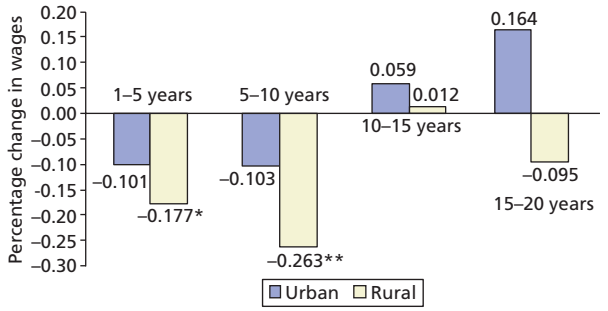
adaptations can begin today and need not wait for climate change to occur.

But autonomous adaptation alone is unlikely to offset the adverse household impacts of climate change. In coping with increased weather variability, vulnerable households can follow adaptation strategies that have negative—and sometimes irreversible—consequences on their current and future living standards. The available evidence suggests that these suboptimal actions are prevalent in rural parts of the LCR. Baez and Mason (2008) examined the major strategies adopted by rural households in four countries in Central America that were negatively affected by the coffee crisis of the late 1990s. Indeed, households engaged in various coping responses to the shock, some of which appear to be especially harmful from a socioeconomic perspective. For instance, food and nonfood consumption fell and the labor supply of children increased at the expense of reduced school enrollment. In Nicaragua, in particular, child labor among coffee-growing households increased by 24 percent between 1998 and 2001 (World Bank 2005a). Households are likely to respond in similar ways to climate-related shocks. Recent findings for Nicaragua suggest that household consumption, school retention and progression, and child labor were all negatively affected in areas hit by Hurricane Mitch in 1998 (Ureta 2005; Baez and Santos 2007). In addition, human health will be at risk in some areas due to increased weather variability and shocks. Increases in the prevalence of malnutrition and infectious diseases, such as malaria and dengue, have been reported in areas of Bolivia, Colombia, Ecuador, Nicaragua, and Peru exposed to extreme rainfall and subsequent floods (Bouma et al. 1997b; WHO 1999; Vos et al. 1999; Baez 2007).

There is a danger that short-term responses can, in fact, lock the victims into long-term poverty. Although all of the long-term effects of climate hazards are not yet known, there are some studies that reveal serious degrees of persistence of the negative impacts. Two recent papers look into the impacts of weather variability on the long-term earnings of households that permanently migrated out of agriculture in Brazil driven by climate shocks between the mid-1980s and mid-1990s. Mueller and Osgood (2007a) use cross-sectional variation together with detailed records of past precipitation to detect a long-term climate-related worsening in the incomes of credit-constrained households that were forced by the severity of multiple rainfall shocks to move from mostly rural states to cities. In a related paper, Mueller and Osgood (2007b) examine the long-term consequences of intense droughts on Brazilian labor markets. The study finds that an increase in the average number of standard deviations below the mean of rainfall reduces rural earnings by 17.7 percent in the following five years and by 26.3 percent between the fifth and tenth year (figure 3.1).[3] In fact, the report shows that it took more than a decade for affected workers to catch up with the wages of their counterparts.[4] There are also harmful interactions between climate risk, short-term risk coping, and asset recovery strategies. For instance, microlevel evidence for Honduras suggests that households at the bottom of the capital distribution were less able to rebuild their few assets in the middle- and long run after being hit by weather shocks (Carter et al. 2004).

In addition to dealing with more variable weather, farmers will certainly need to respond to longer-term climate trends. In general, and taking into account what has been learned from the existing evidence,

FIGURE 3.1
Estimates of the Long-Term Effects of Droughts on Wages in Brazil



Sources: Mueller and Osgood (2007b), with data from Pesquisa Nacional de Amostra Domicilios (1992, 1995).
Note: (*) and (**) stand for 0.10 and 0.05 significance levels. Number of observations: 155,310 (urban), 64,263 (rural). Estimates include controls for age, education, experience, gender, and state-fixed effects. Average effect of the shock is shown. Errors clustered at the state level.

long-run adaptation and economic transitions to new agroeconomic environments is hardest for poor, low-skilled, low-educated, and credit-constrained households. To the extent that such farmers lack the means to undertake the necessary economic adjustments—for example, increasing their productivity in existing activities, switching to more profitable crops, or moving off-farm—they may find themselves with declining income trajectories. What is more, such longer-term economic transitions can be further hindered by the negative and often persistent effects of suboptimal risk management and coping strategies that are commonly adopted by poor households in the short run. As discussed further in the next section, one of the main goals of devising policies to support successful adaptation is to help people avoid having to adapt in these counterproductive ways, either in the short or the long term.

Adapting to changing water resource availability

Water plays a key role in both human and ecological systems. Many of the adverse impacts of global warming will take place because of changes in patterns of water availability. Historically, water management has been based on the assumption of regular hydrological patterns. The predictability of rainfall has therefore played a central role in agricultural planning in terms of crop and soil choices (IPCC 2007). Unfortunately, there is greater uncertainty regarding changes in rainfall than for changes in temperature, and this uncertainty is greater in the LCR than in most other regions of the world. The number of people living in Mesoamerica and South America in water-stressed areas is projected to be 35.7 million (for 2025) and 54 million (for 2050) (Mata and Nobre 2006), but the patterns of rainfall change will be far from uniform, with some areas receiving much more and some much less than they do at present. Even in a relatively small landmass like Chile changes in precipitation patterns may vary greatly, meaning that each watershed will need highly specialized modeling and adaptation design (Bitran 2008).

Adaptation strategies on the individual and institutional levels will reflect both the physical and economic feasibility of available options (IPCC 2007). On an individual level, farmers respond to water scarcity with multiple strategies, some of which were described previously in the section on agriculture. On an institutional level, as precipitation patterns change, it will be critically important to implement policies that ensure that water is used optimally in the areas and activities in which it has the highest value (box 3.2). In virtually every water system thus far analyzed around the world, extensive amounts of water are used on relatively low valued activities, such as growing low-valued crops (see, for example, Howitt and Pienaar 2006; Hurd et al. 1999; Lund et al. 2006; Strzepek et al. 1996). By shifting the water to urban and industrial uses and to high-valued crops, water systems can adapt to large reductions in flow with only minimal losses in welfare. Efficiencies in water use can be achieved through adequate property rights and pricing regimes.

BOX 3.2

Efficiencies and Costs of Water Adaptation Strategies: The Case of Rio Bravo

The effects of reductions in water runoff have been evaluated in the Rio Bravo Basin in Mexico (Mendelsohn 2008). The relative costs of efficient and inefficient adaptation strategies are illustrated by a simple simulation exercise quantifying the economic cost of water shortages forecasted by 2100. Water users include farmers, residences, and industries. In one "maladaptation" scenario, water shortage is accommodated by across-the-board proportional reduction for agriculture, industry, and residential water uses. In another scenario, water is allocated to the highest value uses, as would occur if it were efficiently priced. The economic costs under the former scenario were hundreds of times their size under the latter, underscoring the ability of efficient adaptation policy to reduce the costs of climate change (Mendelsohn 2008).

Institutional innovations are used in a number of countries to improve efficiency in water use. These include water users' organizations, legal institutions to allow trade in water rights, and charges for water use that reflect its scarcity value. These can be viewed as adaptive institutional behavior, which can be built upon in areas where water shortages become more acute. In some cases, transbasin transfers may be useful in dealing with regional scarcity. In the LCR potential for this kind of option exists in the Yacambu Basin (República Bolivariana de Venezuela), Catamayo and Chira Basins (Ecuador and Peru), Alto Piura and Mantaro Basins (Peru), and the Sao Francisco Basin (Brazil) (Magrín et al. 2007).

Water management problems will arise not only in drought-prone areas, but also along coasts where rising sea levels may cause salt water intrusion in aquifers (this issue is further discussed in chapter 2). An ongoing regional initiative by the Caribbean Community Climate Change Center for implementing adaptation measures in coastal zones in the West Indies is assisting countries (Dominica, St. Lucia, and St. Vincent and the Grenadines) in designing specific (integrated) pilot adaptation measures. This includes the development and installation of a reverse osmosis plant powered by wind energy to desalinize water on the Island of Bequia and the design and revamping of key infrastructure in St. Lucia to withstand high intensity hurricanes. The project also involves the conservation and supply of fresh water in the small islands in St. Vincent and the Grenadines. The project seeks to adapt the islands to a scenario of reduced rainfall and increased threat of saline intrusion in local aquifers. The adaptation measures would consist of improving demand-side management in water supply and effective collection of rain water.

Forestry

Forests make up a large part of the LCR's total land area—48 percent of South America, 44 percent of Central America, and 26 percent of the Caribbean is under forest cover (FAO 2005)—and they are an important source of livelihoods for many in the region.

Climate change is already leading to substantial stress on forest ecosystems (Fischlin et al. 2007; Easterling et al. 1993). For instance, the availability of moisture has been reduced, thereby drying out the vegetation that provides the fuel for fire outbreaks. Rising temperatures can also lead to increasing insect outbreaks in a number of ways. First, in many areas warmer minimum daily temperatures allow larger populations of insects to survive the cold season that normally limits their numbers. Second, the longer warm season allows them to develop faster. Third, warmer conditions help expand their ranges into higher latitudes and altitudes. And fourth, drought stress reduces trees' ability to resist insect attacks.

One effective strategy for reducing the incidence and damages of forest fires is to give more control over these resources to local communities that are in a position to monitor them. Adaptation strategies to control insect damage may include prescribed burning to reduce forest vulnerability to increased insect outbreaks, nonchemical insect control, and adjusting harvesting schedules so that those stands most vulnerable to insect defoliation can be harvested preferentially. These proactive measures may potentially reduce the negative economic consequences of climate change. However, lengthy time lags between tree planting and harvesting complicate decisions, as adaptation may take place at multiple times during a forestry rotation.

In contrast with the limited set of adaptation options available for forests, human populations sharing the habitat with the forest and/or exploiting the forest have a wide menu of coping options to confront climate change. A large number of adaptation strategies that require minimal government intervention have been suggested for planted forests, including changes in management intensity, hardwood-softwood species mix, timber growth and harvesting patterns within and between regions, rotation periods, salvaging dead timber, shifting to species or areas more productive under new climate conditions, landscape planning to minimize fire and insect damage, adjusting to altered wood size and quality, and adjusting fire-management systems (Fischlin et al. 2007).

Adaptation can also be reinforced by mitigation strategies aimed at reducing deforestation and forest degradation. Forest conservation involves both biodiversity preservation and climate benefits, which can enhance the adaptive capacity of ecosystems and in turn reduce their vulnerability to climate change. Reducing emissions from REDD and A/R can contribute to short-term adaptation to climate change and foster climate-resilient sustainable development, for example, by retaining moisture, regulating hydrological flows, stabilizing soils and protecting them against erosion, restoring soil fertility, protecting or increasing the supply of timber and nontimber wood products and fuelwood, and so forth. Findings of the U.K. Forestry Research Program show that A/R activities have numerous co-benefits, such as soil conservation and flood control in regions with sufficient water resources. Furthermore, forests increase average water availability in regions with fewer water resources, intense rainfalls, and long spells of dry weather (UK FRP 2005).

This is not to say that trade-offs between mitigation and adaptation do not arise in REDD and A/R activities. With regard to water resources, the adaptation effects of A/R mitigation projects depend on the climate characteristics of the region in which the projects are implemented as well as on the careful selection and composition of the tree species used. There are, for example, documented cases of competition between tree plantations and agriculture in terms of the land and water that are needed. In arid and semiarid regions, A/R activities can reduce water yields. This is an important finding in the effort to align positive mitigation and adaptation effects that has to be considered when planning A/R activities (UK FRP 2005).

Health risks

Although models are still at an early stage of development, many of them agree that the greatest burden of disease related to climate factors will fall disproportionately on low-income countries in the form of increases in infectious diseases and malnutrition. Unfortunately, because higher rates of morbidity and mortality reduce the capacity of poor farmers to adapt to weather risks at the same time as they increase health inequalities, these trends will have additional indirect effects that negatively affect farm household welfare.

Global warming will inevitably produce increased stress from heat, as extreme heat waves become more common (Stott et al. 2004). Rising temperatures and increases in precipitation will have an impact on human and natural systems that goes beyond the economically valuable services they provide. This will be most serious in areas where humans are already closest to their biological maximum tolerance levels, but will be problematic even in temperate climates, as illustrated by the reported 30,000 heat-related deaths in Europe during the 2003 heat wave (UN Foundation 2007). In the aftermath of this heat wave, early warning systems and preparedness programs were implemented in France. Indeed, reviews of the existing evidence show that extreme heat can have negative effects on health. Data—mostly from OECD countries—show strong conditional correlations between heat waves and cardiovascular and respiratory diseases and mortality (Martens 1998). One challenge in adapting to increased heat will be to ensure that the response does not exacerbate the underlying problem by, for example, increasing the demand for electricity for cooling.

The other major health problem foreseen to be exacerbated by climate change is the increase in areas at risk for vector-borne diseases, like malaria and dengue fever in the LCR, and water-borne diseases (Githeko and Woodward 2003). Data from Brazil show that warmer and wetter winters are associated with an increased prevalence of malaria and dengue, whereas infant mortality is very sensitive to the direct effects of higher summer temperatures, in particular in northeastern regions of the country (Timmins 2003). This is particularly critical for previously unaffected poor populations that are at the margin of current distributions of infectious diseases. Typically, these groups lack relevant immunity and have weak public health systems. While there has been little research to date aimed at documenting or analyzing current adaptive behavior on an individual level, some

isolated governmental initiatives have begun in Bolivia (Aparicio 2000) and Colombia (Arjona 2005) with pilot programs in research, vector control, and community education and participation in efforts to control the spread of these diseases. It is clear that key components of a future strategy will involve coordinated medical research, better community-level information, and improved communication through a regional organization, such as the Pan-American Health Organization (Magrín et al. 2007). As part of a health sector strategy, it will also be important to ensure that countries' health systems are adequately prepared (or re-oriented as necessary) to address emerging public health needs and climate-induced changes of the burden of disease.

Ecosystems

As climate changes in each region, the plants and animals native to that region may become increasingly stressed. At the same time, however, other contiguous regions may become more hospitable. In such cases, adaptation can occur through changes in the geographic range in which the organisms live. As temperatures rise, these ranges will generally move away from the equator and/or to higher elevations. Some larger mammals and flying animals (birds and insects) can change ranges relatively quickly through migration. For other animal species and all plants, the process will be slower, as those in the warmer part of the range become stressed and die out due to warming, while others prosper in the contiguous areas which were formerly too cold, but have become more hospitable. Responses to warming are already being observed in the shifting ranges of butterflies and the changing nesting and migration patterns of birds (Parmesan 1996; Bradley et al. 1999; Brown et al. 1999; Dunn and Winkler 1999).

But for many organisms, this kind of automatic adaptation process will not work well. Some are highly specialized to live in a particular location for reasons other than or in addition to its temperature, and warming may exceed their threshold of physiological tolerance in that location. For others, the changes in climate may not produce a hospitable environment in an area contiguous to their current habitat. This would be the case, for example, for organisms already living high in the mountains, with no possibilities to move to a higher altitude; those inhabiting the polar regions; or those inhabiting enclaves surrounded by large areas unsuitable for colonization (for example, coral reefs, or habitats that have become isolated by human development surrounding them). For these, the threat of extinction is high.

Adaptation Policies and Priorities

Research suggests that adaptation does matter, in the sense that losses can be substantially reduced (Mendelsohn and Dinar, 1999; Winters et al. 1998). But while most households undertake strategies to adapt and manage risks, empirical evidence indicates that households, particularly poor, rural households, are only partially able to "insure" themselves against shocks. In addition, poor rural households often lack the human capital and physical assets to adapt and/or facilitate economic mobility across production types and/or sectors. Moreover, in risky environments, in the absence of insurance mechanisms, risk-averse producers may choose less risky, but less productive production mixes, affecting both income levels and growth trajectories. Hence private adaptation with existing mechanisms of support will not be enough to eliminate the expected harmful effects of climate change on Latin American agriculture. Using the Ricardian method, researchers have found that net revenues per hectare in Latin America will likely fall by 10 percent to 50 percent depending on the climate scenario even after farmers undertake autonomous adaptive behaviors (Seo and Mendelsohn 2008). Action by national governments and the international community should aim at minimizing these damages in a cost effective manner. Policies to support adaptation, like those aimed at mitigating emissions, need to be designed keeping in mind the need to promote both efficiency and equity.

Markets will play a critical role in mitigating adjustment costs—for individuals and for the world at large—in several ways. First, prices convey information that will help individuals make the appropriate adjustments. If climate change reduces the supply of a crop, the price of that crop will rise, inducing farmers

to plant more, which in turn will moderate the initial reduction in supply. Similarly, international trade helps moderate fluctuations in prices and quantities of available crops in specific places (Reilly et al. 1999). To the extent that climate change produces different patterns of global production—with some countries increasing and some decreasing production of different products—the patterns of trade will need to shift as well. Of course, there will still be losses but trade can make those losses smaller, and even if there are reductions in aggregate global supply, trade will help diffuse the risks.

Functioning markets and ownership rights also provide the appropriate incentives for investments needed to minimize the costs involved in adapting to shocks, which will often require that resources be moved from one activity to another. Improvements in the functioning of land and water markets are especially important. Individuals farming on common property or on government lands lack long-term incentives to invest in either natural capital or physical capital, and are consequently unlikely to make efficient adaptation choices. Farmers with no access to capital markets also face constraints that may prevent them from adapting fully. Finally, the near absence of water markets in many countries means that water is frequently poorly allocated. All of these institutional failures will impede efficient adaptation.

Designing policies to facilitate adaptation

On a most fundamental level, the idiosyncratic nature of individual adaptation needs—and the fact that most measures taken by individuals in this sphere have minimal external impacts on others—argues that most good policies by governments to support human efforts to adapt in an efficient manner are "facilitative" in nature (Tol 2005). That is, they are nonprescriptive measures that establish a framework for individuals to adjust, but do not direct them how to change behavior, nor subsidize private investments. The high degree of uncertainty involved argues that policy should be flexible over time, easily allowing updating as new information becomes available. The main objective should be to increase options. The point is often made that good development policy is good adaptation policy. Higher incomes and human capital increase resilience to shocks of all kinds and give households the capacity to deal better with change, and the major threats from climate change will manifest themselves over time periods that we think about in terms of development horizons (Callaway 2004b). Important examples of the kinds of policies that meet these criteria would include:

a) Strengthening weather monitoring and forecasting tools

Ex-ante risk-identification, such as weather and crop yield forecasting, can play a key role in restraining the negative effects of weather variability on the well-being of rural households. Yet communities in agricultural areas of the LCR in general do not have access to climate forecasts that have reasonable margins of error and, thus, lack the means to be aware of regional and local weather hazards well in advance and develop their own warning systems. Resources devoted to generate and disseminate this type of information and empower communities will assist localities in assessing the level of hazard associated with specific events and execute local risk-reduction strategies and will induce adaptive behavior at the individual level as well.

Some of the types of information most valuable to reduce uncertainty are an historical climate database, weather monitoring tools, systems for analyzing climate data to determine patterns of intra-annual and inter-seasonal variability and extremes, data on system vulnerability and adaptation effectiveness (for example, resilience, critical thresholds) (FAO 2007). Such interventions are important for the LCR where weather uncertainties are high and where past experience with ENSO events and weather variability has underscored the value of preparedness (box 3.3). But even basic meteorological infrastructure is missing in many countries and current underinvestment is making matters worse (box 3.5).

b) Strengthening households' economic mobility and social protection programs

Enhancing the ability of households to make welfare-enhancing economic transitions in the face of longer-term changes in the external environment can be

BOX 3.3

ENSO and the LCR: Use of Climate Predictions to Respond to Weather Variations

El Niño-Southern Oscillation (ENSO) is the dominant mode of climate variability in Latin America, responsible for considerable variation in both temperature and precipitation, and is the natural phenomenon with the largest socioeconomic impacts. Two extremely intense episodes of the El Niño phenomenon have occurred in the past three decades in Latin America—1982–83 and 1997–98—contributing greatly to the heightened vulnerability of human systems to the increased occurrence of extreme events (for example, floods, droughts, landslides, and so on) (Magrín et al. 2007).

The effect of the 1982–83 El Niño demonstrated the need for reliable seasonal climate forecasts in the LCR. Climate forecasts have been in use in a number of sectors: starting in the 1980s for fisheries in the Eastern Pacific and crops in Peru, and subsistence agriculture in Northeast Brazil since the early 1990s (Magrín et al. 2007). The provision of reliable forecasts jointly with agronomic research has been attributed to a drop in the damage of crops in drought times in areas of Brazil and Peru (Charvériat 2000). A case study in Argentina on the application of seasonal climate predictions to land allocation on farms found that farmers optimize their planting decisions by varying their crop mix for a given reliable seasonal forecast. Maize, soybean, and sorghum yields tend to be lower than normal during La Niña events, while maize is most responsive to increases in rainfall during El Niño events (Hammer et al. 2001).

Recent studies have quantified the potential economic value of ENSO-based climate forecasts and concluded that increases in net return could reach 10 percent in potato and winter cereals in Chile; 6 percent in maize and 5 percent in soybeans in Argentina; and between 20 percent and 30 percent in maize in Mexico when crop management practices are optimized (for example, planting date, fertilization, irrigation, crop varieties). Adjusting crop mix could produce potential benefits close to 9 percent in Argentina. (Magrín et al. 2007)

There are several networks that predict seasonal climate and climate extremes in the LCR. However, there is still limited scope within which they operate as the knowledge requirement for interpreting forecasts in the agricultural sector is limited. Social inequities in access to climate information and the lack of resources to respond can severely constrain anticipatory adaptation in the LCR (Adger et al. 2002).

critical. Strengthening labor mobility and people's ability to make economic transitions through investments in human capital, training, and health and information systems to provide economic opportunities will help households to adjust to the structural changes expected in climate in the long-term. Such measures should help ensure that farmers are prepared to invest in weather-risk management capital, adopt climate-resistant agricultural techniques and inputs, optimally diversify their incomes, and take advantage of emerging farm and off-farm opportunities. Indeed, a recent study found that without labor mobility (that is, without adaptation) changes in climate are expected to reduce agricultural productivity by 18 percent and increase poverty by 3.2 percentage points in Brazil for the period 2030–49. The impacts of climate change on poverty are substantially lower (2 percentage points) when the analysis accounts for adjustments, including migration (Assuncao and Feres 2008).

Well-targeted, scalable, and flexible public safety nets, such as conditional and unconditional transfers, workfare programs (for example, food- or cash-for-work), social funds (community-level programs in infrastructure, social services, training, microenterprises, and so on), or facility-based interventions (for example, fee waivers for school and health) are an important tool to protect households' consumption and investments in education, health, and nutrition, as well as to maintain mobility in the medium- and long run. They comprise much of the equity pillar of a policy response to climate change. Safety nets can help keep the poor from falling into a "permanent poverty trap," from being forced into "low-risk, low-reward,"

production strategies, or liquidation of productive assets in response to a weather shock. Several countries in the LCR have been on the forefront in developing conditional cash transfers as a safety net tool. These include *Bolsa Familia* in Brazil, *Familias in Acción* in Colombia, *Red Solidaria* in El Salvador, and *Oportunidades* in Mexico. The *Atencion a Crisis Pilot*, a program in Nicaragua, was specifically designed to respond to weather shocks. Studies indicate that these programs can be effective means of helping buffer the poor in the face of shocks and introduce the incentives to promote changes in behavior toward optimal risk management prior to a shock and in coping behavior afterward. Social funds have also proven to be a good instrument to respond to climate shocks, particularly when there is damage to physical capital or infrastructure as a result of hurricanes or flooding. These kinds of mechanisms may in the future be adapted for the new needs of climate change (box 3.4).

c) Strengthening ability to manage risk

Strengthening households' and governments' abilities to manage risks, especially weather shocks, is conditioned on the existence of mechanisms for risk sharing. This would include efforts to strengthen both private insurance markets and governments' ability to address specific weather shocks. Globally, the market for agricultural insurance of all types is small, with the LCR second to Asia among developing regions in terms of premiums (Swiss Re 2003). Governments in the LCR can support the development of the index-based weather insurance market by addressing regulatory barriers and making appropriate investments in infrastructure and institutions. One study (EU 2006) to assist the Mexican government in developing its disaster risk management and adaptation strategy emphasized the need to focus more on managing risks by asset protection and prevention, rather than on responding ex post. This has implications for the government budget. The international community can

BOX 3.4

The Insurance Role of Safety Nets: Experiences from Nicaragua and Honduras

Most safety nets are interventions with the specific goal of encouraging low-income households to invest in human capital, health, and productive enterprises. In some cases, these programs are also formulated as expost responses to shocks aimed at protecting the well-being of poor households during emergencies.

However, conditional cash transfers (CCTs) rarely introduce specific incentives aimed at encouraging households to engage in efficient preshock risk management and postshock coping (for example, workshops to promote income diversification and prevent child labor) as a way to isolate their standards of living from risks that remain uninsured.

The experience of Nicaragua provides evidence of a flexible CCT program that directly or indirectly offers insurance to deal with transitory shocks to rural income, including natural disasters. Red de Protecction Social is a CCT that started in 2000 to supplement the income of Nicaraguan households. The program has also produced a sizable decrease in the vulnerability of households to income shocks. An example is the protection offered by the program in the period 2000–03, which marked a sharp economic downturn in Nicaragua, especially for coffee-growing households. Consumption declined by 2 percent for coffee-growing beneficiaries while it fell by more than 30 percent for their counterparts who were not participating in the program (Vakis et al. 2004).

More recently, a pilot (built upon *Red de Protección Social*) was designed and implemented in a drought-prone region in northern Nicaragua. The main goal of the pilot was to reduce rural income vulnerability to uninsured risks related to weather. In addition to this, the *Atencion a Crisis Pilot* was intended to reduce the use of inefficient exante risk management and expost coping strategies, and to improve households' upward economic mobility. As for the impact of the program on short-term vulnerability to shocks, evaluation evidence indicates that the income and consumption of beneficiaries was significantly more resilient to droughts and other natural

(Box continues on next page.)

BOX 3.4
(continued)

shocks, price increases, and health shocks. In addition, the program appears to have improved the use of savings, reduced the use of adverse coping strategies (for example, child labor, sale of physical assets, and reductions in consumption), and promoted more efficient exante risk management through diversification away from agriculture and changes in individual behaviors and attitudes (for example, aspirations and discount factors) that favor investments in human and physical capital.

The pilot program also included a response to a mudslide event in Eastern Nicaragua. This included the introduction of—after humanitarian work—quick transfers to all affected households (approximately three months after the natural event) and the eventual integration of those affected in the traditional CCT (by the sixth month).

The *Atencion a Crisis Pilot* offers operational lessons on how to formulate and implement a CCT that incorporates a specific package to protect households against shocks. To build on accessible resources, they can be integrated with existing CCT systems, which makes it scalable and improves targeting and flexibility to trigger eligibility and waive conditionalities. From a sustainability perspective, such integration can increase the speed of funding and adjustments on the amounts of transfers during shocks. Finally, the program provides insights into solving operational challenges, such as ensuring institutional coordination and capacity among the multiple agents involved in the program that are especially important in the event of shocks (www.worldbank.org/atencionacrisisevaluation and Macours and Vakis 2008).

In Honduras, despite the fact that Hurricane Mitch killed thousands of Hondurans, left a million homeless, and inflicted damage equivalent to two-thirds of GDP, poverty rose only moderately in its wake.

This remarkable reality is attributable largely to the efficacy of the Honduras Social Investment Fund (FHIS), a public program created in 1990 to finance small-scale investments in poor communities. Originally conceived as a response to the adverse socioeconomic effects of structural adjustment policies, FHIS nimbly became an emergency-response program of sorts after Mitch devastated the country in 1998.

FHIS successfully prevented the disaster from aggravating poverty by rejuvenating economic activity and restoring basic social services. Within 100 days of the hurricane, the program approved US$40 million for 2,100 community projects; by the end of 1999, FHIS had financed 3,400 projects, four times the number financed in a comparable prehurricane period. Projects included clearing debris and repairing or rebuilding water lines, sanitation systems, roads, bridges, health centers, and schools, thus hastening national recovery and generating about 100,000 person-months of employment in the three months following the crisis.

The decentralized structure and institutional flexibility of the FHIS enabled its quick and effective response. Building on strong preexisting partnerships with municipalities and communities, FHIS directors established 11 temporary regional offices and quickly delegated resources and responsibilities. Directors reduced the number of steps in the subproject cycle from 50 to 8, established safeguards to ensure accountability and transparency, and effectively accessed International Development Association financing. As an article reviewing program outcomes concluded several years later, "FHIS demonstrates that a social fund can play a vital role as part of the social safety net in times of natural disaster."

provide technical assistance and where needed, financial support. Investments in collecting weather data will lay the foundation for development of the insurance market and will also improve capacity to forecast weather for planning interventions and over the longer term to monitor climate change (box 3.5).

But it has to be recognized that while insurance can help cope with short-term weather shocks—which may become more severe in the future—it cannot compensate for long-term climate trends. On its own, of course, the insurance market will send the appropriate signals—buildings in high-risk areas

BOX 3.5

Weather Insurance Mechanisms

The international donor community has been active in providing technical assistance in a number of countries in the region to help develop the markets for index-based weather insurance. Index-based has many advantages over traditional insurance, including lower transaction costs and lower vulnerability to moral hazard. For these reasons, international companies are more willing to reinsure these policies. Still, development of these markets has not been rapid, as a number of obstacles need to be resolved. One is that insurance markets as a whole are underdeveloped in the LCR. Measured by premiums as percent of GDP, the LCR lags the developing regions of Asia, Africa, and Eastern Europe (Swiss Re 2003). Another is the lack of a regulatory framework conducive to this type of insurance in most LCR countries. A vacuum in weather data is also a problem, which has in some cases become worse over time as weather data collection infrastructure deteriorates. The density of weather stations has been diminishing for most countries in the region, due in part to fiscal constraints in the maintenance of equipment and trained personnel. In Bolivia for example, there are currently about 300 working weather stations out of 1,000 stations a few years ago. Likewise, Jamaica is currently operating about 200 weather stations from a total of 400 in 2004, and similar situations can be found in Guatemala and Honduras.

Source: Arce (2008).

will be charged higher premiums, and this will create incentives not to build in those areas. As climate changes over time, the premium structure will adjust accordingly. But governments must allow this mechanism to function, which may require adjustment of their policies. Government subsidies for insurance to high-risk areas (coastal zones, for example) or activities will reduce the incentives for individuals to exit, as will ad hoc compensation for damages in these areas.

d) Strengthening markets

One of the most critical roles of governments and the international governance architecture will be to ensure that markets continue to transmit appropriate price signals. On a national level, two kinds of markets deserve particular priority because they are currently poorly developed in most developing countries and because they will be especially important in making an adjustment to climate change.

(1) Water markets. Many of the most important impacts of climate change will be intermediated through water availability. As we saw in chapter 2, several regions in the LCR that are currently dry will become even drier, and some that are not considered water-short now may become so over the next 50–100 years. While important today, it will become increasingly critical to make sure that water is used in the areas and activities in which it has the highest value. Yet water rights are currently ill-defined and water grossly undervalued in most countries. In virtually every water system around the world,[5] extensive amounts of water are currently used to grow low value crops. In the LCR, Chile and Mexico have made considerable advances, yet even in these countries, the markets are far from being adequately designed to allocate water to its highest valued use. One background study for this report used a simple illustrative simulation exercise to quantify the economic cost of water shortages forecast for the Rio Bravo Basin in Mexico by 2100.[6] In one "mal adaptation" scenario, the shortage was accommodated by across-the-board proportional reductions in all types of uses (agriculture, industry, and residential). In another scenario, the water was allocated to the highest value uses, as would occur if it were efficiently priced. The economic costs under the former scenario were hundreds of times their size under the latter, underscoring the ability of efficient adaptation policy to reduce the costs of climate change, while not foreclosing complementary measures to address adjustment costs and distributional implications. As noted above, in some

cases, transbasin transfers may be useful in dealing with regional scarcity, as they have been in California. But organizing such transfers will require considerable planning, investments, and in some cases international coordination. Effective international institutions will be necessary not only to facilitate transboundary water trade, but also to improve mechanisms for mediating conflicts provoked by changes in water availability (UN Foundation 2007).

(2) Financial markets. Financial markets play two roles with respect to adapting to climate change. In the short term, they allow individuals to adjust efficiently to shocks through saving and dissaving to smooth consumption. In the longer term, financial institutions are sources of investment capital that will be needed to finance adaptation expenses. While urban areas in many LCR countries are reasonably well served by financial institutions, rural areas—especially small farmers—are generally not, for reasons related to high transaction costs and low ability of such clients to offer reliable collateral. Yet there are good examples of how these barriers can be overcome. Social capital and peer monitoring can be used to good advantage. Using a value-chain approach, for example, FUNDEA in Guatemala finances inputs and outputs for small farmers, accepting standing crops as collateral. Furthermore, public policy can support pilot testing of technological innovations that reduce costs and risks of offering financial instruments to rural small-scale producers. Just as cellular phones can speed market and price information to producers, so-called "mobile or m-banking" now being piloted in Brazil, can also dramatically reduce transaction costs for rural financial transactions.[7] Where necessary, financial regulations may need to be reformed to remove interest rate ceilings and permit institutions to mobilize savings deposits, perhaps via branchless banking, taking advantage of existing post offices, gas stations, and other retail outlets as conduits for rural financial transactions. Stimulating data collection via credit-reporting bureaus can also reduce the current risk premium associated with rural lending, due to information deficits to gauge behavioral risk of potential borrowers. Rural finance for smallholders could also benefit from the creation and expansion of insurance instruments to protect against losses, and in some countries, insurance has been packaged with microcredit.

In connection with the consumption-smoothing role of credit markets, the nature of weather-related shocks has an important policy implication. Weather shocks tend to be highly correlated across fairly large areas. This means that a financial institution with a client base concentrated in one area—particularly a rural area, where many clients rely directly or indirectly on agriculture—is likely to be poorly equipped to deal with a shock, since all of its depositors would need to withdraw savings at the same time. One way to deal with this is to insure the loans against weather risk. The other strategy is to rely on geographic diversification. Regulatory policy can encourage reliance on insurance by, for example, putting a premium on insured loans when calculating capital adequacy ratios. Alternatively (or in addition), it can promote the development of financial institutions with clientele that are not exclusively rural and that are not heavily exposed to weather risks. In small countries especially, foreign banks may be best placed to fill this role, but in any case, regulatory policy could be designed to encourage development of extensive linkages outside of a rural client base.

(3) International trade markets. On an international level, it will be important to ensure that the trade system remains open to allow global markets to play a role in reducing the impact of climate change in many ways. While all the countries that are members of the World Trade Organization (WTO) will play a role, leadership by the high-income countries will be critical in reaching agreement on some of the issues in the WTO that are particularly relevant for helping the world deal with challenges created by climate change.

First, all kinds of barriers to food trade will need to be effectively disciplined. This would facilitate changing patterns of food trade as climate change alters production patterns over the long term, as well as spread the effects of short-term supply shocks and ensure that consumers and producers respond appropriately. With a share of close to 11 percent of world agriculture and food exports, the LCR is currently a major food-exporting region. But some countries may suffer large losses in productivity, leading to dramatic shifts in food trade

patterns inside and outside the region. This issue is therefore of vital concern to the LCR. One of the lessons of the recent precipitous increases in food prices is that when shortages arise, there is a tendency for countries to react with "beggar thy neighbor" trade policies that insulate domestic consumers and producers from international price movements, and in doing so, shift the adjustment costs onto others. This has included ad hoc reductions in import barriers and increases in export barriers, neither of which is effectively disciplined under current WTO rules. Many governments have also responded to the food crisis by focusing on measures to increase their degree of self-sufficiency in food production. In the future, as climate change makes food production increasingly high-cost in some countries, trying to maintain levels of self-sufficiency will likewise become increasingly costly. This underscores the importance of keeping the trade system open in order to give all countries confidence that they can rely on it to supply their food requirements.

Second, barriers to trade in goods and services that help reduce emissions would ideally be eliminated. These are currently being addressed in the Doha Round negotiations, but progress has been limited. Of particular interest to the LCR is the reduction of barriers to trade in ethanol. This is of greatest interest to Brazil, which is the lowest cost producer in the world, but may be important for other countries in the region where ethanol can be efficiently produced from sugarcane. From the dual perspectives of efficiency and effectiveness in reducing emissions, it is in the world's interest to ensure that ethanol is produced where this can be done most efficiently, rather than in countries where it requires large subsidies and high trade barriers. Current trade policies and subsidies in high-income countries have generated huge distortions in agricultural markets, with adverse impacts on poor food consumers worldwide, and at best minimal reductions in carbon emissions.

Finally, the WTO's Committee on Technical Barriers to Trade is already involved in reviewing the increasing number of standards and labeling requirements targeted at energy efficiency or emissions control. It could also play an important role in ensuring that other trade policies—including tariffs levied on the basis of the producing country's emission reduction commitments or environmental regulations—are not discriminatory and do not unnecessarily restrict trade.

Nonfacilitative adaptation policies

Not all adaptation policies are merely facilitative in nature. Some more direct government interventions will be necessary in dealing with public goods,[8] including ecosystems, where the benefits are shared by all and individual payments would be infeasible to organize. Investments to "climate proof" public infrastructure, control floods, protect coastal areas in the face of rising sea levels, or combat public health threats from epidemics fall in this category (box 3.6).

Some regulatory measures may also fall in this category, including land-use restrictions in areas subject to natural disasters, although in some cases, there are more efficient responses than direct regulation (for example, removing subsidies for insurance premiums for flood damage, or subsidies for agricultural production in these areas). Two of the spheres in which these kinds of policies are most relevant for adapting to climate change are natural resource management and technology development and dissemination.

a) Strengthening natural resource management

While individuals will have to make many of the investments to manage changed patterns of water flows, some involvement by government in public aspects of water management will be critical. Since climate change may increase or decrease water flows in specific areas, governments must begin planning for both possibilities. New dams may be required to hold back floodwaters or increasing snow melt. Yet some dams may need to be decommissioned as they may no longer be needed if water flows fall sufficiently. This is one area in which the mitigation and adaptation agendas may intersect—in countries where multiuse dams could help manage flood control while also generating clean electricity. Most important, as noted above, governments need to make institutional changes to facilitate development of internal water markets, and international institutions need to improve mechanisms for mediating transboundary conflicts provoked by changes in water availability (UN Foundation

BOX 3.6

Nonfacilitative Adaptation: In Some Areas, Direct Government Action Will Be Required

Some governments in the LCR have become increasingly aware of the necessity to adapt key networks (road, railway, bridge) and production (agriculture and fisheries) infrastructures to both the observed climate and predicted changes. Since 2003, Argentina's Federal Flood Control Plan has been applied to the development of infrastructure projects including the hydrological recovery of productive lands, flood mitigation in rural areas, as well as road and railway network protection in rural and periurban zones, with a budget of 800 million pesos in the provinces of Buenos Aires, Cordoba, La Pampa, and Santa Fe. In the case of Argentina's Del Plata region, responses to increases in sea and river levels have involved both adaptive and infrastructure measures since the 1980s. Expectations of reduced flows were also incorporated into the design of deeper transport waterways along the Parana River in order to compensate for the possibility of insufficient water levels. Argentina's consecutive flood programs have mainly responded to urban protection and rehabilitation priorities. Infrastructure measures have involved flood prevention through re-conduction and retention of precipitation excesses. However, programs in the rural provinces of El Chaco and Santa Fe, as well as the Plan of Hydrologic Protection in the Islas del Delta, have contributed to mitigating the impacts of flooding on agriculture.

The Mexican government has also implemented public strategies in order to adapt water management to climate changes. In rural areas, water saving systems have been developed especially for the agricultural and fisheries sectors. Adaptation strategy assessments in the highly vulnerable regions of Alto Mezquital and north Mixteca have included different social actors in the design of water management strategies in the area. Water capture and control systems have helped regulate flows and optimize water storage in urban areas. Adaptation projects in Hermosillo, Sonora have taken the first steps in including key actors in the water sector when designing potential adaptation measures.

Uruguay's eastern wetlands are covered by new regulations since they have been designated as Natural Protected Areas. Urban planning legislation and practices have adopted setback requirements for development to 350 meters from the coastline. To preserve coastal ecosystems, Uruguay has demolished illegal constructions (Department of Rocha), built an integrated adaptation strategy (Punta del Diablo), and set good practices and guidelines for land planning projects (Atlantic coast). The Eco-Plata program includes pilot adaptation measures for coastal zone management in two regions of Uruguay. The program also served to create an institutional framework for coastal zone adaptation to climate change as the principal six coastal departments signed a "Coastal Declaration" illustrating their efforts to act jointly. A Global Environment Facility (GRF)-funded program has also developed an integrated management strategy, specifically targeted at the Atlantic coastal zone. Argentina and Uruguay are undertaking a joint environmental, social, and legal assessment of the Rio de la Plata estuary zone in order to facilitate the implementation of a common strategy and management plan.

2007). Investments in preventive measures or reactive measures would depend on country circumstances and priorities (box 3.7), but water resource management will often require planning in entire river basins, requiring government involvement at this level.

Investments will also be needed to preserve ecosystem services in the face of climate change impacts. Magrín et al. (2007) suggest that "biological reserves and ecological corridors can serve as adaptation measures to help protect ecosystems in the face of climate change." A key first step in any kind of effort to help ecosystems adapt is to adequately monitor their current condition and trend. Recent projects to preserve the coral reefs in the Caribbean and protect the integrity of the Mesoamerican Biological Corridor are examples of this kind of effort, which will have to be scaled up in the future (box 3.8).

Helping existing ecosystems adapt to climate change over the next few decades will generally involve reducing other stresses on those systems and

BOX 3.7

Coping with Drought in Northeast Brazil: The Role of Government

The Brazilian semiarid northeast region extends over 18 percent of the national territory and it houses one-third of the country's population (Lemos 2007). The recurrent droughts in the region have challenged the ability of the local and national governments to design effective and efficient policies to mitigate the effects of local climate shocks. Moreover, the repeated occurrence of droughts, with their recessionary effects, has also been found to worsen regional inequalities (Chimeli et al. 2008).

The State of Ceara is representative of the Brazilian semiarid region—95 percent of the state territory is classified as semiarid and a large portion of its population, consisting mainly of subsistence farming families, is highly vulnerable to the effects of drought. The State of Ceara provides a good example of innovative drought-related policy making and improvement in governance, which is essential for the successful use of climate information in the implementation of welfare-improving policies (Chimeli et al. 2008).

For more than a century, local and federal governments have attempted to alleviate the negative effects of drought in the region mostly by managing risk rather than addressing deeper causes of vulnerability to drought. Because early on public officials equated drought to water scarcity, most of the emphasis to respond was concentrated around two actions: (1) increase the region's capacity to store water by construction of waterworks, such as reservoirs and dams, as well as by investing in climate-related data collection and science; and (2) invest in post-disaster emergence relief by funding food and water distribution programs, as well as state-financed work programs for drought victims. The two approaches were not effective in decreasing long-term vulnerability to drought and contributed to a vicious cycle of clientelistic politics related to drought response in the state (Lemos 2007).

By 1987, rather than emergency actions, the state government decided to focus on long-term projects associated with communities. The state created a new integrated drought relief management that attempts to address corruption and inefficiency through the inclusion of stakeholders in decision making, the implementation of institutional arrangements that hold both organizations and public actors more accountable, and the systematic use of knowledge to support response to drought.

Among other approaches to respond to drought, the state is trying new initiatives, such as small farm crop insurance for those who lose 50 percent or more of their crops to drought, access of small farmers to rural extension services, and more lucrative crops targeting export markets. Another initiative is related to the use of weather forecasting. During 1992, based on the forecast of dry conditions in Ceara, it was recommended that crops better suited to drought conditions be planted and this led to reduced grain losses (67 percent of the losses recorded for 1987, a year with similar rainfall but without climate forecasting). The production of vegetable oils from native plants (for example, castor bean) to supply the biodiesel industry has been proposed as another adaptation measure (Magrín et al. 2007).

Recently, the Brazilian government launched the Action Plan for Adapting to Drought in the State of Ceara, targeting 152 of the 177 municipalities in the state. These municipalities were chosen by the National Civil Defense, based on the Municipal Alert Indicator (MAI). The MAI takes into account harvest losses, productivity, climate, distribution of precipitation, water storage, soil aridity, and families targeted by social programs as its main indicators for prioritizing action. The action plan includes immediate responses to drought as well as more medium-term responses—it guarantees food and hydrological security and it dedicates funds to the construction, enlargement, or renovation of dams, wells, cisterns, and canalizations across the 152 municipalities.

attempting to optimize their resilience. Reducing existing stresses is a reasonable strategy for the present, and other potential strategies can be identified for the future (box 3.9). It will be critical for the institutions responsible for managing these ecosystems to collaborate more on larger regional strategies than they currently do.

As demonstrated by the approach of the Nariva project (box 3.9), in some cases it will be possible to address two issues at once through projects that both

BOX 3.8

Monitoring Is the First Step in Designing Assistance for Ecosystems' Adaptation

In the case of coral bleaching, Strong and Causey (2007) have argued that integration of remote and in situ sensors is essential to coral reef observations. Yet very few in situ sensing stations are providing near real-time data. As part of an ongoing project, the Caribbean Community Climate Change Center (CCCCC), with cooperation from NOAA and the World Bank, has installed a CREWS station[9] and several sites are being observed using standard protocols. The CREWS station is installed in Jamaica and is now operated by the CCCCC and the Center for Marine Resources of Jamaica. These observations and those by others are providing solid data on the extent of the crisis for the coral ecosystem in the Caribbean Basin. An analysis of the economic and ecological consequences of coral bleaching is under way.

Another adaptation assistance initiative to improve monitoring capabilities, funded by the Global Environment Facility, focuses on the issue of glacial melt in the Andes and on countries most affected by it, including Bolivia, Ecuador, and Peru. A network of nine glacier monitoring stations, complemented by satellite images using the ALOS (Advanced Land Observation Satellite), is being implemented to aid in the analysis of glacier dynamics. The field stations will continuously monitor weather and hydrology. The ALOS will use its sensors (PRISM, ALVNAR, and PALSAR) to photograph and radiograph the same glacier areas. The network will target glaciers that provide water regulation to major cities or are of major relevance for agriculture or energy supply. The system will complement existing regional efforts made by the International Bank for Reconstruction and Development (IBRD) of the World Bank and others. This and other information will then be integrated and used in the detailed design of selected adaptation measures; implementing regional and strategic adaptation pilots to address key impacts from rapid glacier retreat on selected basins; and supporting continuing observation and assessment of glacier retreat and the associated impacts on the region.

help ecosystems adapt and sequester carbon. The importance of looking for these kinds of synergies, especially in forest conservation, is underscored by a case study of adaptation needs in Chile (Bitran 2008). Here, some of the heavily forested areas in certain regions of the country are likely to suffer from a significant reduction in rainfall. More than 300,000 hectares of forests (mainly used for forestry) are vulnerable. Bitran (2008) finds that a wholesale dieoff of this much forest would release carbon equivalent to five years of losses of native forests in all of the LCR, at current rates. It is therefore critical to find ways to maintain a viable forestry industry here, perhaps through the introduction of drought-tolerant transgenic varieties.

b) Strengthening technological linkages and knowledge flows

While technologies and knowledge systems are available to achieve higher and more stable yields and to better manage natural resources, both of which are necessary for long-term adaptation, their adoption and sustained use has generally been limited to locations with favorable production environments, strong supporting rural institutions, and good governance. In more environmentally or economically marginal areas, which generally coincide with dryland areas, the uptake of agricultural innovations that could support better climate risk management and adaptation has been limited (World Bank 2008).

Farmers in temperate regions should be able to adapt to warmer temperatures using existing varieties that are currently grown in more tropical zones. That is, varieties grown in warmer climates can be adapted to warming environments, moving from low to high latitudes. This assumes that trade and regulatory regimes are open to such technology transfer. One issue that governments need to consider is whether their regulations governing introduction of new varieties (both genetically modified organisms [GMOs]

BOX 3.9

Managing Ecosystems in the LCR: Ongoing Projects

To help the region's countries be better prepared to respond to the ecosystem and livelihood threats posed by climate change, several adaptive projects are currently under way, funded by the UNFCCC through the Global Environmental Facility, as well as by national and multilateral agencies. In the Latin America and the Caribbean Region, a currently ongoing Capacity Building Project, supported by the UK Hadley Centre, aims to help increase the adaptive capacity of Cuba, Mexico, and countries in Central America.

An example of the potential combination of the mitigation and adaptation objectives in the LCR is illustrated by a project aimed at triggering carbon sequestration through the reforestation and restoration of the Nariva wetlands ecosystem. This will be achieved by restoring the natural drainage regime as well as natural and forced recovery of original vegetation cover. The water management aspect of the project is designed to identify the land form composition of the Nariva swamp area, develop criteria to select high priority restoration areas, and pursue natural and engineered drainage options to accelerate the restoration of the area's ecological functions. The reforestation program would entail reforesting between 1,000 and 1,500 hectares using species strictly native to Nariva. The appropriate use of swamp forest or rainforest species will be determined by the water level and extent of the flooding once the surveys provide soil elevation information and the hydrologic conditions have been rehabilitated (Vergara 2005).

Through its Integrated National Adaptation Program, Colombia is implementing specific pilot adaptation measures in order to meet the anticipated impacts of climate change on high mountain ecosystems and insular areas. This has become a standard for adaptation work in the region and has influenced the design of adaptation measures under other initiatives. Data generated by the project are assisting in the development of adaptation measures for water supply to mountain cities dependant on highland water supplies and the development of options to strengthen the resilience of power sectors in the region.

Adaptation to climate impacts in the Gulf of Mexico wetlands has been formulated to reduce vulnerability to the anticipated impacts of climate change on Mexico's water resources, with a primary focus on coastal wetlands and associated inland basins. More specifically, the project seeks to identify national policies to address the impacts of climate change on water resources at the national level, to evaluate current and anticipated effects of climate change on the integrity and stability of the Gulf of Mexico wetlands, and to implement pilot adaptation measures to protect their environmental services from the impacts of climate change.

Adaptation measures aimed at protecting the environmental services offered by the Las Hermosas Massif in the moorlands of the central region of the Andes in Colombia have focused on increasing the buffer zone of Las Hermosas National Park, strengthening the protection of riparian vegetation, changing agricultural practices to reduce other stresses into surface waters, providing incentives for restoration of natural habitat, and strengthening protection for megafauna in the area.

and non-GMOs) should be revised in light of the increased value of technological "spill-ins" from abroad.[10] The cost-benefit calculus on which these regulations are based could be profoundly affected by climate change. But to the extent that existing varieties can in general satisfy the needs of farmers in areas that are not at the extreme ranges of crop tolerances, these conditions should not be the major focus of research and development of new varieties.

But addressing the productivity limitations for crops that are currently being grown in areas close to their thresholds of temperature tolerance is a challenge (box 3.10). Many crops in the LCR are grown in very thin temperature and rainfall ranges and may be susceptible to these threshold effects (Baez and Mason 2008). In such cases, research should focus on the threshold. However, technological improvements take time to materialize and are

BOX 3.10

Bridging the Gap between Climate Change and Agricultural Technology: Embrapa

The Brazilian Corporation for Research in Agriculture (Embrapa) is developing genetic varieties of crops that are more tolerant to high temperatures and water deficit (soybean, maize, cowpea bean, coffee, cassava, tropical fruits) as well as to diseases and pests (cassava and banana hybrids). Efforts have been concentrated on crops, such as cassava, that are naturally more resistant to environment stresses, cultivable all year, and present ample adaptation capacities. Biotechnology can help crops deal with climate stresses and increases in temperatures up to 2°C. Above that temperature, the efficiency of genetic improvements will be limited as it will hinder photosynthesis (Assad and Pinto 2008). It has also identified five plants typical of the Cerrado region's biome in order to isolate the genes which contribute to their adaptive capacity for the preservation of the region's biodiversity (Assad and Pinto 2008). The unit has also integrated agricultural and livestock breeding for the renewal of grazing lands with the objective of reducing climate-related harvest losses.

Furthermore, Embrapa is helping the Roraima region adapt its agricultural irrigation systems to increasing drought and fire outbreaks. The Acre region's research unit has developed a methodology for the sustainable resettlement of agriculture in the Amazon region by developing alternative production systems in agriculture and livestock farming, agroindustries, and forest harvesting activities. The Rondonia regional research unit is generating, adapting, and diffusing technologies for the development of agroforestal systems and the recovery of degraded areas. It has introduced numerous annual and perennial fodder cultivars; developed sustainable management techniques for agriculture and livestock breeding; and provided the regional demands for soil, plant, and seed analysis.

costly. Changes in technology imply R&D costs, along with the costs of farm-level adoption, including possible human and capital investments. It can take between 5 and 10 years for new varieties to be developed and released, and perhaps even longer for them to be adapted to specific agroecological conditions (see box 3.10).

Climate change also poses a threat to the sustainability of agricultural markets and the underlying investments, especially in high-value products. Some of the best high quality coffee areas in Colombia will become unsuitable shortly after 2020, with fundamental changes in the principle coffee growing regions by 2050. Models predict that quality is the first to be compromised as the climate changes, followed by associated losses in productivity (Lane and Jarvis 2007). Hence, marketing channels will need to adapt to changing production patterns, unless technology can preserve the existing patterns.

The World Development Report 2008 emphasizes the need for sustainable technologies in LCR countries to increase productivity, stability, and resilience of their production systems and confront climate change. A broad basket of technologies is available in many countries in the region, though often they only partially satisfy market demand or user needs. Public expenditure and private investment in research and development must increase, and partnerships with the private sector, farmers, and civil society must be strengthened in order to stimulate user demand for R&D, increase market responsiveness and competitiveness, and ensure that the rural poor benefit from technological interventions. Greater and diversified investment in agricultural R&D is essential for an effective transformation of traditional, low productivity agriculture into a modern commercial sector (World Bank 2006).

Prioritizing adaptation policy measures

Many of these policies and investments—both facilitative and nonfacilitative—are "no regrets" in the sense that they are supportive of broader development goals, even in the absence of considerations of climate change. This is certainly true of policies and investments that make markets work better, increase the capacity of individuals to respond to shocks and efficiently manage

risks, or improve the management of natural resources (box 3.11). The possibility that a changed global climate may magnify the payoffs from such measures simply moves them up in the ranking of priorities, but they would be good policy in any case. Other kinds of measures, the benefits of which depend primarily on predicted changes, may be approached more cautiously. In their evaluation it will be useful to account explicitly for the uncertainty and the value of waiting through the use of such instruments as real options analysis. This will automatically result in more built-in flexibility and modularity.

A sensible first step in development of an adaptation strategy for governments could be to sort policies and required investments into three categories:

1. "No regrets" options: undertake immediately. Of course, the fact that these "no regrets" measures have not been undertaken already may mean that they run afoul of vested interests and will be politically sensitive. But the specter of climate change raises the profile of these issues and may facilitate politically difficult decisions.
2. Those that require decisions soon because they have long-term or irreversible consequences or

BOX 3.11

Developing Response Strategies to Reduce Vulnerability of Agriculture to Climate Change

The linkages between predicted climate impacts on agriculture and planned policy interventions are not well defined. They are, however, critical for development and the alleviation of poverty in rural populations that are dependent on agriculture for their well being, as well as for the design of investment strategies and their effective implementation. In order to formulate adaptation strategies or design mitigation approaches, a careful assessment of the linkages between climate factors, and changes in agricultural systems and public responses is required, focusing on specific agricultural production environments within which climate changes and preferred policy responses may vary.

In collaboration with local agricultural institutions, ongoing analytical work is emphasizing the development of a methodology for assessing the scope of agricultural vulnerability to climate change and for formulating the least-cost response strategies across three diverse agricultural production systems representative of Latin America, each having different response capacities to weather variations—drought prone areas (for example, Yaqui Valley in the State of Sonora in Northern Mexico), high mountainous systems (for example, Mantaro Valley in the Peruvian Andes), and favorable high-potential areas (for example, southwestern provinces of Uruguay). This "bottom-up" methodology is based on review of the best available information on climate change in the area, expert opinion elicited in a series of locally held workshops, systematically ranking the identified response options, and designing action plans that reflect the specific characteristics of a given agricultural production environment and the demands of local actors in the context of climate change.

Many of the response options that emerge across the three diverse production environments are similar. Among other things, they point toward investments in (1) *water management technologies* (for example, water harvest, drainage, distribution, and so on); (2) *climate information technologies* (for example, systems for climate predictability, such as early-warning systems, developing capacity for longer term projections, and agroclimatological information and its accessibility by producers); (3) *technological innovations* (for example, use of conventional breeding and biotechnology for drought and pest and disease resistance) and *designing production systems that minimize climate risk* (for example, conservation agriculture, crop and pasture rotations, adjustment of planting dates, and so on); and (4) *agricultural weather insurance*, that is, design of different insurance mechanisms that address both weather variability and catastrophic events that affect agricultural production. While the categories are similar, the specific interventions within each area vary depending on the characteristics of the area.

Source: World Bank. 2009. "Building Response Strategies to Climate Change in Agricultural Systems in Latin America." World Bank, Washington, DC.

have long gestation periods (for example, beginning long-term institution building, discouraging continued construction in areas that are likely to be vulnerable, undertaking basic research, biodiversity projects)[11]: begin to study options immediately if adequate information is not currently available, with the objective of making decisions in the near future.

3. Others that do not fall into the categories above: decisions can be deferred. Given that the worst impacts of climate change will occur gradually over a long period of time, the planning horizon for many investments in adaptation can likewise be long.

Designing payment mechanisms to facilitate adaptation

Adaptation is not costless. Tol (1998), reviewing various studies, estimates that the share of adaptation costs in the total costs imposed by climate change may range between 7 and 25 percent. Timing is critical for some adaptation policies and investments to ensure that funds are spent efficiently. Adaptation has to take into account the pace and direction of climate change. If investments are made too early, they are more costly (that is, money is spent before needed) or ineffective (adapting to impact that does not occur). Callaway (2004a) refers to this as the "cost of precaution." If they are made too late, there will be (avoidable) damages from climate change, Callaway's "cost of caution." Since more information becomes available over time, "precautionary" mistakes are less likely the longer decisions are deferred, but the trade-off is that the "cautionary" mistakes become more likely. The fact that there is great uncertainty over very long time horizons, with even more uncertainty in the LCR than in other regions, underscores again the value of maintaining flexibility. "Real options methodologies" or other nontraditional ways of evaluating costs and benefits of investments and policies, which take explicit account of the implications of uncertainty, can become more useful in the future (box 3.12).

It will, of course, be necessary to ensure that projects are well chosen and transfer mechanisms are designed to get the maximum economic impact. As noted previously, most private investments in

BOX 3.12

Real Options Methodologies

Real options analysis is a recently developing field of inquiry at the frontier between economics, operational research, and statistics. The real option methodology is based on the idea that, because an investment commits scarce resources in an irreversible way under uncertainty, the project can be evaluated as a set of compound options.

The methodology has recently been applied to evaluate adaptation to climate change in agriculture and irrigation water management practices in the Rio Conchos Basin in Northern Mexico, a large trans-boundary river in an arid region facing high growth. The project consists of the substitution of a more efficient irrigation system for the current expensive one and the move to higher value horticultural crops. Both changes, however, are not currently justified from an economic point of view and would require different circumstances in terms of water costs and output prices to warrant project adoption under the ordinary cost benefit tests.

The use of the real options methodology allows us to consider the contingent value of the project as an instrument of adaptation to climate changes. These changes will indeed warrant the undertaking of the project, if the aridity of local climate, the scarcity of water, and the increasing danger of water contamination reach critical threshold levels. By using the traditional test, this conclusion would be reached only on an ex-post basis. Real options analysis allows us to consider the problem from an ex-ante point of view through the use of extended cost-benefit tests, incorporating the contingent assets and liabilities associated with the situation with and without the project.

Source: Scandizzo (2008).

adaptive responses have relatively few externalities and so private incentives for many investments in adaptation are broadly aligned with those for society as a whole. This conclusion could be changed when individuals have imperfect information or liquidity constraints, or when governments implement policy measures that alter the incentives. (For example, if the government gives compensation for flood damage, the incentive to invest in protection is correspondingly reduced.) But the basic principle remains valid that, across a broad range of private adaptation activities, the need for subsidies in order to match individual incentives to those of society is much less than for mitigation activities. This, in turn, implies that investments for adaptation should not be subsidized, at the risk of encouraging "overadaptation" beyond the economically efficient level.

International transfers to support adaptation

The same principle applies at the international level. Most adaptation actions undertaken by national governments have few, if any, external impacts on other countries or the world at large. It does not follow, however, that individual adaptation measures in developing countries should not benefit from external funding, but the reasoning above has implications regarding both the rationale for doing so and the mechanisms for administering it. There are powerful arguments grounded in equity considerations that developed countries—which bear primary responsibility for the greenhouse gases that are causing global warming—should subsidize the consequent adaptation costs in developing countries. But economic logic dictates that these transfers should not be used to lower the price of private investments. Rather, funding for human adaptation efforts would be more efficiently used to underwrite investments in public goods and in safety nets, preferably through some kind of lump-sum transfers to those most vulnerable to the effects of climate change. Transfers will also be needed to support biodiversity preservation and ecosystem adaptation of global significance.

Technology transfer can play an important role in resource allocation. Technology transfer can include "hard" forms of technology (new irrigation systems, drought-resistant seeds) or "soft" technologies (insurance schemes of crop rotation patterns), or they can involve a combination of both (early warning systems that combine hard measuring devices with soft knowledge and skills that can raise awareness and stimulate appropriate action). Mexico is combining soft and hard technologies in the development of risk atlases and early warning systems, which have resulted in greater attention and resource allocation to risk prevention (UNFCCC 2006a).

International funding may also need to be directed at generating international public goods (for example, research) or at resolving international problems created by climate change. Support for international research will be important in many areas, including climate change itself and responses to maintain agricultural productivity. In the latter sphere, private seed companies are investing significantly in developing varieties, including GMOs, with characteristics needed to cope with changing climate conditions, but cannot be expected to focus on open-pollinated varieties that would be most useful for small-scale producers in developing countries. For this, the Consultative Group on International Agricultural Research (CGIAR) centers will be required (box 3.13).

Effective international institutions will also be needed to mediate disputes over riparian rights, which are likely to increase in number and intensity as water availability is reduced in some areas. Whether existing institutions are adequate for the task will need to be considered by the international community. Climate change also has the potential to create large numbers of external "environmental refugees," as did Hurricane Mitch in Central America (Glantz and Jamieson 2000), which will need to be dealt with on an international level.

The international community can play a role in the development of mechanisms to strengthen governments' resilience to shocks by intermediating risk transfer to global insurance markets. This is already being done by the recently created Caribbean Catastrophe Risk Insurance Facility (see box 3.14), and the feasibility of a similar institution serving Central America is being explored.

BOX 3.13

Private and Public Agricultural Research for Climate Change: It Takes Time

Predictions of the impacts of climate change paint a picture of both increasing and decreasing suitability for agricultural production across Latin America. New agricultural technologies can also contribute by either mitigating the negative impacts or by optimizing new opportunities provided by a changing climate. Development and cultivation of new crop varieties is one example of agriculture's adaptation to climate change. The private and public sectors (including international research organizations) play an important role in delivering climate-resilient varieties. Private companies (for example, Monsanto, BASF, Pioneer) are developing transgenic and conventional drought tolerant varieties of maize that achieve yield improvements of 8–10 percent in water-stressed environments. The Drought Tolerant Maize for Africa Project is a strategic public-private alliance led by the International Maize and Wheat Improvement Center that has seen yield improvements of 20 percent to 50 percent in low-yielding areas of Sub-Saharan Africa. A similar effort focused on Latin America could have a substantial payoff in maize yields of smallholder farmers (100 kilograms per hectare per year of investment). However, this would require that similar breeding approaches, like the ones developed for Africa, need to be implemented for Latin America. Investments have to be made in Latin American-adapted maize varieties and cannot be transferred from other regions. Such investments can take a long time to materialize—from 5 to 10 years from development to launching of a new maize variety. For example, it has taken the International Center for Tropical Agriculture more than 20 years to develop and release drought tolerant bean varieties in Central America. Hence, to successfully adapt to future climate changes, investors in agricultural research need to consider the large time lag between investment and impact in the field. Effective breeding programs must be carefully planned to ensure that the varieties are still useful in 10 to 15 years when they are released.

Sources: Zahniser (2008); Baenziger et al. (2004); Lane and Jarvis (2007).

BOX 3.14

The Caribbean Catastrophe Risk Insurance Facility (CCRIF)

Insurance coverage relies on parametric techniques; payouts are calculated based on the estimated impact of an adverse natural event on each government's budget. The estimated impact is derived from probabilistic catastrophic risk models developed specifically for the CCRIF. Participating countries will receive compensation proportional to the losses from the predefined events depending on the level of coverage agreed upon in the insurance contract.

The CCRIF is an independent legal entity acting as intermediary between the participating countries and the international financial markets. The CCRIF is registered in the region and is under the supervision of the participating donor and client countries. All functions in the day-to-day operation of the CCRIF are subcontracted to specialized firms, with general operating expenditures (other than reinsurance activities) expected to remain below 5 percent of premium volume.

Donor support to the CCRIF is essential to ensure its financial viability and long-term sustainability; contributions are to finance the initial capital and its operating expenditures during the first few years of operation. To facilitate the channeling of funds from donor agencies to the CCRIF, the World Bank established a multidonor trust fund. The World Bank, as administrator of this multidonor trust fund entered into a grant agreement with the CCRIF.

CCRIF was able to secure US$110 million of claims paying capacity on the international reinsurance and capital markets. The reinsurance structure consists of

(Box continues on next page.)

BOX 3.14
(continued)

four layers: CCRIF retains the first layer of US$10 million; reinsurers underwrite the second (US$15 million) and third layers (US$25 million); the top layer (US$70 million) is financed with reinsurance (US$50 million) plus US$20 million coverage through a catastrophe swap between the World Bank (IBRD) and CCRIF. The IBRD hedged its risk through a companion catastrophe swap with Munich Re. The US$20 million swap between the IBRD and CCRIF is the first transaction to enable emerging countries to use a derivative transaction to access the capital market to insure against natural disasters. It is also the first time a diversified pool of emerging market countries' catastrophe risk is placed in the capital markets.

As of June 1, 2007, a total of 15 Caribbean countries had purchased catastrophic insurance for a total premium of US$17 million and total coverage of US$444 million. This high level of enrollment allows the CCRIF to efficiently diversify its portfolio and thus access reinsurance on better terms. Reinsurance capacity of US$110 million has been purchased on the reinsurance market which, with the initial US$10 million retention, ensures that the CCRIF could sustain a 1-in-1,000-year event.

Source: http://www.ccrif.org/.

Annex

TABLE 3.2
Current and Projected Future Changes in Runoff in Latin America and the Caribbean Region

	Projected[a] change in average runoff (mid-twenty-first century)				Model Agreement[c]	
		Portion[b] of region for which change is projected to:				
Region	Mean change (% of current average annual runoff)	Decrease by more than 10%	Remain within +/– 10%	Increase more than 10%	% of cells where 50% of models agree	% of cells where 80% of models agree
Northern Warm Temperate	381	1.63	–6%	51%	49%	0%
Northern Equatorial	1224	0.70	–9%	83%	16%	1%
Brazil—Arid	13	2.23	–9%	4%	96%	0%
Arid	6	6.42	–1%	52%	34%	14%
Polar	183	1.19	–2%	35%	60%	4%
Southern Equatorial	1003	0.62	–1%	16%	80%	4%
Southern Warm Temperate	311	1.14	7%	21%	46%	33%
Entire Region[d]	729	1.00	–3%	27%	56%	17%

Source: Table adapted from the World Bank Water Anchor "Water and Climate Change: Hydrologic Drivers and Potential Impacts," December 17, 2007.
Note: a. Estimates of projected change in runoff were determined by averaging the results of Milly et al. (2005) (an analysis of the runoff output of 12 climate models run under the IPCC's SRESA1B emissions scenario, provided as gridded output at the 2.5° longitude x 2.0° latitude scale) over the grid cells that comprise each region.
b. The projected changes in runoff were divided into three categories. The percent of grid cells within a particular region that fall into each category is reported.
c. Model agreement refers to whether or not multiple models project a change in the same direction (that is, increase or decrease in runoff). Twelve different climate models were included in the analysis by Milly et al. (2005). For each grid cell, as few as 6 models may agree on the direction of change (that is, half the models project an increase and half project a decrease), and as many as 12 models may agree (that is, all models show an increase or all models show a decrease). Presented here is the percent of grid cells within a region that have poor model agreement (6 out of 12 agree) and that have moderate to good agreement (10 or more models agree).
d. Mean values for entire region were calculated for all grid cells in the region; note that this is not the same as the average of the 7 subregions table adapted from World Bank Water Anchor "Water and Climate Change: Hydrologic Drivers and Potential Impacts," December 17, 2007.

Notes

1. A Mexican farmer once told an interviewer that the product that generated the most reliable, climate-invariant stream of income was the son he had "planted" north of the border.

2. http://en.wikipedia.org/wiki/El_Ni%C3%B1o-Southern_Oscillation.

3. Regressions accounting for endogenous migration, capital-intensity in the agricultural sector, assets, and access to credit yield similar parameter estimates.

4. Interestingly, the paper shows that these marginal impacts are less severe in rural areas that use capital more intensively, indicating that there is scope for some agricultural technologies to lessen the impacts of weather risk.

5. See, for example, Howett and Pienaar (2006); Hurd et al. (1999); Lund et al. (2006); and Strzepek et al. (1996).

6. Mendelsohn (2008b).

7. Bresnyan and Werbrouck (n.d.).

8. "Public goods" is used here in its economic sense to mean goods or services that by their nature provide broadly shared benefits, for which the provider is unable to charge individual beneficiaries. Many goods which are commonly financed from the public budget are not in this sense "public goods."

9. NOAA developed the Coral Reef Early Warning System (CREWS), an integration of meteorological and in situ oceanographic instrumented arrays (buoys and dynamic pylons) employing artificial intelligence software to monitor corals for conditions theoretically conducive to coral reef bleaching (Hendee et al. 2001).

10. Gisselquist et al. (2002) find that overly restrictive seed regulations interfere with technology flow, particularly in some developing countries.

11. A similar point is made by Smith, J. 1997. "Setting Priorities for Adapting to Climate Change," *Global Environmental Change*. http://www.sciencedirect.com/science/article/B6VFV-3SX4MFH-4/1/dd1ab9c8cc98880fc248b4348af1ec58.

CHAPTER 4

Mitigation Efforts: Moving Beyond the First Generation of Emission Reductions

Despite the various uncertainties involved in estimating the costs and benefits of mitigating climate change, the available scientific evidence underscores the urgent need for stepping up current climate mitigation efforts. Indeed, if current emission trends are maintained, there is a significant downside risk of high rates of global warming during the present century, which could in turn lead to potentially catastrophic impacts on human and natural systems. As argued in chapter 1, in order for climate change mitigation efforts to be both effective and efficient, they would necessarily have to encompass reductions in GHG emissions in industrialized *and* developing countries. In addition, a global deal on climate change would have to explicitly incorporate equity considerations both with respect to the territorial origin of emission reductions, as well as their payment.

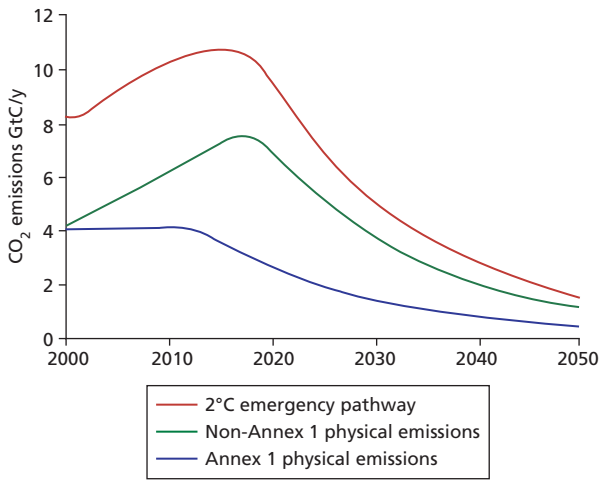
This chapter reviews these various challenges. In particular, we first discuss the equity and efficiency challenges of the climate regime and highlight the role of climate finance in facing these challenges. We then examine the possibility of employing a gradual approach to developing countries' participation in global mitigation commitments. We review the LCR's participation in the CDM over the past nine years and argue that a second generation of mitigation efforts that is policy based and sectorwide may require additional financial instruments. Finally we point to the inclusion of reduction of emissions from deforestation and level degradation, and incentives for the transformation of the energy and transportation sectors as being crucial to fully realize the mitigation potential of the LCR.

The Need for a Truly Global Agreement

Because of the scale of the emission reductions that are required, an effective global agreement to mitigate climate change will necessarily have to involve both industrialized and developing countries. This is the result of the simple arithmetic of the situation. To illustrate this, consider, for example, an aggressive emission reduction scenario that allows for maintaining a low likelihood of global temperature increases above the 2°C threshold. The Stockholm Environment Institute (SEI 2007) calls this scenario the "2° emergency pathway." The expected emission reductions that would be needed in order to stay within this scenario are illustrated in figure 4.1, for the world as a whole as well as for industrialized (Annex I) and developing countries (non-Annex I).

The red line shows the trajectory for global CO_2 emissions, which would peak by 2015 and then drop by 80 percent below 1990 levels by 2050. This would allow for CO_2 concentrations to peak at about 470 CO_2e ppm. The blue line in figure 4.1 shows a possible emission trajectory for industrialized countries in which their emissions would peak by 2010 and then decrease by 6 percent annually, thus dropping to

FIGURE 4.1
Climate Stabilization Paths



Source: Reprinted with permission from the Stockholm Environment Institute (2007).

90 percent below 1990 levels by 2050. The trajectory is much more stringent than the mitigation proposals that are currently being considered by several industrialized countries—for example, in June 2007, the Group of 8 (G-8) countries agreed to reduce their GHG emissions by 50 percent by 2050—so it is deemed "just barely" politically plausible by the Stockholm Institute.[1] The green line is the arithmetical difference between the global maximum emissions that would be needed to meet this target (red line) and the emissions that would be generated by industrialized countries (blue line). That is to say, it would be the remaining emission "budget" faced by developing countries. Thus, in addition to current development challenges—for example, 1.5 billion people without electricity, 1 billion without access to fresh water, and 800 million chronically undernourished—poor countries would face the additional daunting task of having their GHG emissions peak before 2020 and to drastically reduce them thereafter, not only in per capita but also in absolute terms.[2]

One could argue that the above scenario is perhaps too stringent. Consider, then, the more conservative hypothetical target of stabilizing GHG concentrations between 535 ppm and 590 CO_2e ppm, which would be associated with temperature increases of about 3°C with respect to preindustrial levels.[3] What would it take to meet this kind of stabilization target? The IPCC estimates that by 2050 global emissions would have to fall to a range from 30 percent below to 5 percent above their 2000 level. On a per capita basis, and for the world as a whole, emissions would have to be reduced from about 6.9 tCO_2e in 2000 to between 3.2 and 4.8 tCO_2e in 2050. For developing countries, which in 2000 emitted 5 tCO_2e p/c, converging to the average global level of per capita emissions required to meet this target would imply stabilizing at about their current level of emissions per capita or, in a worst case scenario, reducing their emissions by about 36 percent by 2050. Moreover, to the extent that the developing world's share in the world's population would increase from about 80 to 90 percent during this period, the emissions reductions that would be required in developing countries would be largely independent of the stringency of the emission reduction targets taken on by industrialized countries. Thus, for example, even if rich countries were to reduce their emissions to zero—from their current 14.3 tCO_2e p/c—developing countries would still need to reduce their own emissions by as much as 28 percent by 2050.[4]

The Equity Challenge

Would a self-funded substantial contribution of developing countries to global efforts to mitigate climate change be compatible with equity considerations? Clearly not, for three reasons. First, industrialized countries carry a much larger historical responsibility for the existing atmospheric stocks of GHGs that are causing climate change. Second, developing countries, which must first face the challenge of poverty reduction, are the most vulnerable and the least able to adapt to the adverse effects of climate change. They can hardly be expected to shoulder the additional burden of reducing their GHG emissions. Third, developing countries have the right to develop without restraint, just as the current developed nations have done over the past 100 years.

The lower level of responsibility of developing countries can be illustrated by the fact that the cumulative energy related emissions of rich countries from

1850 to 2004 are, on a per capita basis, more than 12 times higher than those of developing countries—respectively 664 and 52 tCO_2 p/c.[5] Thus, even though their share of the world's population is only about 20 percent, industrialized countries are responsible for 75 percent of the world's cumulative energy related CO_2 emissions since 1850. The difference between both groups of countries is smaller but still significant when not only emissions from energy but also from land-use change are considered for the shorter 1950–2000 period—land-use change emissions are not available for previous periods. In this case the cumulative emissions of industrialized countries would be 457 tCO_2 p/c compared to 103 tCO_2 p/c for developing countries. It is thus natural to expect rich countries to assume a much larger share of the cost that will be associated with reducing global GHG emissions.

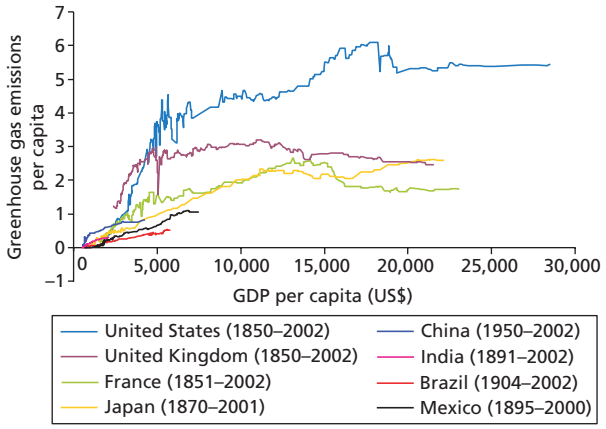
In addition, developing countries face the overarching challenge of achieving and maintaining the high rates of economic growth that are needed to eradicate poverty and converge to the levels of income of the industrialized world. In this context, climate change introduces two additional complications. On the one hand, additional resources will be needed for adapting to the various impacts of climate change, so as to avoid negative and persistent damages, which could compromise development achievements. On the other hand, the above described arithmetic of the emission reductions needed to stabilize GHG concentrations suggests that developing countries will have to find a way of rapidly decoupling their patterns of income and GHG emissions growth, in a way that is unprecedented.

High-income countries were not constrained by requirements to reduce their emissions during their development process. Indeed, as shown in figures 4.2 and 4.3, at least since the industrial revolution, GHG emissions have been closely linked to economic growth. In particular, the first figure shows that in today's industrialized countries emissions per capita grew almost continuously with income per capita between the 1850s and the 1970s. Moreover, the rates of growth of their per capita emissions were much higher during that period than what has been observed, for similar levels of income, in Brazil, China, India, and Mexico during the twentieth century. In order words, when industrialized countries had levels of income per capita comparable to those of today's developing countries, both the level and the rate of growth of their per capita CO_2 emissions were much higher than in today's developing countries.

A similar pattern applies to the evolution of the ratio of emissions to GDP (figure 4.3), which grew at much faster rates in today's industrialized countries, when their levels of income were comparable to those of today's largest developing countries. Thus, even

FIGURE 4.2

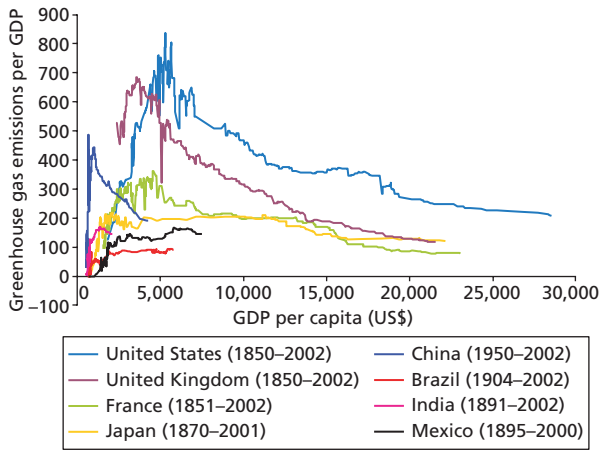
Historic Trends in Per Capita GDP and Per Capita CO_2 Energy Emissions



Source: World Bank staff calculations using data from Angus Madison and World Resource Institute.

FIGURE 4.3

Historic Trends in Per Capita GDP and CO_2 Energy Emissions over GDP



Source: World Bank staff calculations using data from Angus Madison and World Resource Institute.

though in France, Japan, the United Kingdom, and the United States emissions per unit of GDP peaked during the early twentieth century and have been declining ever since, they only reached levels that were comparable to those of today's developing countries when their levels of income per capita had reached between two and four times those exhibited in the present decade by Brazil, China, and Mexico.

This suggests that patterns of development have already become relatively "cleaner" at least in comparison to the historical experience of today's rich countries. This is probably a result of several factors. First, thanks to technological change, during the past 150 years the world has shifted to relatively cleaner energy sources—for example, with gas and oil substituting for coal. Second, energy consumption has been reduced significantly, at least in industrialized countries, as a result of increasing oil prices, particularly after the oil shocks of the 1970s (see chapter 5). Finally, the growth in global trade has caused many energy and carbon intensive industries to move from industrialized to developing countries, with the former specializing in the production of cleaner knowledge intensive goods and services.

In this context the challenge that the developing world will face is that of further decoupling GHG emissions from economic growth during a relatively short period of time without compromising their economic development goals. Indeed, while there are a number of opportunities for reducing emissions in ways that have concomitant development benefits and relatively low costs, a theme we will explore later, the rapid deployment of low-carbon energy technologies will likely come at a significant cost. How to maximize efficiency in order to minimize this cost and how to share the corresponding "bill" across countries with different levels of development and responsibility for GHG emissions are the questions that we address next.

The Efficiency Challenge

Setting equity aside, and as shown in chapter 1, in an ideal situation in which the marginal costs and benefits of mitigating climate change are known with certainty for different alternative levels of emission reductions, the optimal level of mitigation expenditures would be that for which the cost of abating an additional ton of GHG is equal to the value of the marginal climate damages avoided. To reach that optimal level of abatement at the lowest cost, in an ideal world, policy makers would use economic instruments—namely, global "cap-and-trade" or "carbon tax" systems[6]—that result in the emergence of a price on carbon emissions that is equal to the marginal damages of additional emissions (the so-called "social cost of carbon").

In practice, however, there are considerable degrees of uncertainty on both the costs and the benefits of mitigating climate change. This, coupled to the presence of irreversibilities associated both with mitigation investments (for example, in fixed assets to produce clean energy) and with increases in the stock of GHG (for example, the difficulty of reducing them if "bad news" arises on their actual size or negative impacts), may tilt the balance in favor of one or the other policy instrument, as well as lead to lower or higher levels of optimal abatement than the above simple framework would suggest (Pindyck 2008). Moreover, the relative virtues of both instruments would also depend on how governments use the revenues generated respectively through carbon taxes or the auctioning of allowances (Aldy et al. 2008). In summary, there are differing views on how to weigh the pros and cons of these two approaches, with no consensus having emerged as yet. In the end, which is more likely to be adopted will probably be decided by what is politically feasible to negotiate.

But regardless of the level of abatement envisaged and of the specific mechanism used to generate a price on GHG emissions, mitigation efforts will only be efficient when the same "carbon price" applies to all emitters. Indeed, this would ensure first that all possible mitigation opportunities are considered when deciding—in most cases implicitly, through market mechanisms—which ones to pursue at each level of abatement. Second, a common price on carbon would also ensure that only the least expensive mitigation alternatives, with marginal costs below the common carbon price, are implemented.

A recent study found, for example, that reducing global emissions by 55 percent in 2050 (relative to a baseline scenario) using a uniform carbon tax would

have a cost equivalent to 1.7 percent of global GDP. In contrast, the cost of achieving the same global emission reduction without a common price on carbon would be about 50 percent higher. In particular, if country-specific taxes were to be used, setting their rates so as to deliver the same 55 percent emission reduction in each and all countries, the cost would reach 2.6 percent of global GDP (Medvedev and van der Mensbrugghe 2008). The lower mitigation costs achieved in the first case would result from a different allocation of emission reductions across countries, with larger efforts being implemented in those that offer cheaper mitigation opportunities, as opposed to the second alternative in which all countries would reduce their emissions in the same proportion, regardless of their different mitigation costs.

Achieving a common carbon price within national boundaries implies harmonizing various domestic government policies across sectors, so that the combined impact of emission caps, carbon taxes, and other government policies and regulations—that is, the shadow price of GHG emissions—is the same for all emitters. While this is not trivial, achieving the same goal at the global level is certainly much more challenging, especially if one expects the corresponding global agreement to also satisfy equity considerations.

Combining Equity and Efficiency: A Critical Role for Climate Finance

The discussion above implies two desirable characteristics for a global agreement to address climate change mitigation: First, equity considerations would call for developing countries to carry a very small share of the burden. Second, efficiency would require a mechanism to establish some kind of uniform price for carbon, which would mean that the reductions would be carried out in the ways and places that it could be done most cheaply. So if developing countries have a comparative advantage in activities that could reduce GHG emissions—for example, relatively low production costs for renewable energy, or a potential for reducing deforestation at a relatively low opportunity cost—cost-efficiency considerations would call for a relatively large share of global mitigation efforts to be allocated to them. In fact, the Investment and Financial Flows study of the UNFCCC estimates that 68 percent of the mitigation needed for a total reduction of 31 $GTCO_2$ by 2030 is located in developing countries and can be achieved for 46 percent of the global mitigation cost (UNFCCC 2007).[7]

Is it possible to build a "global deal" that could satisfy both equity and efficiency considerations? The answer is a clear yes. As argued by Spence et al. (2008), the key is to decouple the *cost* of mitigation from the *site* of mitigation. The traditional interpretation of the principle of "common but different noted responsibilities and respective capabilities" would have us conclude that the only way of addressing the extreme inequality in both capability (wealth) and responsibility for the problem is to defer aggressive action on climate change in the poorer countries. As long as we assume that every country has to pay for the emission reductions achieved on its territory, developing countries will understandably argue that they cannot act on climate in a significant way because of inequity and their other priorities that have to take precedence. However, we have seen that in order to stabilize the climate, we need urgent action everywhere. The only solution to this dilemma is to share the global burden according to transparent principles of equity and capability, independently of the territorial origin of the emission reductions.

The delinking of the site of emission reductions from their payment can be achieved in several ways. One option is to adopt an international cap and trade scheme, through which a common price on carbon would emerge even if countries agree on different levels of contributions to global efforts—that is, different caps on emissions. Resources would flow automatically to pay for emission reductions in countries that offer the lowest cost-mitigation opportunities, thus potentially funding an important level of mitigation efforts. A similar outcome could be achieved with a carbon tax mechanism—and some authors argue that such a mechanism might even be easier to negotiate and easier for developing countries to administer (Aldy et al. 2008). But with a carbon tax, equity would require a parallel agreement on a set of international resource transfers aimed at ensuring that the share of the global "bill" of climate change mitigation that is paid by each county is proportional to its responsibility for generating

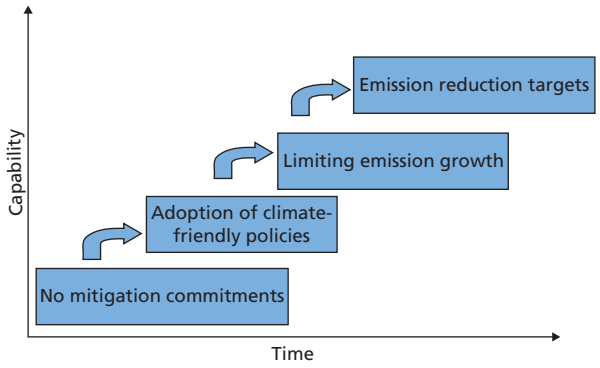
the problem and not necessarily to the country's actual contribution to its solution.

Considering the challenges associated with negotiating a global cap-and-trade scheme or a global carbon tax, however, it is worth considering other possible alternatives for decoupling the site of mitigation from its payment. While some of these alternatives may be more cumbersome, some of them may constitute more acceptable avenues from a political point of view. First, assuming that industrialized countries (including the United States) could be expected to take deeper emission reduction commitments, expanded market-based instruments may play an important role. These could include an improved and potentially expanded CDM. Second, complementary nonmarket financial instruments could help defray some of the costs of mitigation in developing countries, even if not serving to transfer emission rights to those who provide the funds. Finding the appropriate combination of these different types of instruments will be complex, both from a technical point of view, and in terms of the challenges associated with negotiating the corresponding agreements. In particular, such an agreement will have to not only adequately balance supply and demand within the market mechanism(s), but also to balance, within the nonmarket mechanism(s), willingness to pay on the part of the industrialized countries and effectiveness to promote reductions in the south.

If negotiated, this palette of climate finance instruments could provide the framework for a global agreement that would confirm most (small) developing countries as continued hosts of market-based mitigation efforts, but would at the same time provide the necessary incentives for the larger developing countries to gradually move toward the adoption of their own climate mitigation commitments. In order to alleviate the trade-offs between economic development and climate change mitigation objectives, some developing countries could start with a focus on "climate-friendly" development policies without explicit mitigation commitments, and transit over time, based on demonstrated capability (for example, as measured by per capita income) to limiting emission growth and, finally at some point in time, to some of them adopting emission reduction or at least emission intensity targets (figure 4.4).

FIGURE 4.4

A Possible Scheme for Gradual Incorporation of Developing Countries



Source: Figueres (2008).

In order to uphold the integrity of the system, all mitigation efforts, whether based on climate friendly policies or eventually on targets, would have to be measured and reported, and internationally verified. In order to ensure fairness and equity, the gradual incorporation of developing countries could be linked to—that is, conditional upon—industrialized countries' verified performance (for example, in terms of both the provision of financing for developing countries mitigation efforts and emission reductions achieved at home). Moreover, an agreement would have to be reached on possible objective criteria for defining the thresholds that would trigger an increasing degree of incorporation of developing countries. In this respect, it is important to recognize the wide variety of country circumstances that are found not only across rich and poor countries, but also within the group of developing countries.

In particular, as argued by Yamin et al. (2006), it is important to take into account countries' different degrees of *responsibility* for the climate challenge, as well as their *capability* for addressing it, and their *potential* to implement mitigation activities. In the context of the *North-South Dialogue,* Ott et al. (2004) have proposed a specific framework in which (1) mitigation efforts would be concentrated in countries with medium or high potential; (2) the amount that each country would contribute to the funding of global efforts would depend on its levels of responsibility and

capability; (3) the contributions by countries with low responsibility would be voluntary; and (4) those of countries with medium responsibility or with low to medium capability would be conditional on financial and technical transfers from high capability countries.

In order to make such a framework operational, an agreement also would have to be reached on how to measure the relevant variables. *Responsibility* could be proxied by cumulative GHG emissions, starting for example in the mid-nineteenth, when global man-made emissions experienced their first significant trend break or starting much more recently, when a sizable scientific consensus was reached on the climate impact of GHG emissions—for example, in 1990, when the first IPCC report was launched.[8] The level of *capability* of different countries, in terms of their ability to fund adaptation and mitigation activities, could be proxied by levels of GDP per capita or with the UN's Human Development Index. As for countries' mitigation *potential*, it could be proxied by the level and rate of growth of their GHG emissions, either relative to population or GDP, or in absolute terms. Indeed, as argued by Ellis and Kamel (2007), there is less room for domestic mitigation actions where emission levels or growth rates are already low.

As shown in table 4.1, in comparison with industrialized countries and the rest of the developing world, LCR countries can be described as having intermediate levels of *potential*, *responsibility*, and *capability* to mitigate climate change. The region's standing on the first two criteria, however, critically depends on whether emissions from land-use change are considered in the analysis. If not, the region can be described as having, at most, medium levels of responsibility and potential for implementing mitigation activities.

LCR's Performance in the CDM

For the time being the CDM is the only financial vehicle for developing country mitigation efforts that are recognized and quantified under the UNFCCC. The CDM represents the first generation of mitigation efforts in developing countries: it promoted a first wave of emission reductions achieved by single site projects that either displaced more carbon intensive alternatives (for example, renewable energy displacing fossil fuel energy) or were submitted to a "carbon upgrade" (for example, capture of methane in landfills, increasing efficiency in energy generation, and so on). And yet, in the face of the shortcomings that we discuss below, and the concurrent need to scale up mitigation, the calls to expand/reform the CDM are well documented. As we approach the end of the first commitment period, countries may create other avenues (market and/or nonmarket based) to catalyze a second generation of mitigation efforts that are broader in scope and higher in volume, and that are discussed at the end of this chapter. However, the CDM, with its strengths and weaknesses, has undoubtedly been successful in creating a class of market-based mitigation activities in the LCR and elsewhere in the developing world.

We first review the LCR's participation in the CDM and identify the barriers that have been encountered, before exploring options to further promote mitigation by stimulating a second generation of emission reductions in developing countries.

The CDM has evolved rapidly since the adoption of the Kyoto Protocol in December 1997, growing from 20 $MtCO_2e$ in emission reductions traded in 1998, to 100 $MtCO_2e$ traded in 2004 and 537 $MtCO_2e$ in 2007. In that year the value of primary CDM Certified Emission Reductions (CERs) reached US$7.4 billion. Moreover, 2007 also saw the emergence of secondary markets, which traded 240 $MtCO_2e$ in emission reductions for an amount of US$5.4 billion.

By mid 2008 the LCR accounted for about 20 percent of the 3,498 active projects in the CDM pipeline. If all the expected CERs from these projects were to be delivered, they would generate 2,640 $MtCO_2e$ in emission reductions, of which about 15 percent would be sourced from LCR projects. Assuming an average price of US$15 per ton, the investment in emission reductions in the region would be US$5.8 billion by 2012. It is worth noting, however, that after accounting for various risks—for example, of issuance failure, negative validation by Designated Operating Entities (DOEs), the auditors of CDM projects, or rejection by the CDM Executive Board (EB)—and taking into account registration delays and the expected future stream of new projects, most market participants expect a smaller

TABLE 4.1

Potential, Responsibility, and Capability to Reduce Greenhouse Gas Emissions

Criteria for differentiating countries	Annex I (*)	LCR	Brazil	Mexico	Other developing countries	China	India
Potential to mitigate							
GHG/GDP, 2000 (in tons CO_2/Mill. US$-PPP)							
Group Range	239–2,446	203–16,486			352–35,632		
Group Average	759	2,477	1,876	752	3,619	975	655
Group Total	643	1,425			1,395		
CO_2 (excluding LUC)/GDP, 2000 (in tons CO_2/Mill. US$-PPP)							
Group Range	208–1,583	117–2,166			0.1–3,310		
Group Average	561.5	460	280	436	511	686	434
Group Total	535	377			630		
GHG/capita, 2000 (tons CO_2e Per Person)							
Group Range	5.5–26.6	1.3–93.7			0.7–53.8		
Group Average	12.3	12.2	13.4	10.0	7.7	3.8	1.5
Group Total	14.3	10.0			4.4		
CO_2 emissions growth, 1990–2000 (in %)							
Group Range	–6.8–4.3	–5.5–8.1			–11.3–17.4		
Group Average	–0.44	0.30	–2.3	0.8	2.35	2.2	5.2
Group Total	0.07	–1.60			2.51		
Responsibility to mitigate							
Cumulative CO_2/capita, 1990–2000 (in tons CO_2)							
Group Range	32.5–241.8	–75.1–1,099.3			–12.4–373.4		
Group Average	100.9	107.5	117.0	51.5	53.3	27.2	8.6
Group Total	121.1	82.4			33.5		
Capability to mitigate							
GDP/capita, 2000 (in US$-PPP)							
Group Range	4,037–50,564	1,499–16,958			226–42,166		
Group Average	20,446	6,442	7,142	9,262	4,994	2,371	1,517
Group Total	22,170	7,026			2,399		
HDI, 2000							
Group Range	0.75–0.96	0.67–0.86			0.92–0.32		
Group Average	0.89	0.76	0.79	0.81	0.61	0.732	0.578
Total GHG emissions, 2000 (in $MtCO_2$ equiv.)							
Sum (of each group of countries)	17,583	5,166	2,333	682	18,777	4,850	1,574
Top five	United States 6,611	Brazil 2,333			China 4,850		
	Russia 1,991	Mexico 682			Indonesia 3,068		
	Japan 1,406	Venezuela 384			India 1,574		
	Germany 1,044	Argentina 353			Malaysia 861		
	Canada 751	Colombia 274			Korea (South) 547		

Sources: For GDP - PPP in constant intl $ 2000 and Population 2000 is WDI; Emissions: Climate Analysis Indicators Tool Version 5.0., (Washington, DC: World Resources Institute, 2008, Human Development Index UNPD.

Note: (*) Defined as Annex 1 countries in the UN Framework Convention on Climate Change including all the developed countries in the OECD and economies in transition. GHG = CO_2, CH_4, N_2O, PFCs, HFCs, SF6 (includes land use change and international bunkers), CO_2 emissions growth (CO_2, including land use change and international bunkers), cumulative CO_2, CO_2 (energy), CO_2 (land use change).

number of CERs to be delivered by 2012. Thus, for instance, UNEP Risoe Centre on Energy, Climate and Sustainable Development (URC) estimates that only 1,568 $MtCO_2e$ will be issued before the end of 2012.

A declining market share

The LCR was clearly the early mover in the CDM. The region began experimenting with Activities Implemented Jointly (precursor to the CDM) in the early 1990s. The *Programa Latino Americano del Carbono* (PLAC), the first carbon finance program to be established by a regional development bank, was created by the Andean Development Corporation in 1999, even before the Marrakesh Accords established the modalities and procedures for CDM. From 1999 to 2002, the region had more Designated National Authorities (DNAs)—the entities that handle the host country CDM project approval process—than any other region in the world, and received a total of US$18 million in CDM-related capacity building.[9] The investment in technical training bore immediate fruits—from 2001 to 2004 the region had submitted 62 percent of all CDM projects to the EB, and had prepared 68 percent of all approved CDM methodologies. The first project to be registered by the EB was the landfill methane capture project of NovaGerar in Brazil in 2004, and the first certifications of emission reductions were issued to Rio Blanco and La Esperanza hydro projects in Honduras in 2005.

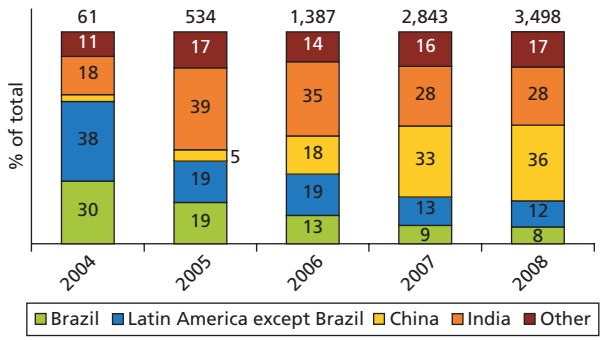
By the middle of 2006, however, the region had lost its dominant position in the market, as India and China had entered with much higher volumes. As shown in figure 4.5, the LCR went from accounting for 68 percent of all active projects in the CDM portfolio in 2004—there were just 61 active projects at the time—to 32 percent of the 1,387 projects in the pipeline in 2006 and just 20 percent of the 3,498 projects that were active by early June of 2008. Similarly, the share of the LCR in the total volume of transacted CERs fell from 72 percent in 2003 to 11 percent in 2007—6 percent of which were from Brazil—compared to 74 percent for China and 6 percent for India (figure 4.6).

The rapidly growing market shares of China and India were originally due to a few "end of pipe" HFC-23 destruction projects that, given the very high global warming potential of HFC-23 as compared to CO_2, achieved extremely large volumes of certified emission reductions.[10] However, this type of project has been nearly exhausted worldwide and over the past few years China and India have been able to diversify their supply, expanding their CDM portfolio to other sectors (renewable energy, energy efficiency improvements in the industrial sector, and methane recovery and utilization) while managing to maintain their hold on the market.

In contrast, the projects from the LCR have been, since the early years of the CDM, smaller than those from other regions. For instance, the region's share in the 2012 CERs expected from the active CDM pipeline—assuming no risks—was always smaller than

FIGURE 4.5

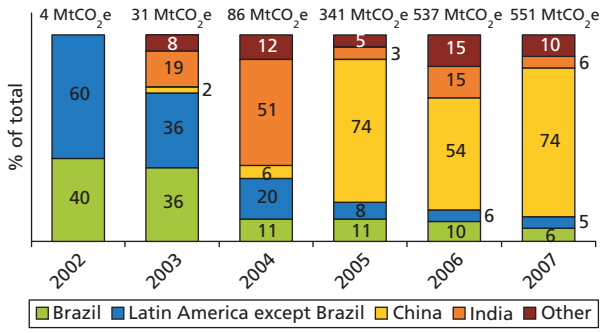
Cumulative Number of Projects in the Clean Development Mechanism Pipeline, by Country/Region of Origin



Source: World Bank staff calculations using data from the Clean Development Mechanism Pipeline database published by UNEP Riso, June 2008.

FIGURE 4.6

Primary Clean Development Mechanism Transactions for Compliance, by Country/Region of Origin



Source: World Bank staff calculations using data provided by Philippe Ambrosi of the World Bank.
Note: $MtCO_2e$ = million tons of CO_2 equivalent.

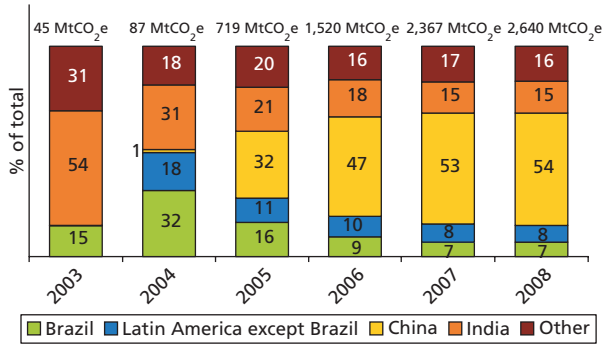
its share in terms of number of projects. For example, while in 2004 the LCR had 68 percent of all active projects, it had just 50 percent of the corresponding 2012 CERs (figure 4.7). By 2007, when the region's share of the pipeline had fallen to 22 percent, its fraction of the expected 2012 CERs was only 15 percent. In contrast, with 33 percent of the active projects in 2007, China was able to capture 53 percent of the 2012 expected CERs.

LCR's Supply

While LCR countries have been outperformed by China and India as CER suppliers, one could hypothesize that this is a result of their higher GHG emission levels. In particular, it should not be a surprise if countries with high emission levels were also among those with a high supply of emission reductions. We thus compare the fraction of 2012 CERs from projects in the CDM pipeline held by selected countries, to their respective share in GHG emissions from non-Annex I countries—the only ones that can supply the CDM. Land-use change and forestry emissions are not included as most of these emission reductions cannot be included in the CDM. Using this approach, figure 4.8 reveals that if emission levels can be interpreted as an indication of potential supply to the CDM, Brazil, Mexico, and the rest of the LCR are almost "on target"—if anything, Brazil is slightly oversupplying and the rest of the region is slightly undersupplying CDM projects. However, India and particularly China are clearly overperforming, and the rest of Asia and Africa are underperforming in the carbon market.

FIGURE 4.7

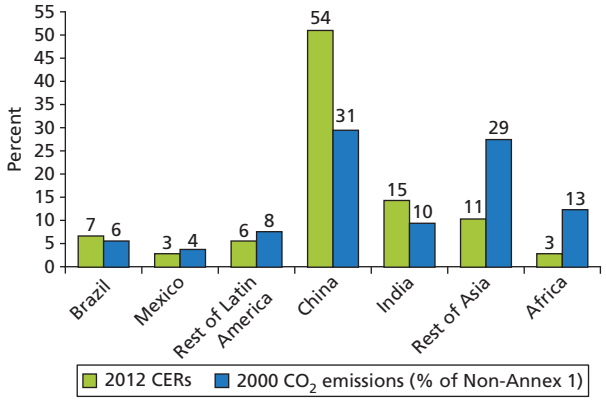
Cumulative 2012 Certified Emission Reductions from the Clean Development Mechanism Pipeline, by Country/Region of Origin



Source: World Bank staff calculations using data from the Clean Development Mechanism Pipeline database published by UNEP Riso, June 2008.
Note: $MtCO_2e$ = million tons of CO_2 equivalent.

FIGURE 4.8

Shares of 2012 Clean Development Mechanism's Certified Emission Reductions and Non-LULUCF Emissions (Non-Annex I Countries)



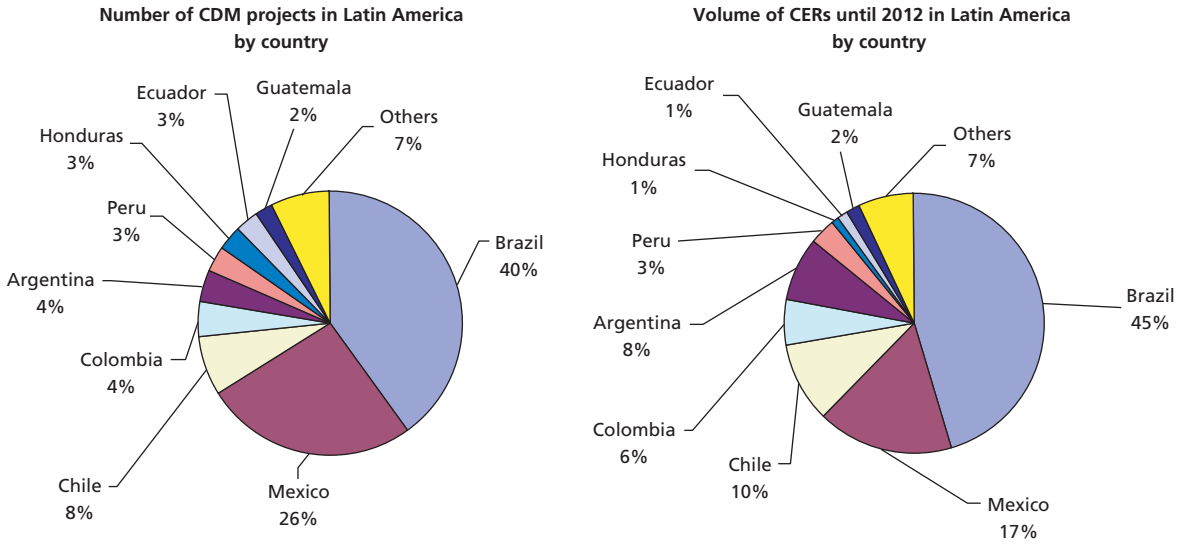
Sources: CO_2 emissions (without LULUCF): CAIT; 2012 CER: World Bank staff calculations using data from the Clean Development Mechanism Pipeline database published by UNEP Riso, June 2008.
Note: LULUCF = Land use, land-use change and forestry.

The pattern of the highest emitters being the largest suppliers can also be observed at the regional level. Within the LCR the market is clearly dominated by Brazil and Mexico, both in terms of absolute numbers of CDM projects, as well as in volume of CERs. From either perspective the two countries represent more than 60 percent of the supply from the LCR (figure 4.9), compared to a share of 55 percent in the region's emissions, excluding land-use change. This over performance of Brazil and Mexico could be attributed primarily to their size, which allows them to support industries that have the potential for projects entailing sufficiently large emission reductions to justify the transaction costs involved in the CDM. This category of projects was initially made up mainly of projects to reduce HFC-23 emissions. However, more recently, renewable energy, methane capture from landfills, and agroindustries have also become attractive project types for taking advantage of the CDM in the LCR (see figure 4.9).

In summary, patterns of over- or undersupply in carbon markets (with respect to countries' shares in GHG emissions) are likely to reflect the relative availability of large-scale, low-cost, and low-risk mitigation projects.

FIGURE 4.9

Clean Development Mechanism Portfolio in Latin America and the Caribbean Region, by Country, 2012 Certified Emission Reductions



Source: Clean Development Mechanism Pipeline database published by UNEP Riso, June 2008.

For example, China's larger share of the carbon market compared to its share of developing countries' emissions would be a reflection of the large number of projects in that country that meet the aforementioned profile. In fact, as argued below, the limited participation of small and medium countries in the CDM, to a large extent the result of the small scale of their mitigation projects (relative to CDM transaction costs), has been one of the reasons for introducing the option of registering programs of activities—as opposed to single projects—in the context of the so-called *programmatic* CDM.

LCR's CDM portfolio by sector

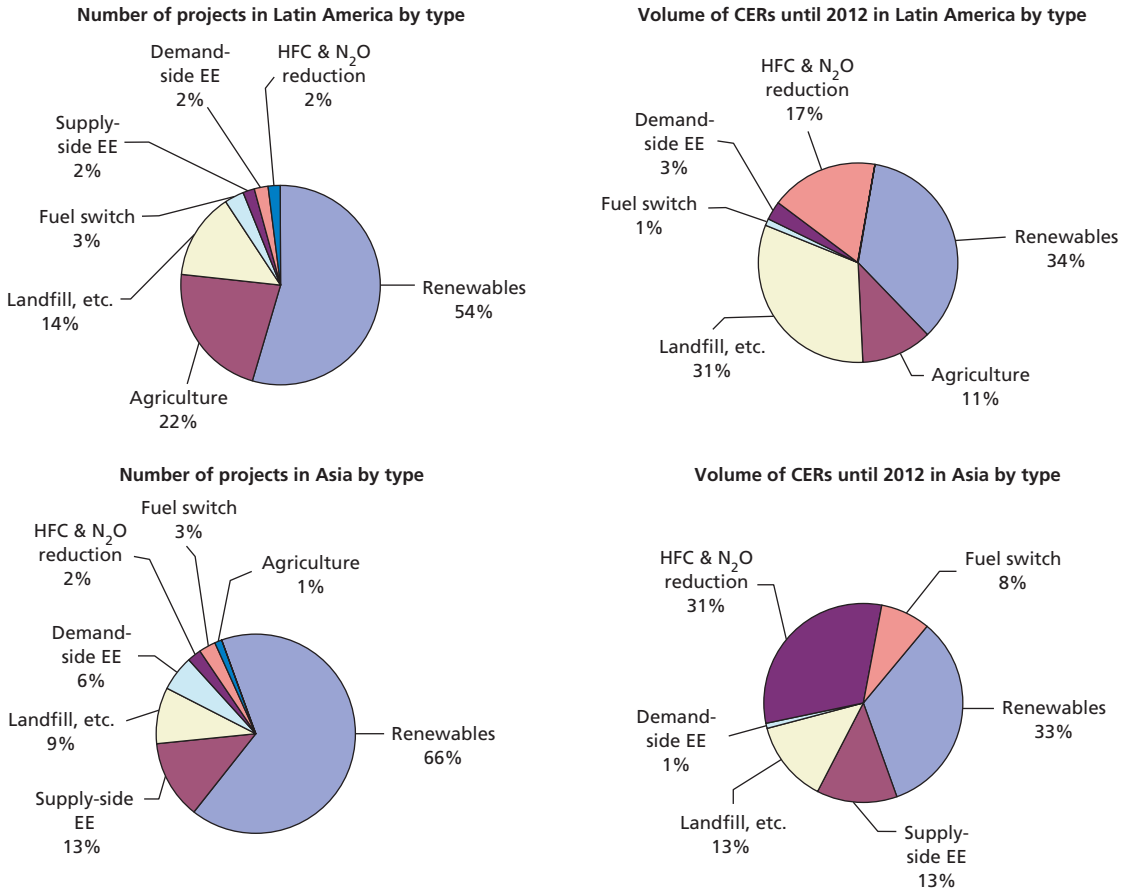
An analysis of the LCR's current CDM portfolio by sector indicates some issues of concern. Industrial gases (HFC-23 and N_20) continue to have a 17 percent share in 2012 CERs despite representing only 2 percent of the region's CDM projects. These shares are even higher in Asia, where industrial gases account for 31 percent of 2012 CERs (figure 4.10). The potential of this type of project, however, will decline in the future, as most major industrial gas projects have now been tapped and are being gradually balanced out by other types of projects. Today's portfolio also shows that 54 percent of the LCR's projects are in the area of renewable energy, whose share in 2012 CERs is 34 percent. The share of renewable energy in the LCR's portfolio is comparable to that found in Asia and probably commensurate with the mitigation potential of this sector in the region, at least if large hydroelectric projects are excluded.[11] Besides hydros, the sugarcane industry's use of bagasse comprises most of the remainder of the CDM renewable energy projects in the region and will likely continue to do so.

Other major categories of emission reduction projects in the region are methane capture from landfills, agriculture, and the emerging field of sewage treatment. While projects aimed at capturing landfill gases represent only 14 percent of the LCR portfolio, they are responsible for 31 percent of the region's 2012 CERs. The average size of these projects is larger than in Asia, where the share of this project type is similar in terms of both number of projects and volume of 2012 CERs. As for CDM projects in the agricultural sector, they represent less than 1 percent of Asia's portfolio but 22 percent of LCR's portfolio.

Looking forward, there are still many undeveloped landfills and agroindustry opportunities in the region. However, sites that may seem ripe for development may yield fewer reductions than expected for a variety of technical reasons. Unlined and unsorted landfills

FIGURE 4.10

Clean Development Mechanism Portfolio in Latin America and the Caribbean Region and Asia, by Sector, 2012



Source: Clean Development Mechanism Pipeline database published by UNEP Riso, June 2008.
Note: EE = energy efficiency.

are susceptible to leakage of methane and low organic content to produce methane (Zeller 2008). Agroindustry methane capture success depends on the pH, temperature, and antibiotic and water content of the excrement, which is determined by the relationship of the farmer, the veterinarian with the project developer (Lokey 2009). For these reasons, despite the high global warming potential of methane, the CDM has not provided a sustainable solution to the burgeoning urban waste management problem.

However, the aspect that stands out most clearly in the analysis of the LCR portfolio is the absence of two asset classes that represent high emission levels in the region. The first of them is the reduction of emissions from deforestation. There is no doubt that one of the region's main contributions to global mitigation efforts would be a decrease in deforestation rates. However, activities that reduce emissions from deforestation are not eligible under the current modalities of the CDM. Land-use change and forestry assets are currently limited in the CDM to afforestation and reforestation activities. Discussions are underway about the role that emissions from deforestation may have in a post-2012 regime, but until then that mitigation potential—perhaps the largest of all sectors for the region—remains unleveraged by carbon finance.

The second sector that is clearly underrepresented in the region's CDM portfolio is transportation. As discussed below, transportation is the sector with the largest share of LCR's energy-related emissions.

However, the potential of this asset class in the CDM is curtailed by the lack of methodologies. Currently there is only one approved CDM methodology in the transportation sector (rapid transit lanes as implemented by the Transmilenio project in Bogotá, Colombia). Several other types of transportation methodologies are under preparation (construction of underground transportation systems, use of biofuels, and so on) but until they are approved, transportation will remain underrepresented in the CDM portfolio of the region, despite the fact that it is one of the major emitting sectors.

Finally, the aforementioned problem of relatively high transaction costs limiting the participation in the CDM of projects with few emission reductions, particularly in small and medium countries, has a particularly dampening effect on projects in the area of energy efficiency. Indeed, by their own nature these projects tend to be dispersed among many small sites, although this could be less of problem in large countries (where each site could be of a large scale). Thus, energy efficiency projects represent almost 20 percent of Asia's CDM pipeline, compared to less than 5 percent in the LCR.

Barriers to the expansion of the CDM in the LCR

The decreasing participation of the LCR in the CDM can be traced to several factors. An early 2006 survey of market participants[12] identified the following strengths in the LCR, as compared to other regions of the world: better understanding of the CDM project cycle, more solid project design documents (PDDs), higher participation of the private sector, more knowledgeable local consultants to prepare PDDs, and clear mandates from respective governments to actively engage in the CDM. However, the same survey pointed to the fact that the region was losing its first mover advantage in the market, and identified the following policy and regulatory weaknesses in the LCR: major differences in procedures among DNAs in the region, more host country requirements than other regions, and slower national approval processes. In addition, the survey mentioned the region's lower emission reduction potential as compared to Asia.

Another critical factor driving LCR's declining market share in the CDM is the *uncertainty regarding the post-2012 regime*. Long-term commitments by industrialized countries are necessary to sustain carbon markets. The recent proposal of the European Union for the Third Phase of the European Trading Scheme (ETS) severely limits the use of the CDM for the purpose of compliance with European regulations unless an acceptable multilateral agreement is reached. Moreover, even if such an agreement materializes, the Third Phase of the ETS would only marginally expand the use of the CDM. The proposal has not been ratified by the European Commission, but the potential ceiling on demand for CERs has already had a stifling effect on market optimism. Should it be carried through, the ceiling could result in an increased emphasis on projects with short lead times and projects where the financial closure does not strictly depend on the forward sale of emission reductions. This means that until the uncertainty regarding the future of the CDM is significantly reduced, carbon finance will have limited influence on investment decisions for large-scale infrastructure projects with long gestation periods that have the potential to deliver a large quantity of emission reductions. In the LCR, where many CDM projects require high and long-term investments, the absence of a long-term carbon market signal is already being reflected in the dwindling of CDM transactions.

A third key barrier to the development of CDM projects in the LCR is the lack of concerted CDM strategies. Only a very few countries in the region (for example, Brazil underway, Mexico) have a concerted mitigation strategy, and in most cases this strategy does not involve any specific measure to boost CDM utilization. During the past decade, however, in the context of the National Strategy Study Program supported by the World Bank, several LCR countries took advantage of external technical assistance to identify the best way to implement CDM projects. Many of the initial CDM portfolios were drafted through this initiative but further follow-up and commitment from usually divorced public and private sectors prevented them from going much further. A remarkable exception to this was Chile, where an unusual synergy between the private sector and the government served as a framework for the promotion of CDM projects by business organizations, such as

the Manufacturers Society and the Chilean investment promotion agency.

A fourth issue is the lack of appropriate CDM methodologies. As discussed previously, several asset classes that are critical to the region's abatement potential have not been incorporated into the CDM. Land-use change and forestry assets in the CDM are limited to afforestation and reforestation activities, and even those are restricted in size and type. The issue is compounded by the fact that there is a lack of demand since the European Union ruled out forestry projects from the sectors eligible as offsets in the ETS. As also mentioned previously, in the transport sector there is only one approved methodology. Broader and less onerous methodologies have to be developed for mass public transit, as well as to support the switch from fossil fuels to liquid biofuels for vehicles.

A fifth problem is that public enterprises remain, at least in the LCR, for the most part unaware or unwilling to participate in carbon markets. In this respect, some of the limitations faced by these companies have to do with issues related to data disclosure and other procedural constraints. State-owned utilities, for example, are usually not allowed to consider CDM revenues in their least-cost planning process. As a result, CDM projects that hope to make the financial additionality argument cannot be pursued (Mayorga 2007). Furthermore, state utilities must declare all major capacity additions in their future expansion plans, which makes the additionality argument complex, as expansion plans are the basis for business-as-usual scenarios (Mayorga 2007). Finally, state-run utilities have little incentive to engage in the complex CDM process since the regulator determines the tariff calculation that will dictate the state utility's profits. In fact, the Public Utility of Medellín, Colombia, was audited for participating in the CDM: the regulator questioned why the prices the utility received for the sale of CERs were so low and why the process took so long (Vélez 2007).

There has also been a relative absence of the domestic financial sector in the market for CDM credits. In addition to the well-known reluctance of banks to lend for renewable energy or energy efficiency projects, commercial banks in the region have not recognized CER revenues as a bankable income stream. At best, banks are heavily discounting the carbon revenue stream, in part due to lack of knowledge or uncertainties regarding the carbon market, and will not consider Emission Reduction Purchase Agreements (ERPAs) as part of collateral or guarantees to finance a project with climate-friendly technologies. Thus the majority of CDM projects are either financed on the balance sheet or financed without taking into account potential carbon finance revenues, which directly restrict the size of the projects that can be brought to the carbon market.

Finally, a barrier to CDM development in the LCR that has already been mentioned is the lack of aggregation possibilities, which prevents taking advantage of emission reduction projects that are individually small in size and are dispersed among many sites. The CDM modalities and procedures have been implemented mostly on the basis of single mitigation sites that offer a relatively high volume of emission reductions per site. This practice benefits larger countries and the highest-emitting sectors, and disfavors smaller economies with lower mitigation potential as well as those sectors in which the mitigation potential is dispersed, such as energy efficiency, distributed rural energy, and transportation. As discussed in the following section, however, the newly introduced programmatic CDM offers the possibility of aggregating and structuring many small mitigation efforts. This could allow smaller countries without large emitting facilities to take advantage of the CDM by aggregating in a single program a large number of small projects which, together and over a period of time, could have the potential to achieve significant emission reductions.

The role of development banks in LCR's carbon markets: the World Bank

Mulitilateral development banks have had an active role in fostering the participation of LCR in the CDM. The World Bank initiated its activities in carbon finance in 1999 with one initial Prototype Carbon Fund and has since expanded its fund management to nine funds and facilities. These funds are public or public-private partnerships managed by the Carbon Finance Unit (CFU) of the World Bank. Unlike other Bank development products, the CFU does not lend or grant resources to projects, but rather contracts to

purchase emission reductions. These purchases are akin to commercial transactions with the fund paying for emission reductions annually or periodically once they have been verified by a third-party auditor.

These carbon funds and facilities are capitalized by government and private sector investors from industrialized nations that are under emission reduction commitments and are interested in the expansion of the carbon market. The funds under World Bank management have a total capitalization of US$2 billion, most of which has been channeled through the CDM. Of this total, approximately US$96 million or 5 percent has been invested in emission reductions sourced by projects in LCR countries. Table 5.1 provides the breakdown by fund. Other than the obvious attractiveness of higher volume markets, there is no specific reason why the LCR share is so low. However, it is interesting to remember that the LCR represents 5 percent of the world's energy-related emissions (and land-use reductions are virtually excluded from the CDM), emphasizing the previously discussed relationship between emission levels and mitigation potential.

In the face of the IPCC Fourth Assessment Report's call for global mitigation scale-up, the World Bank has recently launched a series of new financial instruments that intend to jumpstart a second generation of mitigation activities in the developing world. These instruments have the participation of other multilateral banks and are discussed below.

The Andean Development Corporation

In 1999 the Andean Development Corporation established the *Programa Latino Americano del Carbono* (PLAC) to support the development of potential CDM projects in the LCR region, as well as to offer capacity building and strengthen climate change institutions in all shareholder countries. The program has recently also begun to develop innovative financial instruments focused on renewable energy and energy efficiency. PLAC managed an emissions reduction contract for the government of the Netherlands for a total of 77 million euros, and has successfully delivered the corresponding 8.7 million tons of certified emission reductions. These stem from 19 mitigation projects in Latin America and have been channeled through the CDM. In addition, PLAC has an emissions reduction purchasing contract from the government of Spain for a total of 9 million tons, 3 million of which have been committed to LCR projects. PLAC has invested US$1.5 million in technical cooperation and capacity building in the region.

The Inter-American Development Bank

The Inter-American Development Bank created a Sustainable Energy and Climate Change Initiative (SECCI) in March of 2007, with an initial capitalization of US$10 million. The goal of this initiative is to support the LCR in finding economically and environmentally sound energy solutions. SECCI focuses on financial solutions and will complete its task by helping renewable energy and energy efficiency projects achieve financing, removing institutional barriers and promoting novel policy ideas, making sustainable energy investment and financing tools more mainstream and accessible, utilizing the carbon finance market, addressing adaptation needs, and forming new partnerships with both the public and private sectors.

Moving Beyond the First Generation of Mitigation Efforts

For LCR, as for any of the other developing countries, the architecture of the post-2012 climate regime is going to be critical. As currently designed, the CDM cannot deliver LCR's potential to reduce its GHG emissions in a cost-effective way. Appropriate design of the new incentives to mitigate could help resolve this. There are two prominent issues for LCR. First, from the perspective of high-volume, cost-effective mitigation and critical biodiversity protection, the new chapter of the regime must incorporate REDD. Second, from the perspective of long-term low-carbon (sustainable) economic growth, the region needs incentives to significantly shift the carbon intensity of investments that will be made over the next decades and that will have direct implications on energy-related emissions (for example, from power and transport). Many of those investments are long lived, and as discussed, they will lead to significant increases in the LCR's energy-related emissions, at least in a business-as-usual scenario. Avoiding the lock-in of

such technology-related emission growth is critical for LCR.

It is as yet unknown whether the post-2012 climate regime will continue to rely exclusively on market-based financial instruments to mobilize emission reductions in developing countries, or if nonmarket-based mechanisms, for example, abatement fund(s) (discussed further on), will be added. There are, however, two elements that are clear: mitigation cannot continue to be pursued only on a project-by-project basis, and climate friendly policies need to be incorporated into future financial mechanisms.

First, the CDM was created as a project-based instrument, and we must go beyond that now. Restricting the CDM to emission reductions from single-point sources has curtailed its potential to promote the needed sector-wide transformation, attained by cost effectively channeling capital and know-how to decarbonize carbon intensive sectors, such as energy, transport, and infrastructure. The project-by-project approach cannot stimulate technology development and underwrite the risk of major scale-ups in R&D in low-carbon/zero carbon technologies. From a financial perspective, project-based CDM cannot stimulate an adequate and reliable new source of risk capital to finance technology shifts and required policies/incentives on the scale of whole economies. It has yet to provide the essential investment climate of regulatory certainty and manageable business risk to ensure that a stream of anticipated CERs is bankable collateral for financing specific projects. Without that assurance, it is also unable to finance rapid expansion of already commercially proven, leading-edge lower carbon power and infrastructure technologies (Figueres and Newcombe 2007).[13] The transaction costs associated with a project approach also make it difficult to take advantage of small-scale reduction opportunities, even when they are significant in the aggregate.

Second, decarbonization of the key sectors will not occur without the necessary regulatory framework, and thus future financial mechanisms need to explicitly encourage climate-friendly policies. The importance of policies is not a recent discovery. The 2004 World Energy Outlook published by the International Energy Agency warned that "if governments stick with the policies in force as of mid-2004, the world's energy needs will be almost 60 percent higher in 2030 than they are now," (IEA 2007) with well more than two-thirds of the projected increase in emissions coming from developing countries. However, under an alternative policy scenario, global energy trends could markedly improve "if countries around the world were to implement a set of policies and measures that they are currently considering or might reasonably be expected to adopt" (IEA 2007). While it is clear that policies are critical for the success of the post-2012 regime, they have had an evolving treatment within the CDM.

Additionality and the issue of perverse incentives in the CDM

In order to have a substantial impact on the GHG emissions of developing countries, mechanisms, such as the CDM, would have to be able to help transform overall development policies and make them more climate friendly. One important obstacle for achieving this objective through the CDM has been the ambiguity on how to treat policies with respect to the project baseline. If climate-friendly policies that had already been announced by developing countries at the time of project submission are considered part of the baseline or business-as-usual scenario, the emission reductions to be achieved by the potential project can be diminished to the point of making the project nonviable.

While environmental integrity must be maintained, this is problematic for several reasons. First, as argued by Heller and Shukla (2003), baseline scenarios are often difficult to determine because they hinge on a range of policy decisions that are not yet sufficiently settled. As a result, the execution of the corresponding policies is in many cases uncertain and one could argue that including them in baseline scenarios—and thus failing to support them through such mechanisms as the CDM—would amount to missing an opportunity for providing critical further incentives for the implementation of climate-friendly policies. More generally, whereas many climate-smart development policies could be justified solely on the basis of their domestic benefits, explicitly recognizing their contribution to climate change mitigation could be useful for gathering additional political and

financial support, and ultimately for reinforcing their chances of success.

At least until 2005, the additionality requirements of the CDM created perverse incentives for governments in host countries, in some cases leading them to delay the issuance of climate-friendly policies (Ellis 2006). In other words, countries with the least climate-friendly policies were implicitly rewarded, while those that were more proactive ran the risk of having most of their mitigation projects excluded from the CDM (Figueres 2004). As a result, countries had an incentive to keep their climate-friendly policies in the realm of plans and programs and to not take the additional step of embedding them into their official regulatory framework. This was reportedly the decision made by Colombia during 2003–04, following countrywide consultations aimed at identifying potential CDM projects and low-carbon policy options in the sectors of transport, energy, and forestry (Hinostroza et al. 2007). Another example, in this regard, is Costa Rica's 1995 requirement that privately generated power stem from renewable sources: while this measure has contributed to decarbonizing the country's energy matrix, the CDM Methodology Panel has questioned the additionality of private hydroelectric plants and thereby severely limited Costa Rica's participation in the CDM.[14]

Fortunately, in November 2005 the Executive Board of the CDM issued new guidance on how to take into account national policies when calculating a CDM project's baseline, which to a large extent eliminated the perverse incentives for host countries to adopt carbon-friendly policies. The new guidance excludes from baseline scenarios climate-harmful policies and regulations issued after the adoption of the Kyoto Protocol in December 1997, thus eliminating the incentive for host countries to inflate their claims for emission reductions by means of enacting policies that favor more emission-intensive technologies or fuels.

In addition, the new guidance allows for the exclusion from baseline scenarios of policies or regulations that give a comparative advantage to lower-emission intensive technologies (for example, through subsidies to renewable energy or more stringent energy efficiency standards), provided that they were enacted after the adoption of the CDM Modalities and Procedures in November 2001. The issue, however, is far from being settled, as the application of the new guidance for the definition of baseline scenarios may be hampered by methodological challenges associated with disentangling the effects of various policies. Moreover, as argued by Ellis (2006), the new guidance explicitly allows for either exclusion or inclusion of recent policies and regulations in baseline scenarios. In summary, while progress has been made in addressing the trade-offs raised by the additionality requirement of the CDM, LCR countries need to closely monitor developments in this area so as to make sure that the mechanism does play its intended role of supporting more climate-friendly development policies in the region.

Climate mitigation and sustainable development under the CDM

Despite the considerable resources channeled through the CDM toward climate-friendly projects in developing countries, there are some concerns about the ability of the mechanism, under its current governance structure, to contribute to its sustainable development objective. The CDM modalities and procedures defined in the 2000 Marrakech Accords are silent with respect to the criteria for assessing the contribution of CDM projects to sustainable development objectives, which are to be defined by each of the DNAs to be set up by developing countries in order to evaluate CDM projects and issue national approval letters. From the point of view of developing countries, the lack of standardization of the sustainable development criteria may have the advantage of making explicit their sovereign right to determine their development priorities and strategies. However, this aspect of the Accords has also implied a lack of international guidance on how to achieve and monitor the sustainable development objective of the CDM. In practice, not all host countries have made explicit their sustainable development criteria for assessing CDM projects, and among those who have established those criteria there is considerable heterogeneity with regard to their level of stringency. Moreover, DNAs tend to interpret the requirement that CDM projects

should help achieve sustainable development in terms of the project's congruency with the existing legal framework and sectoral guidelines, most of which are not carbon friendly (Figueres 2004).

A second fundamental weakness of the CDM, in terms of its ability to promote sustainable development, is related, somewhat ironically, to its main strength as a mechanism to support reductions in GHG emissions, namely, the fact that it uses market forces to allocate resources to projects that offer the lowest mitigation costs. Indeed, as shown by Ellis and Corfee-Morlot (2004) and Ellis and Kamel (2007), there is a great variety of project types to reduce GHG emissions, and market forces naturally direct resources to those that offer lowest costs and capital requirements, as well as the lowest payback periods and risk. The problem is that those projects that are most attractive under these criteria—for example, brownfield "end-of-pipe" projects for HFC, N_2O, or CH_4-reductions—are not necessarily those that offer larger local development benefits. In contrast, projects that do have more important co-benefits—including in terms of potential for technology transfer and replicability, such as those in renewable energy, energy efficiency, and transport—tend to be more risky and involve higher costs and upfront investments, which makes them less attractive for CDM investors.

From project to sectorwide approaches: programmatic CDM

We recall that a fundamental concern with the current functioning of the CDM is whether its focus on project-level emission reductions is sufficient for achieving an adequate engagement of developing countries in global mitigation efforts. As argued by Figueres, Haites, and Hoyt (2005), the CDM's single project approach makes it unlikely to "catalyze the profound and lasting changes that are necessary in the overall GHG intensities of developing countries' economies." A more effective approach would entail transforming the baselines themselves so as to make development pathways more carbon-friendly (Heller and Shukla 2003). In this context, rather than focusing on actions at the project level, mitigation efforts in developing countries have to shift toward promoting policy-based reforms across entire sectors—for example, energy, transport, agriculture, and forestry.

One way of implementing such sectorwide approaches is to broaden the market mechanism to include reductions obtained by developing countries while pursuing climate-friendly "development-first" policies—not unlike the way in which domestic emission reductions of industrialized countries are counted toward their commitments under the Kyoto Protocol regardless of their source. One first important step in this direction was the decision to include programs of activities in the CDM, taken in December 2005 at the first session of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP 1) in Montreal. The inclusion in the CDM of so-called programmatic CDM project activities, along the lines of a proposal made by Figueres et al. (2005),[15] has increased the ability of the CDM mechanism to support lower carbon-development pathways, without requiring a renegotiation of the basic architecture of the Kyoto Protocol.

The decision made in Montreal states that while government policies, regulations, or standards themselves cannot be submitted as CDM projects, "project activities under a programme of activities" that implement a policy/measure or stated goal can be registered as a single clean development mechanism project activity. As argued by Figueres et al. (2005), the decision not to incorporate into the CDM the adoption of a policy itself is justified within the constraints of the Marrakech Accords that define the CDM as a project-based mechanism. Furthermore, even after being officially adopted, government policies oftentimes fail to be implemented, either because of financial or technological barriers or the government's failure to enforce its laws and regulations.

However, the COP/MOP 1 decision does open a door—albeit a small one—to policies. It states that if a policy is implemented through a group or program of concrete activities whose emission reductions can be measured and verified under the rules of the CDM, the whole program of activities (POA), then, can be submitted as a single project. As defined in the specific guidance issued by the CDM EB in June 2007, a CDM program of activities can be coordinated by a

private or public entity, and it may involve the implementation of an unlimited number of voluntary actions. The latter must result in emission reductions, or removal of GHG by sinks, as compared to what would have occurred in the absence of the POA. Programs stemming from mandatory government policies are eligible, provided that the POA increases its level of enforcement (Hinostroza et al. 2007).

Pros and cons of programmatic CDM

Traditional CDM modalities already allowed for the bundling of stand-alone projects for registration purposes and the December 2005 CDM guidance incorporated the possibility of bundling large-scale projects (Ellis 2006). However, when using "bundling" as a registration option, the sites of all projects have to be specified ex-ante and all projects need to take place at the same point in time (Figueres and Philips 2007). The bundling approach is thus not well suited to dispersed activities that are the result of a large number of decisions made over a period of time, for instance, by households, offices, or factories in the context of energy efficiency incentives. In particular, it may not be possible to accurately predict at the outset the level of GHG emission reductions that will be achieved through a particular public sector incentive scheme or private initiative. While this would not have been possible under traditional CDM, programmatic CDM allows for open-ended registration whereby the entity coordinating the program can add subsequent emission reductions during the duration of the POA, for a period of up to 28 years in the case of energy-related programs and 60 years in the case of afforestation and reforestation programs. In other words, when using programmatic CDM (pCDM), one does not need to specify ex-ante all the constituent activities of a POA.

As argued by Figueres et al. (2005), the programmatic approach is especially relevant in the areas of energy efficiency and fossil fuel switching. Indeed, in these areas the deployment of carbon-friendly technologies usually does not occur on an individual basis but rather by multiple coordinated actions executed over time, often by a large number of households or firms as the result of a government measure or a voluntary program. Moreover, the transaction costs associated with CDM submissions, coupled with the relatively low volume of emission reductions generated by each individual activity or project, would often eliminate the possibility of incorporating the small individual stand-alone projects into the CDM. However, programmatic submissions could allow for diluting those transaction costs across many projects and, even in less developed small and medium countries, take advantage of the potential for emission reductions associated with the implementation of national or sectorwide programs.

As of September 2008, only four POAs were in validation: a solar home systems program in Bangladesh, methane capture in swine farms in Brazil, compact fluorescent lights in Mexico, and solar water heaters in South Africa. The slow uptake of this new registration opportunity is probably due to the fact that the modalities and procedures are still not well understood and to the reticence of DOEs to engage in POAs because of a perception of undue liability—for example, a fear that they would be held responsible for the "erroneous inclusion" of project activities that do not comply with the inclusion criteria stipulated in the project design document. Faster deployment of the pCDM approach may also point to the need to better address complicated methodological issues in the context of pCDM projects—for example, leakage, baseline, double-counting, and monitoring (Ellis 2006). However, once the initial hurdles are overcome, pCDM will continue to be limited in its scope as long as the current restriction to one single methodology remains. Indeed, this requirement limits the potential for supporting large-scale initiatives that involve system wide improvements that may require the combination of several CDM methodologies.

Potential for implementing programmatic CDM in the LCR

Despite these difficulties, studies undertaken by the World Bank show that there is a significant potential for deploying pCDM projects in Latin America. In Peru, for instance, Hinostroza et al. (2007) show that the most promising options are in energy efficiency in the public sector, small landfill programs, solar energy in the highlands, and industrial boilers. The latter

project, for instance, is estimated to have the potential for generating a yearly GHG emission reduction of more than 600,000 tCO_2e. More generally, the pCDM approach allows for dealing with several of the obstacles that limit the deployment of energy efficiency programs, which are considered the single largest source of low-cost potential reductions in GHG emission reductions over the next decades (IPCC 2007). In particular, end-use energy efficiency improvements account for two-thirds of energy-related abatement potentials (EIA 2006). One example is the conversion of the inefficient and contaminating public transportation systems in the megacities of many developing countries, which could be accompanied by a reduction in the excessive and inefficient use of private vehicles (Figueres 2007).

Among the advantages of using pCDM for supporting energy efficiency programs is the possibility of offering guaranteed financial revenue to households or businesses that invest in appliances or equipment that reduce GHG emissions. This approach can thus help overcome the "split incentive" barrier to energy efficiency programs, which is derived from the fact that those who pay for the costs of the corresponding technologies—for example, landlords who want to keep building costs as low as possible—are often not the same as those who benefit from them—for example, tenants who pay the energy bills (Figueres and Philips 2007). By using the expected revenues from the sale of CERs to be generated by the program to compensate those who pay for the more efficient technologies—for example, landlords or developers—the pCDM approach could help align their incentives with those of the users who benefit from the energy savings. As a by-product, the use of pCDM in energy efficiency programs can contribute to the standardization of national procedures for reporting GHG emissions to DNAs—standardization is a must given the large number of participants in those programs—thus contributing to the strengthening of the environmental governance of host countries (Hinostroza et al. 2007).

From programmatic CDM to broader sectoral and policy-based mitigation

Programmatic CDM is the first opening toward policy-based and sectorwide emission reductions in developing countries. By assigning a CER value to reductions achieved under a program of activities, the regime is providing the first necessary albeit insufficient incentive for developing countries to adopt and implement climate-friendly policies and measures. However, in the context of an urgent need to scale up mitigation, a financial instrument that operates with modalities and procedures that were designed with a project by project logic may not be able to leverage the sectorwide transformation that is necessary. It is possible that the market mechanism will have to evolve further in the direction of actively promoting enabling policies that will influence private investment and shift investment patterns.

Post-2012 climate finance

Over the past few years a number of proposals have emerged on potential market and nonmarket mechanisms for the post-2012 period that would share with the CDM the dual objective of supporting sustainable low-carbon development and achieving climate change mitigation in developing countries. These proposals have emerged both in the context of formal negotiation processes and as a result of the large amount of research, analysis, and informal discussions on future regimes that have taken place during recent years.[16] Two particularly promising groups of proposals encompass the so-called policy-based and sectoral approaches.

The policy-based approach

This approach centers around providing abatement funding to countries that adopt binding or nonbinding policies, voluntary or mandatory standards that reduce GHG emissions, even if they are primarily aimed at sustainable development objectives. On the one hand, developing countries would be expected to make nonbinding commitments in the form of voluntary pledges of either emission growth controls—for example, as in a proposal by the South-North dialogue (Ott et al. 2004)—or in the form of policies that they would pledge to implement—such as in the Sustainable Development Policies and Measures (SD-PAM) proposal originally suggested by Baumert and Winkler (2005).

The purpose of SD-PAMs is to capture the potential co-benefits of local sustainable development and promote them via the multilateral climate framework. SD-PAMs backcast from the desired future state of development and define more sustainable (that is, lower emission) pathways to meet those development objectives. The focus is on large-scale policies and measures, not individual projects. Although crediting could be incorporated, typically the SD-PAMs are a nonmarket approach based on international funding made available specifically for this purpose. Developed countries would support the voluntary efforts of developing countries, both financially and through technology transfers. SD-PAMs are well suited for sectors that are important for sustainable development (energy efficiency, transport) and those that have many small emissions sources (for example, households, buildings, and so forth).

Several issues remain open for discussion under SD-PAMs: would countries be allowed to propose the policies they choose, or would there be an eligible list of policies that are supported internationally? How closely would emission reductions have to be tracked and reported, particularly if it is not used as a market mechanism? As argued by Cosbey et al. (2007), one of the main concerns with policy-based approaches is the difficulty to prove additionality. To deal with this issue, specific criteria would have to be agreed upon to distinguish between policies that would have probably not been implemented had it not been for the support of carbon finance. Alternatively, the corresponding emission reductions could be discounted to account for the difficulty in proving their additionality.

The sectoral approach

Originally proposed by Samaniego and Figueres (2002), the sectoral approach can be seen as an extension of the market mechanism in the sense that it would award CERs to developing countries that overachieve on emission reduction or intensity targets adopted voluntarily for specific sectors.[17] The origins of the sectoral approach are related either to the previously described limitations of the project-based traditional CDM, or to concerns over leakages and negative competitiveness effects associated with regional or country-specific mitigation commitments (Sawyer 2008). Motivated by the first type of concerns, one version of the sectoral approach focuses on unilateral country-specific emission reductions commitments.

An evaluation of this proposal focuses on Sectoral No-Lose Targets (SNLTs). SNLTs are a form of nonbinding emission targets, according to which developing countries would voluntarily propose some form of national emission intensity target for the sector in question, over a commitment or "management" period of time. The target would be below the business-as-usual projection and it would be negotiated internationally. The country would reach the crediting baseline through domestic efforts and would then be allowed to sell any surplus emission reductions achieved beyond the crediting baseline, but there would be no penalty for not achieving that baseline.[18]

Countries would typically opt for sectoral approaches where there was a high degree of alignment between domestic development priorities and climate change management. In principle, countries could be attracted to consider SNLTs in those sectors for which they seek significantly scaled-up private sector investment and where the current carbon finance tools could be inadequate. Some likely candidates are electricity generation (measured in tons CO_2e per MWh generated); cement, aluminum, or steel production (measured in tons CO_2e per ton produced); and "upstream" emissions of oil and gas production—for example, gas venting and flaring—(measured in tons CO_2e per barrel of oil delivered to refineries or export facilities, or volume of gas delivered).[19]

A second version of the sectoral approach, motivated by international competitiveness concerns, would involve international agreements aimed at leveling the playing field for specific industries in order to avoid competitiveness gains being obtained through regulatory arbitrage. This is a special concern for trade-exposed energy intensive industries, such as cement, aluminum, and steel. Crediting could be considered between companies within the same industry in both developed and developing countries. This type of initiative would normally be industry-led and would aim at engaging a sector on a broad international basis. It is aimed at industrial sectors that are concentrated in few

companies worldwide and that are so energy intensive that they alone represent a significant share of emissions (Egenhofer et al. 2007).[20] A current example is the Cement Sustainability Initiative (CSI) formed under the auspices of the World Business Council for Sustainable Development. The CSI intends to propose industry baselines to be negotiated on a country level.

A host of other concepts involving mitigation at the sectoral level have been explored (Bodansky 2004; Baron and Ellis 2006; De Coninck et al. 2007; Fischer et al. 2008). The common focus is to use the international regime to accelerate the decarbonization of a sector by moving from nonregulation to regulation or at least to agreements across the sector. There are, however, a number of practical issues that could greatly complicate the implementation of the sectoral approaches. Egenhofer and Fujiwara (2008) emphasizes the fact that benchmarking is very data intensive and may not be realistic in some countries or some sectors. Cosbey et al. (2007) point to the challenge of negotiating adequate international baselines that take into account national circumstances and balance the risk of free-riding with the need to avoid perverse incentives that reward carbon-harmful policies. Moreover, the negotiating parties would have to agree on whether developed countries could or could not use their contributions to the implementation of sectoral programs in developing countries toward their own mitigation commitments, and on whether large developing emitters would be able to use their sectoral achievements toward their own possible future mitigation commitments.

Sectoral approaches may only make sense for larger middle-income countries with world-scale carbon intensive industries where aggregation of revenue potential provides financial leverage sufficient to transform the sector over a 10 to 20-year period (such as the iron and steel industry and cement industries in China and India, and pulp and paper industry in Brazil). However, while the sectoral approach is explicitly mentioned as an option in the Bali Action Plan, some developing countries have expressed concern that it could be used as a "backdoor" strategy to push them into binding reduction commitments.

Some considerations about the climate finance options

It is still too early to know how the various 2012 climate finance options will be designed, how they will relate to each other, and whether there will be decisions on differentiated access to them. At present, most of the political support for the consideration of how to structure mitigation efforts is coming from industrialized countries, while developing countries are more concerned with the need for reassurance that appropriate and predictable climate finance revenues will be on the table.

Not all the options under consideration would be relevant for a market-based mechanism, but those that are could only be effective if there is a demand. Given the supply of credits already prospectively in the pipeline from existing CDM projects, demand from the EU-ETS Phase III (2013–20) provides limited extra demand, even if the European Union takes on the 30 percent emission reduction target it has proposed for 2020 if a comprehensive multilateral agreement is reached. In order to strengthen demand, ambitious reduction targets of all industrialized countries are needed, which is only consistent with the science-based calls for significant global emission reductions by 2020.

On the supply side, the CDM process needs to be cautious about the automatic renewal of projects that have already produced large volumes of credits, such as the hydroflourocarbon (HFC) destruction projects. With the bulk of industrial gases now eliminated by technically sound and cost-effective means, developing countries could be expected to require their continued elimination as a production standard.[21] Continued eligibility for industrial gases as a compliance asset would exacerbate existing biases in carbon finance flows to middle income industrializing-countries and divert capital away from decarbonizing their energy supply and infrastructure.

Finally, even if successfully negotiated, it is highly unlikely that any of the climate finance approaches described previously will deliver, on their own, the needed mitigation volumes in developing countries, given the different national circumstances and the variety of sectors that could achieve emission reductions. It is more probable that countries will have to use some combination of these, targeting each to the

more appropriate national realities and types of mitigation activities, thereby achieving a mutually reinforcing effect.

Specific challenges associated with reducing deforestation

Reducing deforestation may be one of those types of mitigation activities that require special consideration. The first commitment period of the Kyoto Protocol did not include reduced emissions achieved by means of avoided deforestation. This was due in part to concerns over technical issues, including with regard to baseline setting and monitoring—that is, to ensure the additionality and permanence of emission reductions—and with respect to leakages—that is, the risk that avoided deforestation in some places could be compensated by increases in others (Schlamadinger et al. (2007). Moreover, at the time there were also concerns with a possible trade-off between the use of this potentially low-cost mitigation option and the implementation of domestic emission reductions in Annex I countries (Sawyer 2008). More recent international negotiations, however, have moved toward recognizing decreases in deforestation from a preestablished baseline as generating credits and/or compensations in a post-2012 regime. In particular, the Bali Action Plan explicitly calls for addressing "policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries."

A conceptual framework for reducing deforestation rates in the Brazilian Amazon has been proposed by Nepstad et al. (2007). In their proposal, financial incentives would be used to partially compensate forest-based local populations—for example, indigenous groups, traditional rural populations, and some small landholders—and legal private landholders, respectively for their "forest stewardship" role and forest conservation efforts. Moreover, a "government fund" would be needed in order to compensate the government for expenditures above and beyond current outlays, including for the management of public forests, the provision of services to local populations, and the monitoring of private forests (including expanded environmental licensing). Over a 30-year period, the deforested area would be 490,000 km^2 smaller and avoided emissions would be 6.3 billion tons of carbon lower than in a business-as-usual scenario estimated by Soares-Filho et al. (2006).[22] The overall cost of such a program would be about US$8.2 billion, or about US$1.3 per ton of avoided carbon emissions.

How does this compare to the opportunity cost of maintaining the Amazon forest instead of switching to other possible land uses, such as agriculture and cattle ranching? Nepstad et al. (2007) estimate that preserving the remaining forests of the Brazilian Amazon—3.3 million km^2 and 47 billion tons of carbon—would have an opportunity cost of US$257 billion. This implies an opportunity cost of avoiding emissions from deforestation of about US$5.5 per ton of carbon. It must be noted, however, that in 6 percent of the total area under study, the opportunity cost of forest maintenance is estimated to be about 17 times higher than in the remaining 94 percent. Excluding this area, which is located closer to the agricultural frontier, the opportunity cost of avoiding emissions through forest maintenance would be about US$2.8 per ton of carbon, or about US$18 billion for the emissions that would be avoided through the previously described REDD program (about 6 billion tons of carbon). As argued by Nepstad et al. (2007), part of the difference between the estimated cost of their REDD program and the opportunity cost of the corresponding avoided emissions could be diminished by the consideration of the substantial benefits that avoiding deforestation could bring to Brazilian society—beyond the mitigation of climate change.

In the context of the climate negotiations several different proposals have emerged over recent years with regard to possible global frameworks for reducing emissions from deforestation and forest degradation. Perhaps the main distinction between the various proposals is whether developed countries would be allowed to gain credits for their possible contributions to REDD efforts in the developing world. Using this approach, Costa Rica and Papua New Guinea have proposed to incorporate REDD into the CDM, thus allowing for the possibility of issuing credits to projects or programs that reduce deforestation with respect to some established baseline.

Brazil, on the other hand, has established a specific "nonmarket" fund dedicated to REDD. The Tropical Forest Fund will channel contributions from Annex I countries into activities that reduce tropical deforestation, but reductions achieved would not count toward Annex I mitigation commitments. The fund will award financial incentives, either in the form of payments, technology transfer, or capacity building, to countries that lower their deforestation rates below an established baseline rate. There would be no penalties for not meeting the corresponding goals, although failing to do so could count against future reductions below the baseline (Sawyer 2008). The fund hopes to receive donations in the order of US$21 billion by 2021. Norway has already pledged US$1 billion to the fund. Other proposals have combined aspects of both market-oriented and fund-based alternatives. In all proposals, the resources allocated to reducing deforestation are to some extent transformed into financial incentives per avoided ton of CO_2. However, as noted by Strassburg et al. (2008), in order for those financial incentives to be effective in addressing the local drivers of deforestation, and because of sovereignty issues, the intranational distribution of the resources to be allocated to reducing deforestation needs to be decided at the country level and is unlikely to be included in international REDD mechanisms.

Notes

1. G-8 is the group of leading economies, which includes Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, and the United States.

2. The trajectory shown covers CO_2 emissions only, including approximately 1.5 GtC of emissions from land use in non-Annex I countries in 2000 (note that each ton of carbon corresponds to about 3.7 tons of CO_2). The radiative forcing from non-CO_2 gases is assumed to decline by about 50 percent by mid-century.

3. Note, however, that even for this relatively conservative target, higher rates of warming cannot be excluded. The level of expected warming in the hypothesis of meeting this target rises from 3°C to 4.9°C when using high end—instead of mode—estimates for the so-called "climate sensitivity" parameter, which measures the expected warming associated with a doubling of GHG concentrations. Stern (2008), for instance, using a very similar target of 550 CO_2e ppm, reports a 7 percent probability of temperature increases above 5°C, which could potentially lead to the melting of most of the world's ice and snow, as well as to sea level rises of 10 meters or more, and losses of more than 50 percent of current species.

4. Note, however, that there is a sizable degree of heterogeneity within both groups of countries. Japan and most of Europe, for instance, have emissions of about 10 to 12 tCO_2e per capita, while the United States and Canada emit about twice as much. Similarly, while India's per capita emissions are below 2 tCO_2e, China's are close to 5 tCO_2e.

5. Data are from WRI (2008): http://cait.wri.org/cait.php (September 9, 2008).

6. These could be complemented with government regulations aimed at addressing various types of market failures that may limit the diffusion of low-carbon technologies—for example, lack of information, credit constraints, or the presence of split incentives.

7. UNFCCC (2007), *Investment and Financial Flows to Address Climate Change*.

8. An agreement would also be needed on whether to look only at cumulative per capita emissions or, alternatively, to also consider total absolute levels of emissions. The latter could be particularly relevant in the context of stringent stabilization targets, which would require a strong involvement of the world's largest emitting nations, regardless of their level of development (Ellis 2006).

9. Figueres, C. 2004. "Institutional Capacity to Integrate Economic Development and Climate Change Considerations: An Assessment of DNAs in Latin America and the Caribbean." Inter-American Development Bank.

10. In terms of warming potential, 1 ton of HFC is equivalent to 117,000 tons of CO_2.

11. Currently the European Union (EU), the main buyer in the market, requires that CERs derived from hydropower projects greater than 20 MW must comply with the guidelines of the World Commission on Dams (WCD), which adds complexity to project registration and practically prevents the registration of those projects. Thus the inclusion of large hydropower projects in the CDM has been limited to mostly smaller-size plants. However, Annex I DNAs are sovereign while applying its own criteria on whether or not a given hydropower project complies with the WCD. In an effort to bring homogeneity to WCD compliance criteria for CDM projects, the EU Commission foresees the future introduction of an EU guideline on this matter.

12. Figueres (2006).

13. Figueres and Newcombe (2007).

14. Similarly, the original interpretation of the Marrakech Accords led CDM stakeholders to believe that if a country issues regulations to toughen energy efficiency standards, projects aimed at upgrading existing technologies to meet the new standards could not be eligible for CDM financing. As a result, countries could have an incentive to keep their climate-friendly

policies in the realm of plans and programs, and to not take the additional step of embedding them into their official regulatory framework. This was reportedly the decision made by Colombia during 2003–04, following countrywide consultations aimed at identifying potential CDM projects and low-carbon policy options in the sectors of transport, energy, and forestry (Hinostroza et al. 2007).

15. Among the various precedents to their proposal, Figueres et al. (2005) mention the "sectoral approach" proposed by Samaniego and Figueres (2002), the "programmatic crediting mechanism" proposed by Bodansky (2004), and the "policy-based" mechanisms proposed by Cosbey et al. (2005) and Sterk and Wittneben (2006).

16. Cosbey et al. (2007) describe 44 proposals that have been made within and outside of formal UNFCCC processes. Thus, some of those proposals have come forward in the context of formal negotiations that are taking place both under the Kyoto Protocol, on possible future commitments beyond 2012—the "Protocol track"—and in the context of a nonbinding dialogue on cooperative actions to address climate change by enhancing the implementation of the UNFCCC—the "Convention Track" (Figueres 2007).

17. See also Bodansky (2004), Bosi and Ellis (2005), Figueres et al. (2005), Schmidt et al. (2004), Cosbey et al. (2005), and Sterk and Wittneben (2006). The interest in this approach permeated the political spheres with the 2005 OECD high-level roundtable on transnational sectoral agreements for climate policy, the G-8 Gleneagles Plan of Action, and the Major Economies Meetings.

18. Two variations of the SNLTs concept have emerged, one by the Center for Clean Air Policy (CCAP) and the other by Ecofys/GtripleC. On the one hand, in the CCAP version, international benchmarks would be featured explicitly as a negotiation parameter, that is, to draw links with the performance of these sectors in industrialized countries for competitiveness reasons. See Schmidt et al. (2006) and Center for Clean Air Policy, International Future Actions Dialogue, August 2006. Ecofys/GtripleC, on the other hand, have developed sectoral proposal templates, the purpose of which is to provide a standardized tool by which countries can prepare and propose crediting baselines without referring to international benchmarks. See www.sectoral.org.

19. Ward (2008). Proponents of the SNLT mechanism argue that crediting-baselines be negotiated at the same time as Annex I country targets for post-2012 are being agreed upon, so additionality would no longer need to be an issue as it is not for actions taken by industrialized countries that have emission-reduction targets. This distinguishing feature of SNLTs is its major strength and at the same time its fundamental drawback. The absence of the additionality criterion suggests it might have the potential for scaling-up investments, at least in the appropriate sectors. However, the critical prerequisite for data and prepared institutions could mean that proposals for SNLTs for some key sectors in some developing countries will not be sufficiently developed at the time it is expected that industrialized countries' targets should be agreed upon. If this were to be the case, it would severely curtail the potential impact of SNLTs.

20. Egenhofer et al. (2007).

21. In the case of smaller economies that still have such facilities, the OECD could consider a grant program to ensure that they have the incremental funds to install the required catalysts and incineration equipment and operate this as per the Multilateral Fund for Phaseout of Ozone Depleting Substances.

22. As per the estimates of Soares-Filho et al. (2006), current trends in agricultural expansion would lead to the elimination of 40 percent of Amazon forests by 2050.

CHAPTER 5

LCR's GHG Emissions

The LCR has an ample climate mitigation potential waiting to be unlocked through increases in energy efficiency and the deployment of low-carbon technologies in the areas of energy and land use. As argued in the previous chapter, an expanded climate finance architecture could potentially play a critical role in ensuring that the region's mitigation potential is exploited in a way that is both equitable and efficient. In order to take full advantage of this potential, however, international transfers of technology and financial resources for mitigation will have to be complemented with appropriate climate-friendly domestic development policies. Exploring the specific mitigation technologies and corresponding policy options available to LCR countries is the objective of the next chapter. As a preamble to that discussion, this chapter maps the unique composition and evolution of the LCR's GHG emissions.

Latin America is a relatively minor source of energy-related GHG emissions from the burning of fossil fuels but a significant source of GHG emissions from land-use change. The LCR's distinctive characteristics set it apart from the rest of the world. Indeed, the composition of its GHG emissions is unique, both with respect to OECD countries and to the rest of the developing world. First, the LCR has disproportionately high emissions from land use, land-use change, and forestry (LULUCF). Second, the LCR has a relatively low share of emissions related to energy supply.

Is the LCR Part of the Problem? The Region's Share of Global GHG Emissions

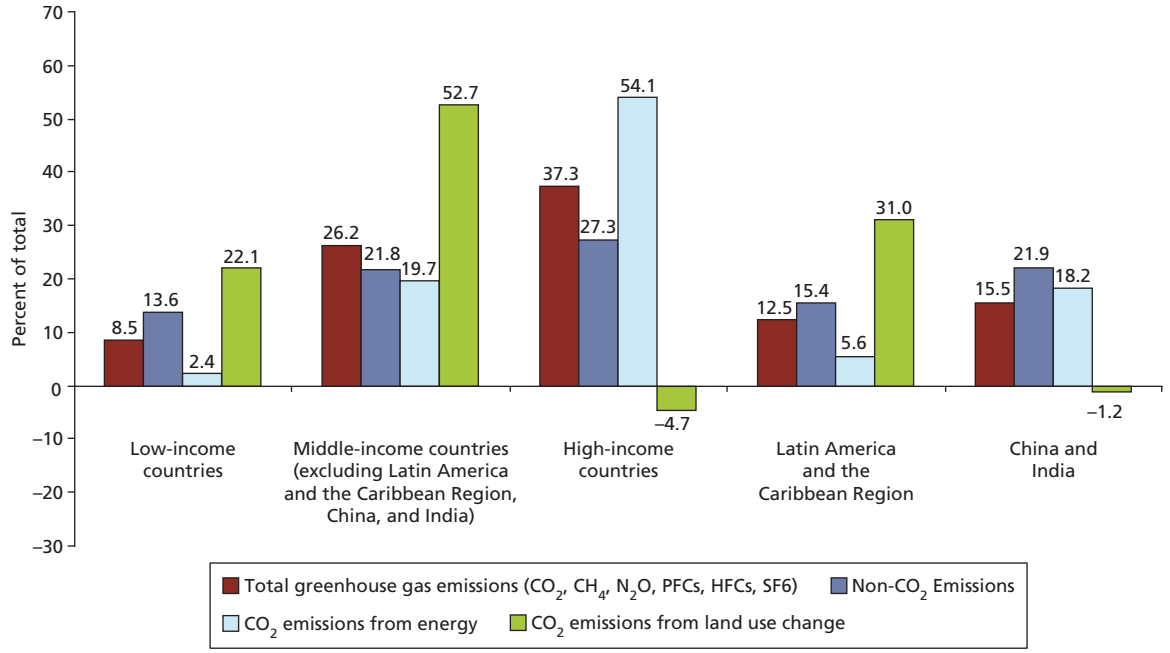
Latin America is a relatively minor source of energy-related CO_2 emissions but a significant source of CO_2 emissions from land-use change and of non-CO_2 GHG emissions. About 70 percent of the latter are related to agriculture, with the remaining associated with waste and industrial activities. In particular, despite having about 8.5 percent of the world's population and GDP, in 2000 the LCR accounted for only 5.6 percent of global energy-related CO_2 emissions (figure 5.1). In contrast, the LCR's share of global emissions from land-use change amounted to 31 percent and that of non-CO_2 emissions to 15.4 percent. When all GHG emissions are considered—including those from land-use change—the LCR's share of global GHG emissions reaches 12.5 percent.

When focusing only on the emissions of developing countries, the LCR accounts for 22 percent of the total flow of GHG emissions, 14 percent of energy-related CO_2 emissions, and 30 percent of CO_2 emissions from land-use change (figure 5.2). In all cases, the LCR's total emissions are below those of East Asia. However, they are above those of the developing countries of Europe and Central Asia, the Middle East and North Africa, South Asia, and Sub-Saharan Africa.

Overall, if all GHG emissions are considered, the LCR's share of developing world emissions (22 percent) is above its share in the total population of those countries (11 percent), and it is comparable to its share in the GDP of that group (21 percent). The LCR's share in non-CO_2 emissions (23 percent) is also close to that in developing countries' GDP. In contrast, LCR accounts for only 14 percent of the energy related CO_2 emissions of those countries and for 30 percent of their land-use change emissions. Thus, as shown in figure 5.3, the region exhibits higher emissions per capita than the rest of the developing world, with 10 tons of CO_2e per capita compared with 3.5 for low-income countries,

FIGURE 5.1

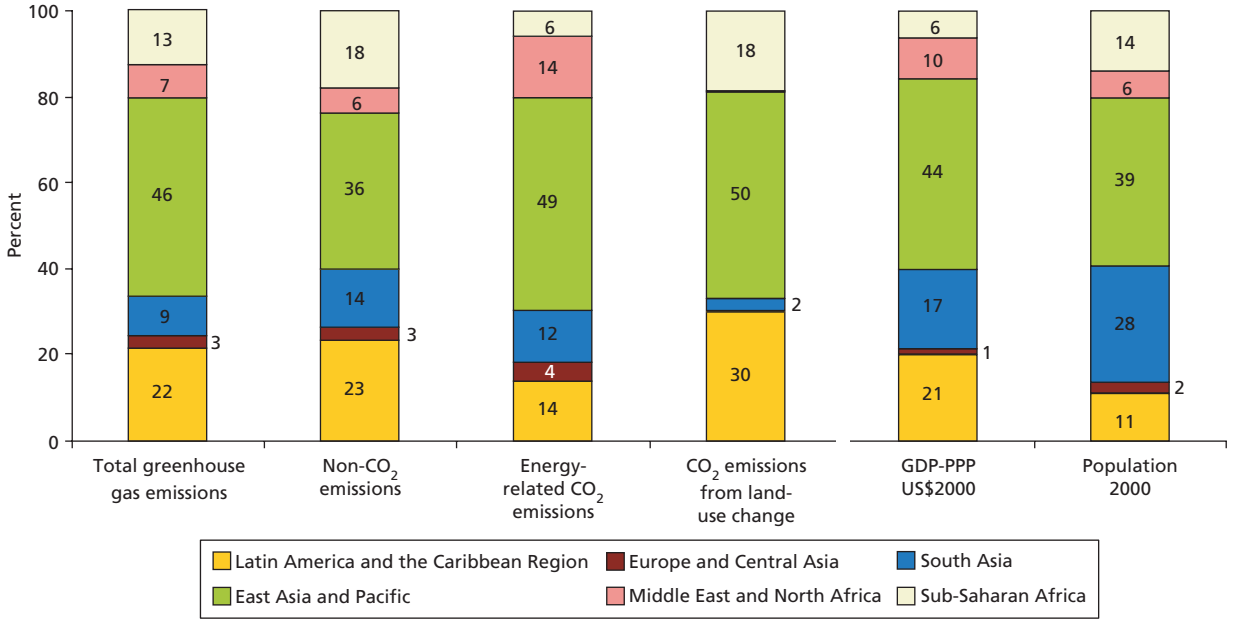
Latin America and the Caribbean Region's Share of Global Greenhouse Gas Emissions, 2000



Source: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).
Note: HFC = hydroflourocarbon; PFCs = perfluorocarbons.

FIGURE 5.2

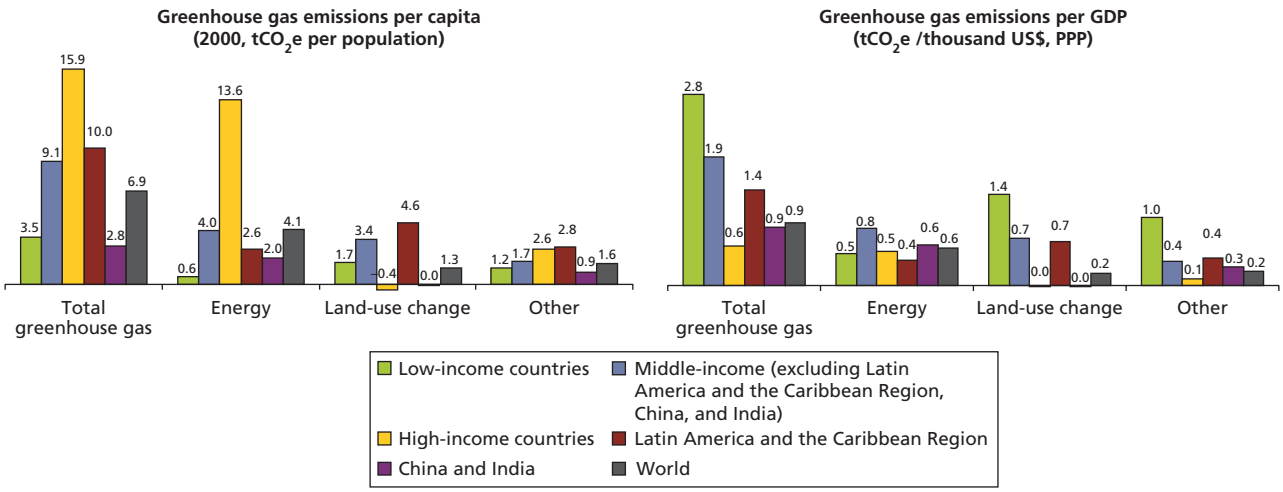
Greenhouse Gas Emissions by Latin America and the Caribbean Region and Other Developing Regions, versus GDP and Population, 2000



Source: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).

FIGURE 5.3

Greenhouse Gas Emissions Per Capita and Per GDP



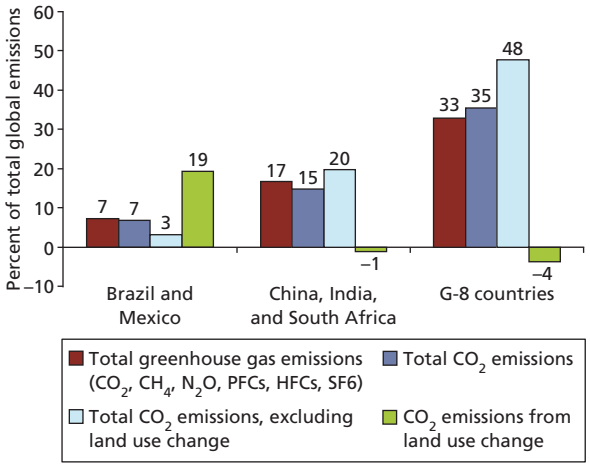
Source: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).

2.8 for China and India, and 9.1 for other middle-income countries. However, while LCR's emissions per unit of GDP—about 1.4 tCO_2 per 1,000 US$ PPP—are also above those of China and India (0.9 tCO_2e), they are below those of low-income and other middle-income countries (respectively, 2.8 and 1.9 tCO_2e). In comparison with industrialized countries, LCR's emissions are 37 percent lower in per capita terms and 144 percent higher as a fraction of GDP. However, when the focus is on energy-related emissions, the region's emissions become, respectively, 80 and 25 percent lower than those of industrialized countries.

The diversity among LCR countries also adds to the complexity of the region's emissions profile. It is important to note that two large LCR countries—Brazil and Mexico—are among the world's top 20 largest GHG emitters. Brazil is ranked fourth when considering all GHG emissions, including those from land-use change, whereas Mexico is ranked twelfth. When considering CO_2 emissions without land-use change, Mexico is ranked eleventh and Brazil fourteenth. Together with China, India, and South Africa, Brazil and Mexico are among the five developing countries with the largest energy-related CO_2 emissions, in absolute levels. As shown in figure 5.4, those five developing countries account for about one-fourth of the world's total GHG emissions, compared to a 33 percent share for the G-8. The conclusion that can be drawn from this general picture of LCR's GHG emissions is that the region's main contribution to global emissions is the result of land use, land-use change, and forestry. However, the cases of Brazil and Mexico show there is notable heterogeneity across the LCR, both in terms of the extent and composition of GHG emissions.

FIGURE 5.4

Greenhouse Gas Emissions by G-8 and Major Developing Countries



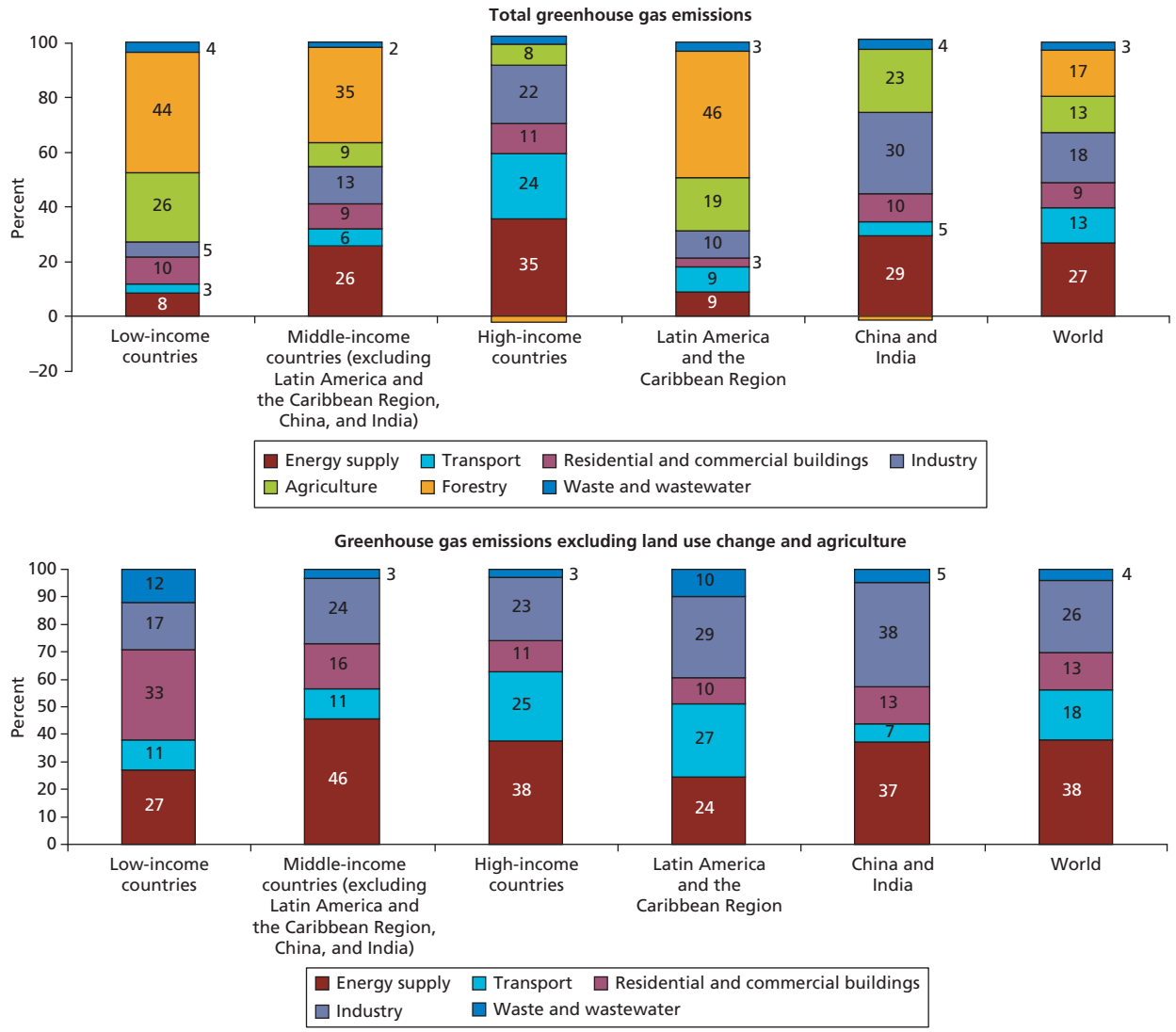
Source: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).

A different sector composition of GHG emissions

Not surprisingly, given the comparisons presented above, the sector composition of the LCR's GHG emissions is quite different from that found in the rest of the world (figure 5.5). In contrast with LCR, industrialized countries capture more carbon than they release into the atmosphere through forestry and land-use change activities. Having already exhausted most of their natural forests, industrialized countries therefore exhibit slightly negative emissions from land-use change. Emissions from forestry and land-use change are much more important in the LCR, representing 46 percent of the region's total GHG emissions, compared to 17 percent for the world as a whole. Low-income countries have a share of land-use change emissions close to that of LCR (44 percent). As for other middle-income countries, land-use change (LUC) emissions are negative in China and India and they represent 35 percent of the emissions of other middle-income countries. The LCR also has a higher share of emissions from the agricultural sector, which represents 19 percent of total emissions compared to 8 percent for high-income countries, and

FIGURE 5.5

Sector Composition of Greenhouse Gas Emissions, 2000



Source: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).

13 percent at the global level. As for other developing countries, those with low incomes, as well as China and India, exhibit higher shares of agriculture in total GHG emissions than the LCR—26 and 23 percent, respectively, compared to 19 percent for LCR—while other middle-income countries have a share that is closer to that of rich countries (8 percent).

Even when the focus is only on non-LULUCF emissions, LCR still exhibits a relatively unique emissions profile (figure 5.5). At the global level, as well as in high-income and other middle-income countries, energy supply accounts for approximately 40 percent of those emissions, whereas in the LCR it represents only 24 percent, a share that is closer to that of low-income countries (27 percent). In contrast, the share of emissions originating from the transport sector (27 percent) is close to that found in industrialized countries (25 percent) and much higher than in other developing regions (between 7 and 11 percent). Moreover, the share of emissions from waste and wastewater (10 percent) is well above that found in high-income and other middle-income countries—between 3 and 5 percent—and closer to that of low-income countries (12 percent).

The region's relatively high shares of emissions from transport and waste management are likely the result of intense urbanization. Indeed, 75 percent of the population in Latin America and the Caribbean already lives in urban areas (GEF 2009), where most of the travel and waste production occur. The LCR's large volume of emissions from the transport sector is particularly worrisome as this is the fastest growing sector in terms of GHG emissions. The International Energy Agency projects that CO_2 emissions from worldwide vehicles will increase by 140 percent, from 4.6 gigatons in 2000 to 11.2 gigatons in 2050. The vast majority of this increase will take place in developing regions, especially the LCR and Asia, as a result of increased motorization and vehicle use.

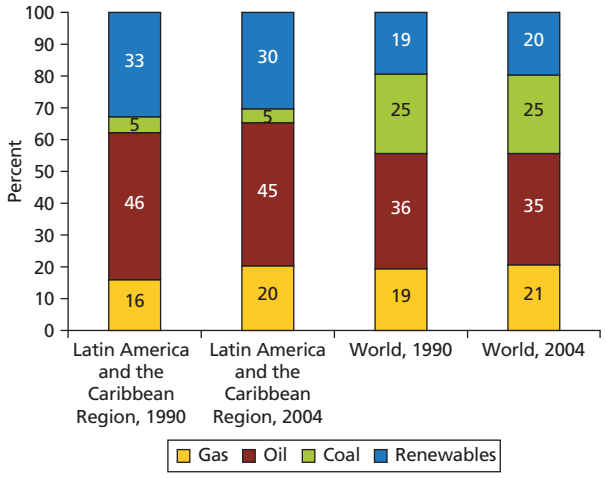
A cleaner energy mix

The LCR's energy mix also sets it apart from other developing countries. Indeed, the relatively low percentage of emissions from energy supply found in the LCR reflects a cleaner energy mix in comparison with other regions of the world. Not only does the LCR have a higher share of its energy supply produced from renewable sources, particularly hydro power (IEA 2006), but the carbon intensity of the region's fossil fuels is lower than that of other regions of the world. As seen in figure 5.6, the share of renewable energy sources is 30 percent in the LCR, compared to 20 percent at the global level. Moreover, while coal accounts for 25 percent of the world's energy supply, in the LCR it has a share of merely 5 percent. This constitutes a significant difference considering that the carbon content of coal per unit of energy is 70 percent higher than that of gas and 40 percent higher than that of oil.

The composition of the LCR's primary energy supply shows striking differences with the rest of the world. For instance, the share of natural gas in the LCR's energy matrix has increased over the past 15 years, from 16 percent to 20 percent, bringing the region closer to the world average of 21 percent (figure 5.6). It is worth noting that most of the increase in the share of natural gas took place at the expense of renewable energy. Nevertheless, the composition of the LCR's fossil fuel emissions reveals a significant change in the share of gas fuel emissions, which has actually risen from 13 percent to 23 percent

FIGURE 5.6

Composition of Total Primary Energy Supply for Latin America and the Caribbean Region and the World, 1990 and 2004



Source: IEA (2007).
Note: The LCR figures from the International Energy Agency exclude Mexico.

between 1980 and 2004. Most of this increase has been at the expense of oil, whose share fell from 73 percent to 64 percent. The difference between the share of solid fossil fuels in the LCR's fossil fuel emissions in comparison with global figures is striking. Indeed, solid fossil fuels, such as coal, account for only 8 percent of emissions in the LCR, compared with 30 percent to 50 percent in most regions of the world and almost 80 percent in China (figure 5.7).

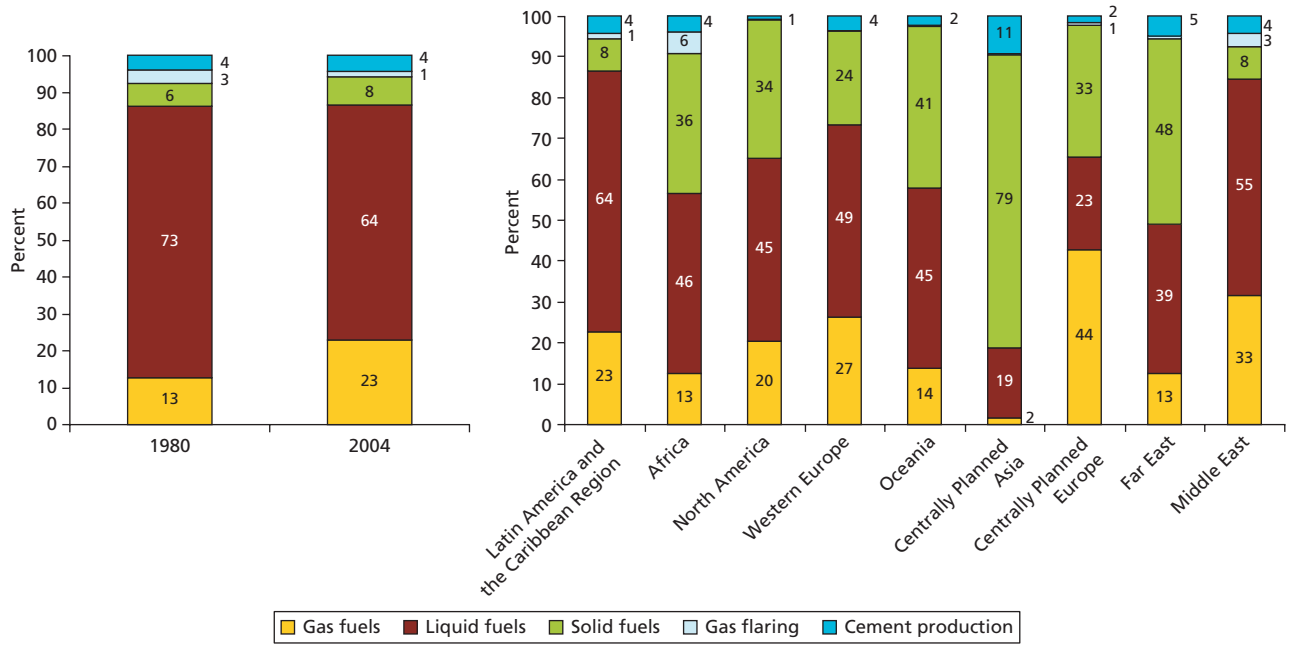
Further inquiry into the LCR's electricity generation mix can help explain the relatively low share taken up by the power sector in the region's energy-related emissions. Looking in more detail at the LCR's electricity generation mix can also explain why the region's energy sector continues to exhibit relatively low-carbon intensity. As seen in figure 5.8, hydroelectric generation has accounted for more than 60 percent of the generation mix for most of the past 25 years. If anything, there has only been a gradual increase in the participation of thermal generation, mostly after power sector reform and private participation were introduced in many LCR countries, starting in the early 1990s.

Between 1980 and 2004, electricity demand increased at an annual rate of 4.7 percent in the LCR, driven by economic development and major progress in electricity coverage, which reached 90 percent in 2005. In the same period, emissions from the power sector grew at a rate of only 3.7 percent per year. As a result, the carbon intensity of the LCR's power generation was much lower than the world average. Indeed, in 2004 it represented 261 grams CO_2 per kWh (kilowatt hour) for the LCR in comparison with 500 for the world (Dussan 2008).

The reasons behind the LCR's success in reducing the carbon intensity of its power sector by 20 percent, despite increasing the share of thermal power generation by 3 percent, lies in the region's unique energy profile. As illustrated in figure 5.9, the carbon intensity of the power sector generally exhibits a high positive correlation with the use of conventional thermal plants. However, in the case of the LCR, the lower rate of growth in emissions in comparison with electricity demand can be traced to the development of cleaner fuels, such as natural gas, and to improvements in

FIGURE 5.7

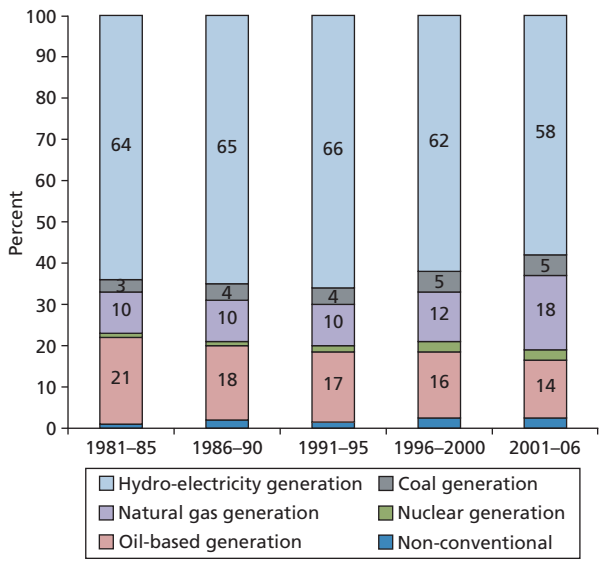
Composition of Fossil Fuel CO_2 Emissions for Latin America and the Caribbean Region and the World, 1980 and 2004



Source: Marland, Boden, and Andres (2007).

FIGURE 5.8

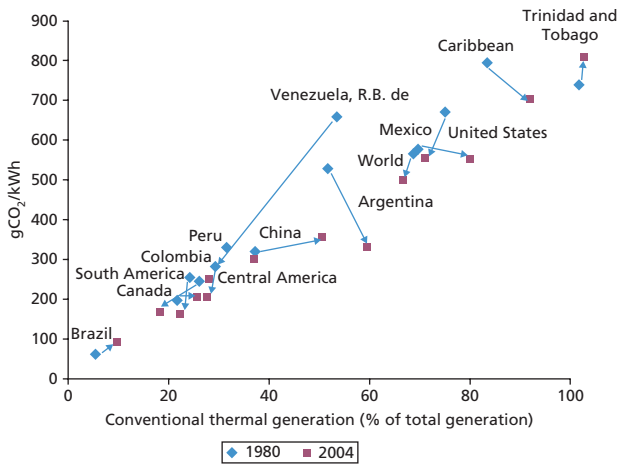
Latin America and the Caribbean Region's Electricity Generation Mix, 1981–2006



Source: Dussan (2008).

FIGURE 5.9

Latin America and the Caribbean Region's Carbon Intensity of Electricity and Share of Thermal Generation, 1980–2006



Source: Dussan (2008).

the efficiency of thermal plants, mainly by means of retiring old steam turbines and introducing combined cycle gas turbines (CCGTs) and medium-speed diesel engines.

Nonetheless, as shown in figure 5.9, the differences in emissions from electricity generation across LCR countries are striking. Brazil, for instance, due to its hydro-based generation system and a very low-carbon intensity of electricity generation (87 grams CO_2/kWh in 2004), ended up increasing its carbon intensity as the share of thermal generation increased. In contrast, Argentina and Mexico were able to reduce the relatively high levels of carbon intensity of their power sectors and at the same time increase the share of conventional thermal generation, mainly by developing high-efficiency gas-fired plants and retiring obsolete low-efficiency oil-fired steam plants through an aggressive strategy. Similarly, Central America successfully reduced its carbon intensity while increasing the share of thermal generation by developing high-efficiency diesel engines running with residual oil. Finally, República Bolivariana de Venezuela made spectacular progress in reducing its carbon intensity by means of decreasing the share of thermal generation through the development of low-cost generation projects mainly in the Caroni Basin.

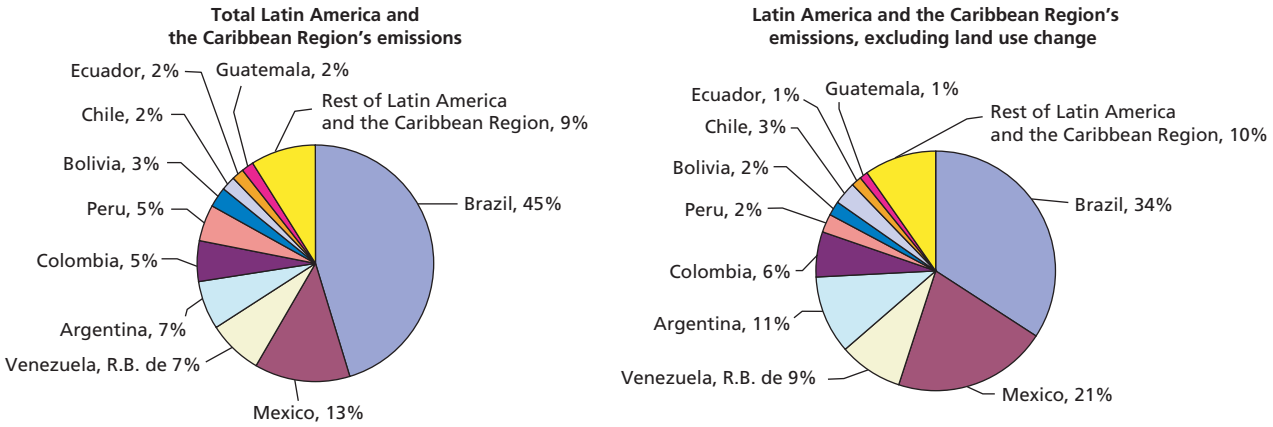
Country-Specific GHG Emission Patterns

Brazil and Mexico account for almost 60 percent of both the region's total GHG emissions and its GDP. Another 25 percent of the LCR's emissions and GDP are accounted for by Argentina, Colombia, Peru, and República Bolivariana de Venezuela (figure 5.10). A similar ranking emerges if one excludes emissions from land-use change, with the exception of Brazil and Mexico, whose share of the LCR total emissions, respectively, falls from 45 percent to 34 percent and increases from 13 percent to 21 percent.

Emissions from land-use change are responsible for 46 percent of the LCR's total GHG emissions. However, land-use change emissions are distributed heterogeneously across the region. As shown on the right side of figure 5.11, Brazil alone is responsible for 58 percent of LCR emissions from land-use change, followed by Peru with 8 percent, and Colombia and República Bolivariana de Venezuela with about 6 percent each. The share of land-use change in total emissions also varies across countries. In five LCR countries—Bolivia, Brazil, Ecuador, Guatemala, and Peru—emissions from land-use change are responsible for at least about 60 percent of GHG emissions. In contrast, in Argentina, Chile, and Mexico, the share of

FIGURE 5.10

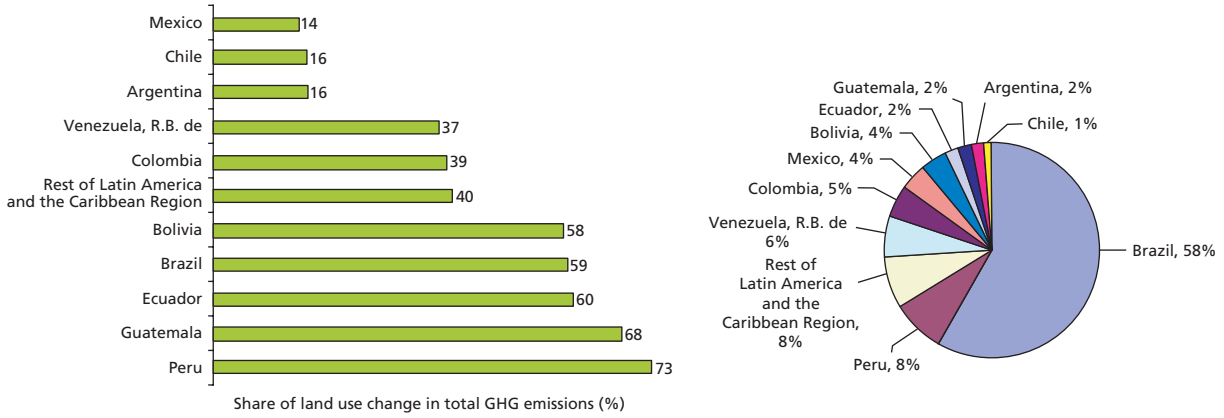
Composition of Latin America and the Caribbean Region's Greenhouse Gas Emissions, 2000



Source: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008); Venezuela, R.B. de, World Resources Institute (2008).

FIGURE 5.11

Composition and Share of Latin America and the Caribbean Region's Emissions from Land Use Change, 2000



Source: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).

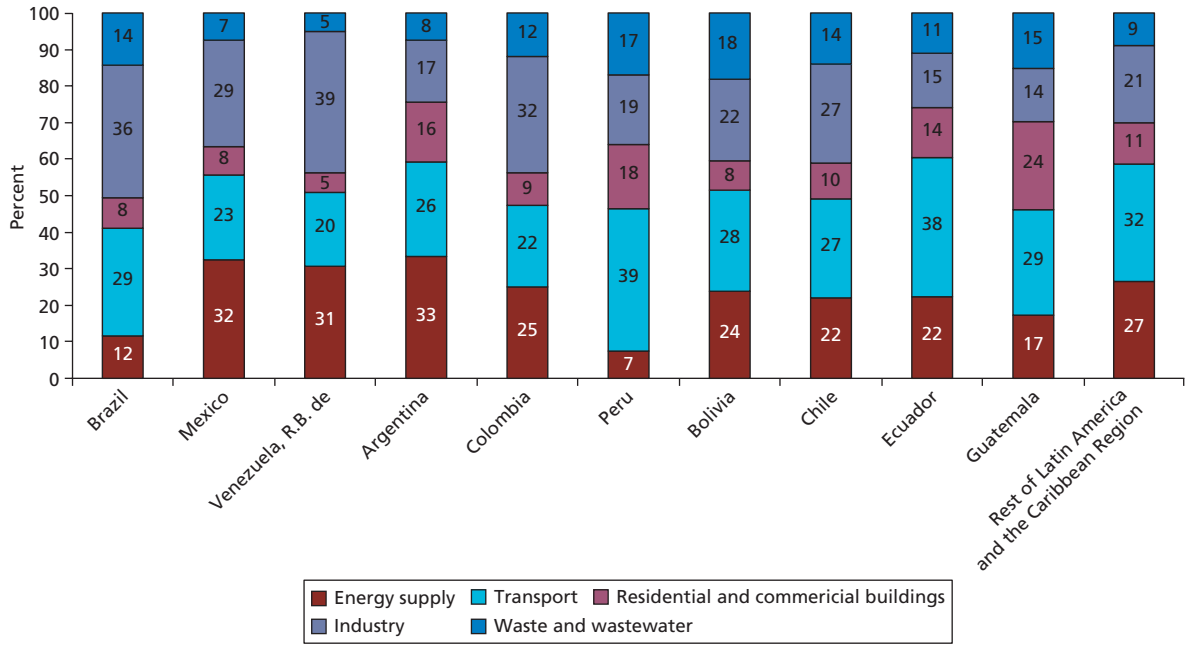
land-use change emissions is close to 15 percent of total GHG emissions.

There are also large differences across countries in the sector composition of non-LULUCF emissions (figure 5.12). For example, while the share of energy supply is relatively low in Brazil and Peru, at, respectively, 12 and 7 percent, it is above 30 percent in Argentina, Mexico, and República Bolivariana de Venezuela, which have power sectors among the most carbon intensive of the region. The high shares of the transport sector in Ecuador and Peru, which make up almost 40 percent of non-LULUCF emissions compared to the region's average of 27 percent, constitute another variation worth highlighting. Also, the shares of the industrial sector in Brazil, Colombia, and República Bolivariana de Venezuela, are situated between 32 percent and 39 percent of non-LULUCF emissions compared with 29 percent for the LCR as a whole.

While emissions from residential and commercial buildings account for only 11 percent of the region's non-LULUCF emissions, they are responsible for as much as 24 percent of non-LULUCF emissions in the case of Guatemala and about 16 percent for Argentina, Ecuador, and Peru. As for emissions from waste and

FIGURE 5.12

Greenhouse Gas Emissions from Non–Land Use/Land Use Change and Forestry, 2000



Source: Climate Analysis Indicators Tool (CAIT) Version 5.0 (2008) and Marland, Boden, and Andres (2007).

wastewater, they represent 10 percent of LCR emissions when excluding LULUCF. Nonetheless, their share is about 50 percent higher in Bolivia, Brazil, Chile, Guatemala, and Peru.

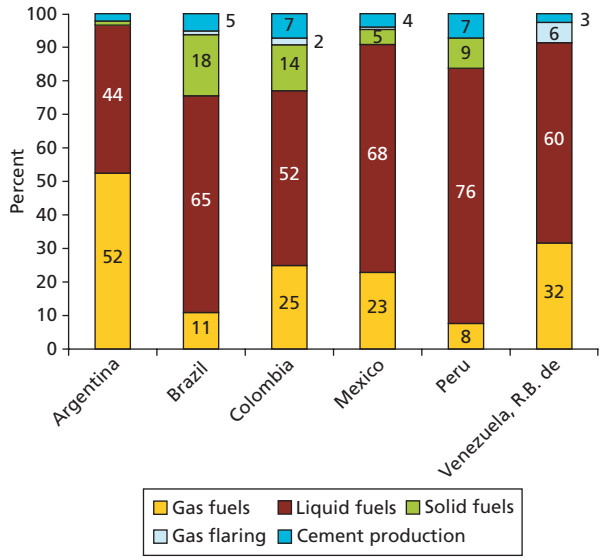
The composition of energy-related emissions also varies considerably by type of fossil fuel (figure 5.13). Indeed, whereas the share of emissions from gas fuels is 23 percent for the LCR as a whole, it reaches 52 percent in the case of Argentina but only about 10 percent in Brazil and Peru. While coal accounts for only 8 percent of the region's fossil fuel emissions, it is about twice as high in Brazil and Colombia.

Cross-country differences in emission levels

There is considerable heterogeneity in the levels of GHG emissions per capita (figure 5.14) across LCR countries. For example, total GHG emissions per capita are between 13 and 17 tCO_2 in Bolivia, República Bolivariana de Venezuela, and Brazil, and below 7 tCO_2 in Chile, Colombia, and Mexico. The former three countries are also among the region's top per capita emitters even if land-use change is excluded, although in this case their emissions per capita are much closer to those of Argentina, Chile, and Mexico.

FIGURE 5.13

Fossil Fuel CO_2 Emissions for Selected Latin America and the Caribbean Region Countries, 2000

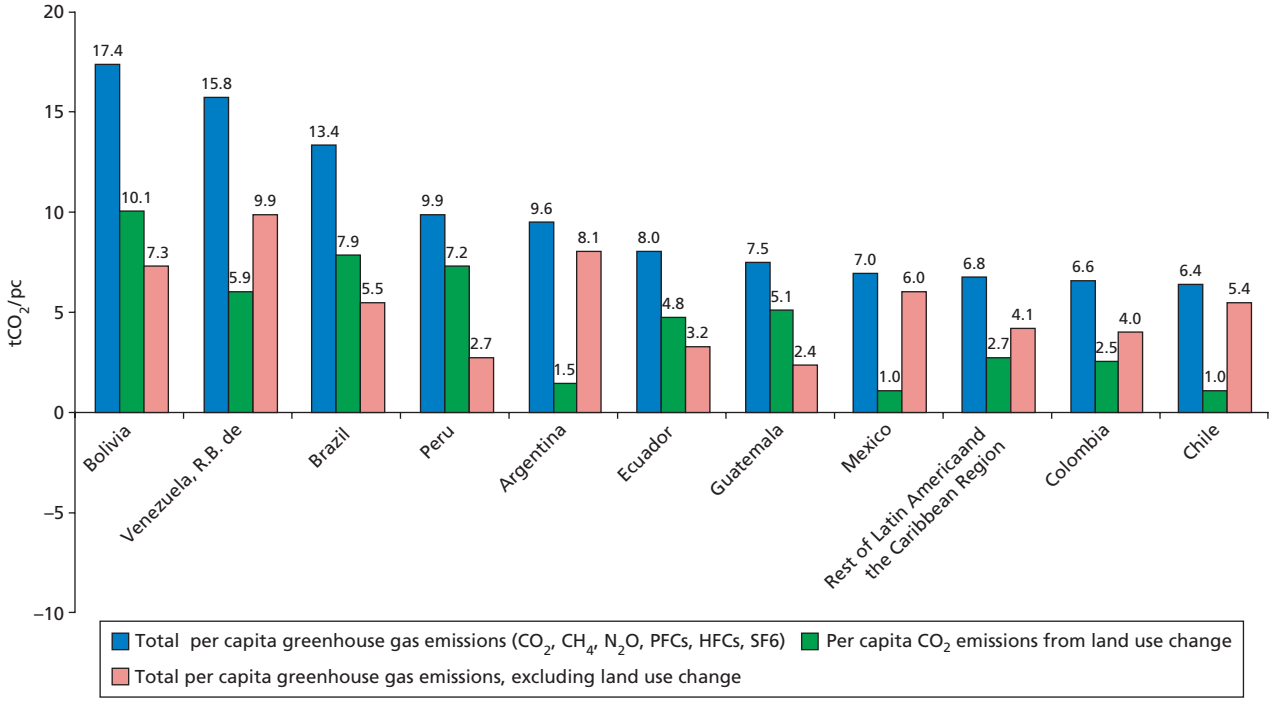


Sources: Climate Analysis Indicators Tool (CAIT) Version 5.0 (2008) and Marland, Boden, and Andres (2007).

There is less heterogeneity in terms of emissions per unit of GDP, with the exception of Bolivia, which outranks all countries in the region (figure 5.15). Bolivia whose emissions are 7.3 $kgCO_2$ per US$ of GDP

FIGURE 5.14

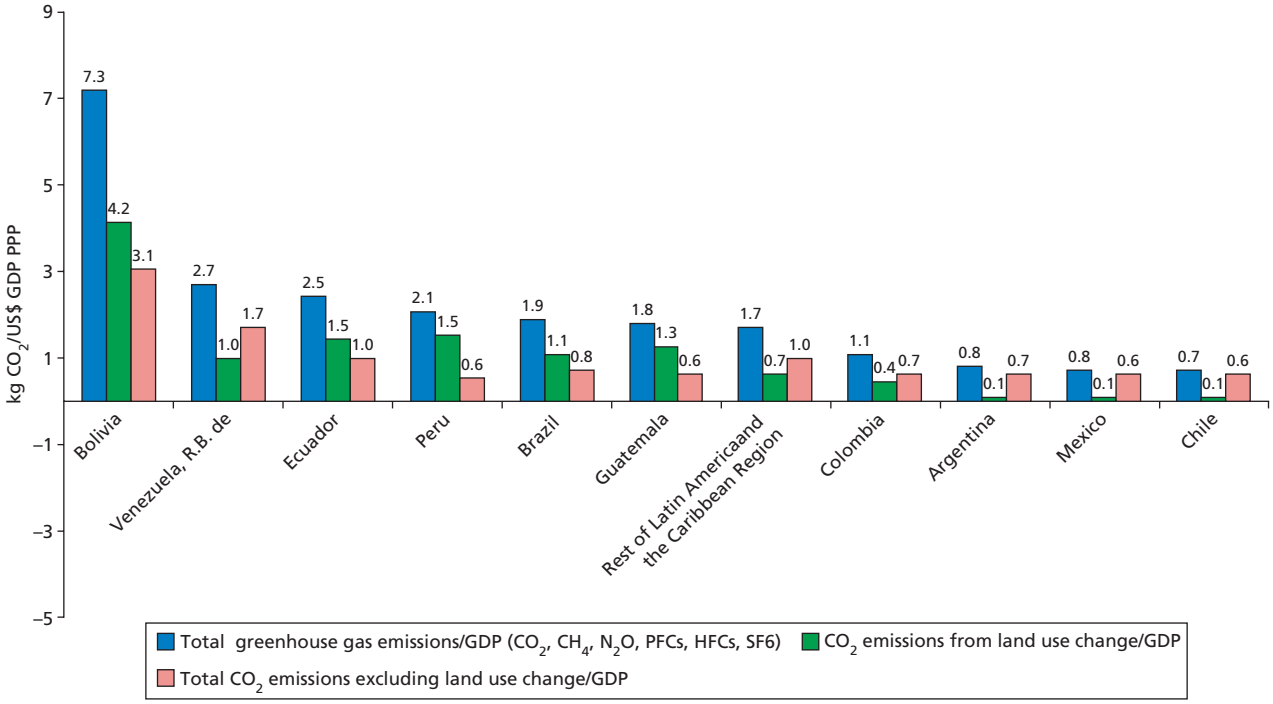
Greenhouse Gas Emissions Per Capita for Selected Latin America and the Caribbean Region Countries, 2000



Sources: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).

FIGURE 5.15

Greenhouse Gas Emissions per GDP for Selected Latin America and the Caribbean Region Countries, 2000



Sources: Climate Analysis Indicators Tool (CAIT), Version 5.0 (2008).

(purchasing power parity [PPP]) the equivalent of about five times the region's average. Bolivia is followed by República Bolivariana de Venezuela and Ecuador, with about 2.5 $kgCO_2$ per US$ of GDP (PPP). These three countries are the top emitters regardless of whether or not emissions from land-use change are excluded. Interestingly, when emissions are calculated in terms of their ratio to GDP, Argentina, Chile, Colombia, and Mexico are well below the region's average.

The Evolution of LCR's Fossil-Fuel Emissions

In 1950, LCR's fossil fuel emissions per capita were only 6 percent of North America's and 23 percent of Western Europe's. Between 1950 and 1980, emissions in the LCR grew by 170 percent, compared to the rates of growth of about 30 percent in North America and 90 percent in Western Europe (figure 5.16). However, by 1980, the LCR still had a mere 13 percent of the per capita emissions of North America, and 32 percent of those of Western Europe. Over the past two-and-a-half decades, emissions per capita have been relatively stable in the LCR while they have fallen in North America and Western Europe, after peaking in the late 1970s.

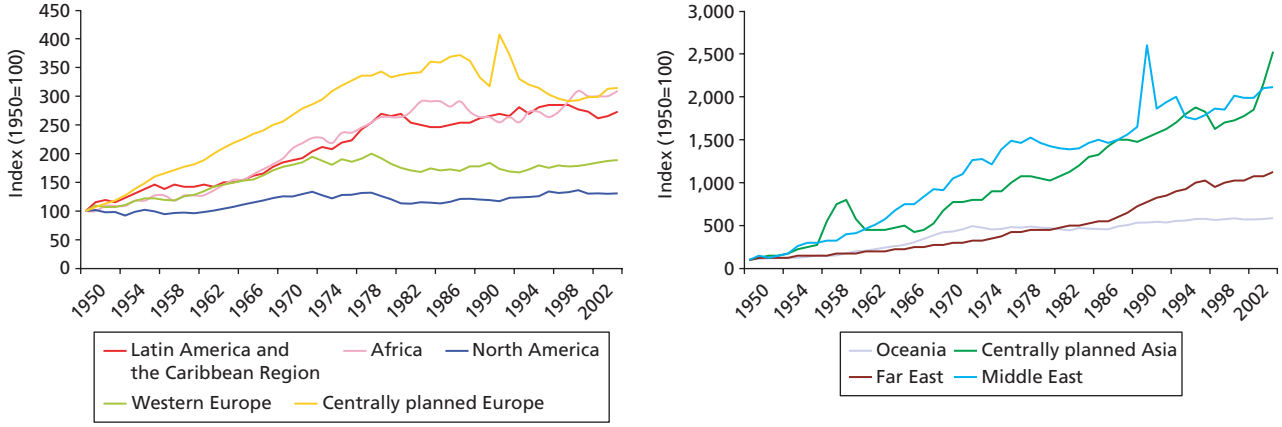
A growth pattern similar to the LCR's has been observed in Africa and centrally planned Europe, although in 2004 those regions exhibited, respectively, about one-half and three times the levels of per capita emission found in the LCR. In contrast, the countries from Centrally Planned Asia (mainly China), the Far East (including India, South Korea, and Indonesia) and the Middle East have exhibited uninterrupted and explosive rates of growth in per capita emissions reaching levels of up to 20 times their initial 1950 emissions by the beginning of the present decade. In comparison with the LCR, in 2004 Far East countries had 35 percent lower emissions per capita while those from Centrally Planned Asia and the Middle East were, respectively, 40 and 140 percent above the levels found in the LCR.

The LCR's ratio of emissions to GDP, also known as the index of "emission intensity," has remained relatively stable since 1980, much as the ratio of emissions to population (figure 5.17). In fact, the former index increased by 2 percent in the LCR between 1980 and 2004. In contrast, there was a 28 percent global decline in emissions per unit of GDP during the same period, a 33 percent reduction in industrialized countries and a 48 percent drop in the case of China and India. Other developing countries experienced relatively small declines: 9 percent in low-income countries and 4 percent in other middle-income countries (excluding the LCR as well as China and India).

The effect of LCR's relatively small increase in emission intensity on the evolution of the region's total fossil fuel emissions has been minimized, however, by the fact that the region's per capita GDP has been growing at a slower pace than the rest of the

FIGURE 5.16

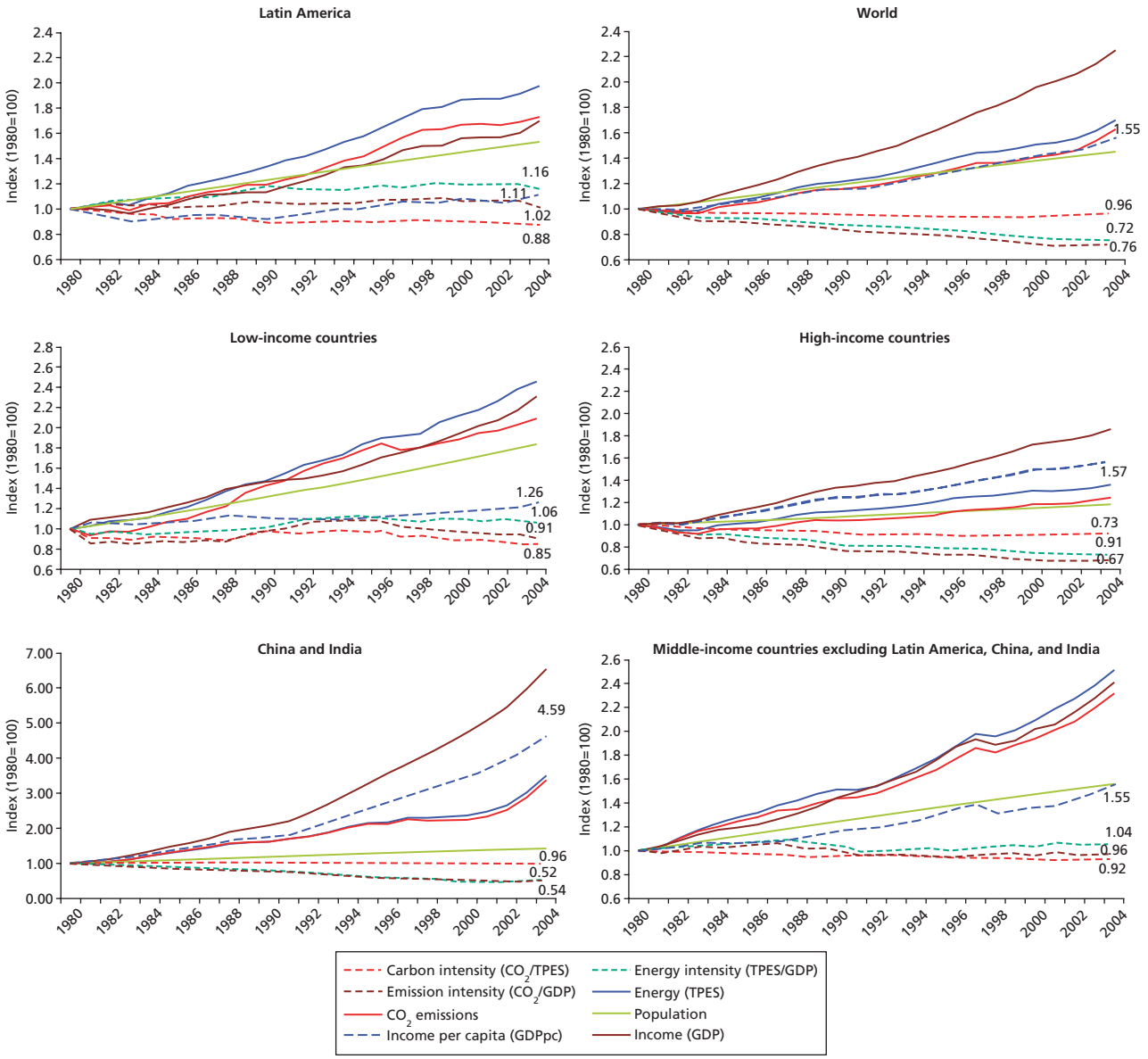
Per Capita Fossil Fuel CO_2 Emissions



Source: Marland, Boden, and Andres (2007).

FIGURE 5.17

Intensities of Energy Use and Fossil Fuel CO_2 Emissions



Sources: For primary energy consumption: Energy Information Administration (2005); for CO_2: Energy Information Administration (2005) and Marland, Boden, and Andres (2007); for GDP and population: World Development Indicators (World Bank).
Note: TPES = total primary energy supply.

world. In fact, between 1980 and 2004 LCR's per capita GDP grew by only 11 percent, compared to 55 percent for the world, 58 percent for industrialized countries and 165 percent for other developing countries. Thus, LCR's total emissions have grown at a rate that is only slightly above the growth of the region's population.

Small increase in emissions over GDP driven by increasing energy intensity

In order to better understand the drivers of changes in emission intensities, it is standard to decompose them as the sum of changes in the ratio of energy to GDP, referred to as energy intensity, and the ratio of emissions to energy, referred to as carbon intensity (figure 5.17).

In the case of the LCR, this decomposition reveals that the region's small increase in emissions per unit of GDP, in comparison with other regions of the world, has been driven by the region's increasing energy needs per unit of output, which have partially balanced off the region's relatively large reductions in the carbon intensity of its energy. As shown in figure 5.17, in the LCR the energy intensity index increased by 16 percent from 1980 to 2004, which contrasts with reductions of 24 percent at the global level, 30 percent in industrialized countries, and 46 percent in China and India. Low-income countries and other middle-income countries, however, have also experienced an increase in their energy consumption, although lower than in the LCR: respectively, 6 and 4 percent. In other words, while the rest of the world has reduced the average amount of energy needed per dollar of goods and services produced, the LCR and other developing countries (except for China and India) have been increasing their energy needs per unit of output.

The impact of the region's increasing energy intensity on its comparative emission levels has been minimized, however, by the fact that the LCR has exhibited larger reductions in the carbon intensity of its energy production. In fact, this index fell by 12 percent between 1980 and 2004, compared to a reduction of only 4 percent at the global level and 9 percent in industrialized countries. Low-income countries have also experienced a sizable reduction of 15 percent in that index, but declines have been smaller in middle-income countries: 4 percent in China and India and 8 percent in other middle-income countries (figure 5.17).

Thanks to its cleaner power generation mix, in 2000 the LCR exhibited a level of carbon intensity per unit of energy that was 10 percent below that of high-income countries, 17 percent below the world average, and 40 percent below the average for China and India (figure 5.18). Moreover, despite having increased over the past decades, in 2000 the LCR's levels of energy intensity were still 18 percent below the world average and 45 percent below other middle-income countries (excluding China and India). In sum, due to its relatively low and declining carbon emissions per unit of energy, and as a result of its relatively low, albeit increasing, level of energy use per unit of GDP, the LCR has managed to maintain levels of energy-related fossil fuel emissions per unit of GDP that are 32 percent below the world average, 26 percent lower than those of industrialized countries, and between 39 and 55 percent lower than other middle-income countries.

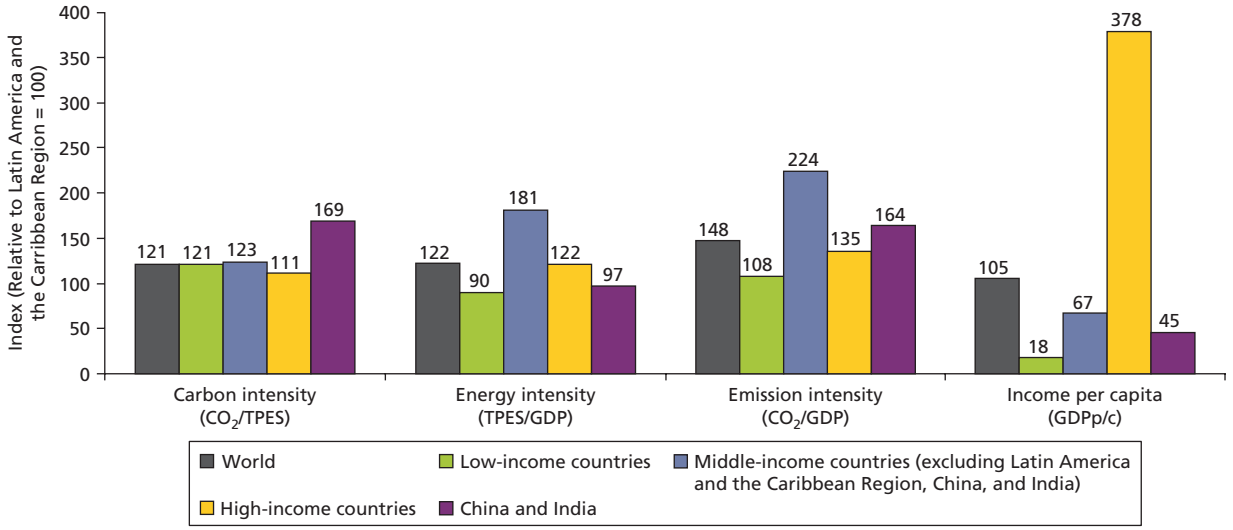
In order to visualize the role played by the various drivers of fossil fuel emissions during different subperiods, it is useful to follow the approach proposed by Kaya (1990) to decompose fossil fuel CO_2 emissions into the following factors: (1) the change in the carbon intensity of energy (emissions per unit of energy); (2) the change in the energy intensity of output (energy consumed per unit of GDP); (3) the change in GDP per capita; and (4) the change in population. Although the "Kaya decomposition" is not based on an estimated model of causal links between the relevant variables, it can be useful for uncovering the main factors driving observed changes in CO_2 emissions (see Bacon and Bhattacharya 2007).

Figure 5.19 presents summary "Kaya decompositions" for the LCR and other regions of the world during 1980–2005. The figure reports the changes in fossil fuel emissions that can be attributed to different factors, expressed as a percentage of initial 1980 levels. The figure shows that during the past 25 years changes in the LCR's energy intensity of output contributed to increasing emissions by 15 percent but the region's falling carbon intensity acted to reduce emissions by 17 percent. In contrast, at the global level falling energy intensities contributed to reducing emissions by 35 percent and reductions in carbon intensities helped reduce emissions by about 9 percent. Finally, the LCR's relatively low rates of growth of per capita GDP are reflected in a smaller contribution of this factor to fossil fuel emissions, equivalent to 23 percent of their initial level, compared to 82 at the global level, 51 percent in the case of high-income countries, and as much as 309 percent in China and India.

In order to understand the timing of the above effects, figure 5.20 reports similar "Kaya" decompositions by subperiods. The figure shows that the contribution of rising energy intensities to the growth of the LCR's fossil fuel emissions was concentrated in the 1980s. During the 1990s, energy use also increased, but its contribution to the

FIGURE 5.18

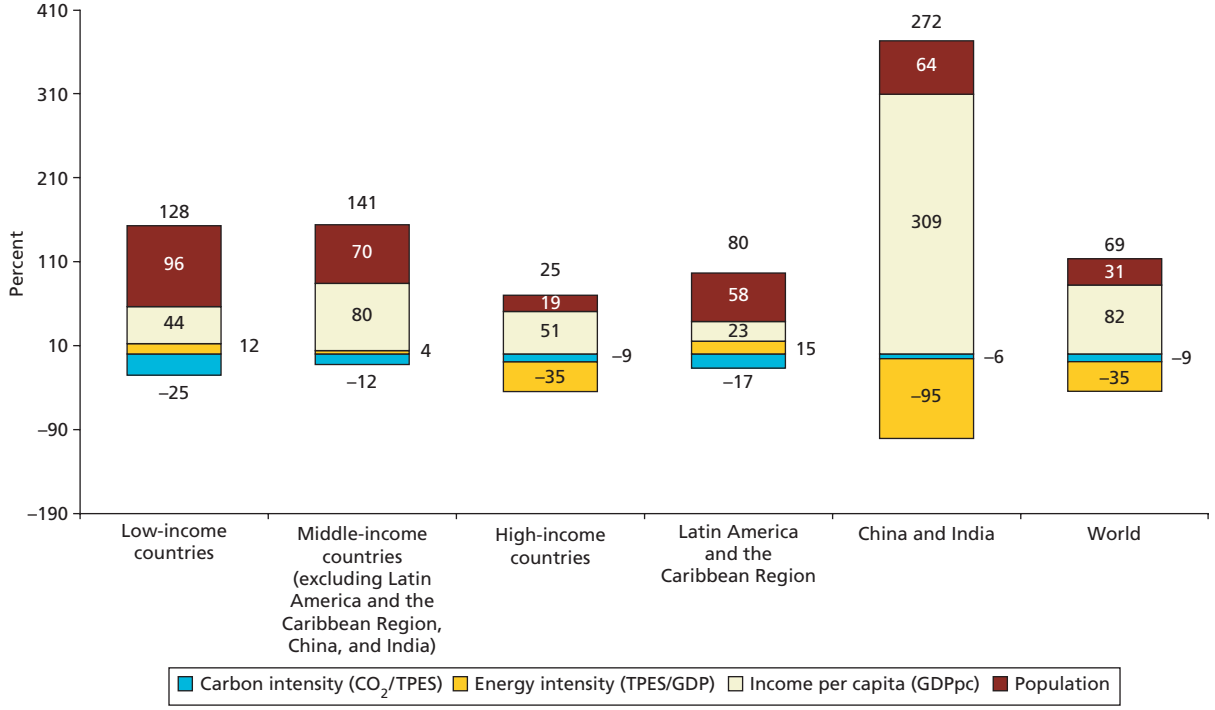
Indexes of Carbon, Energy, and Emission Intensity, and Per Capita GDP, 2000



Sources: For primary energy consumption: Energy Information Administration (2005); for CO_2: Energy Information Administration (2005) and Marland, Boden, and Andres (2007); for GDP and population: World Development Indicators (World Bank).

FIGURE 5.19

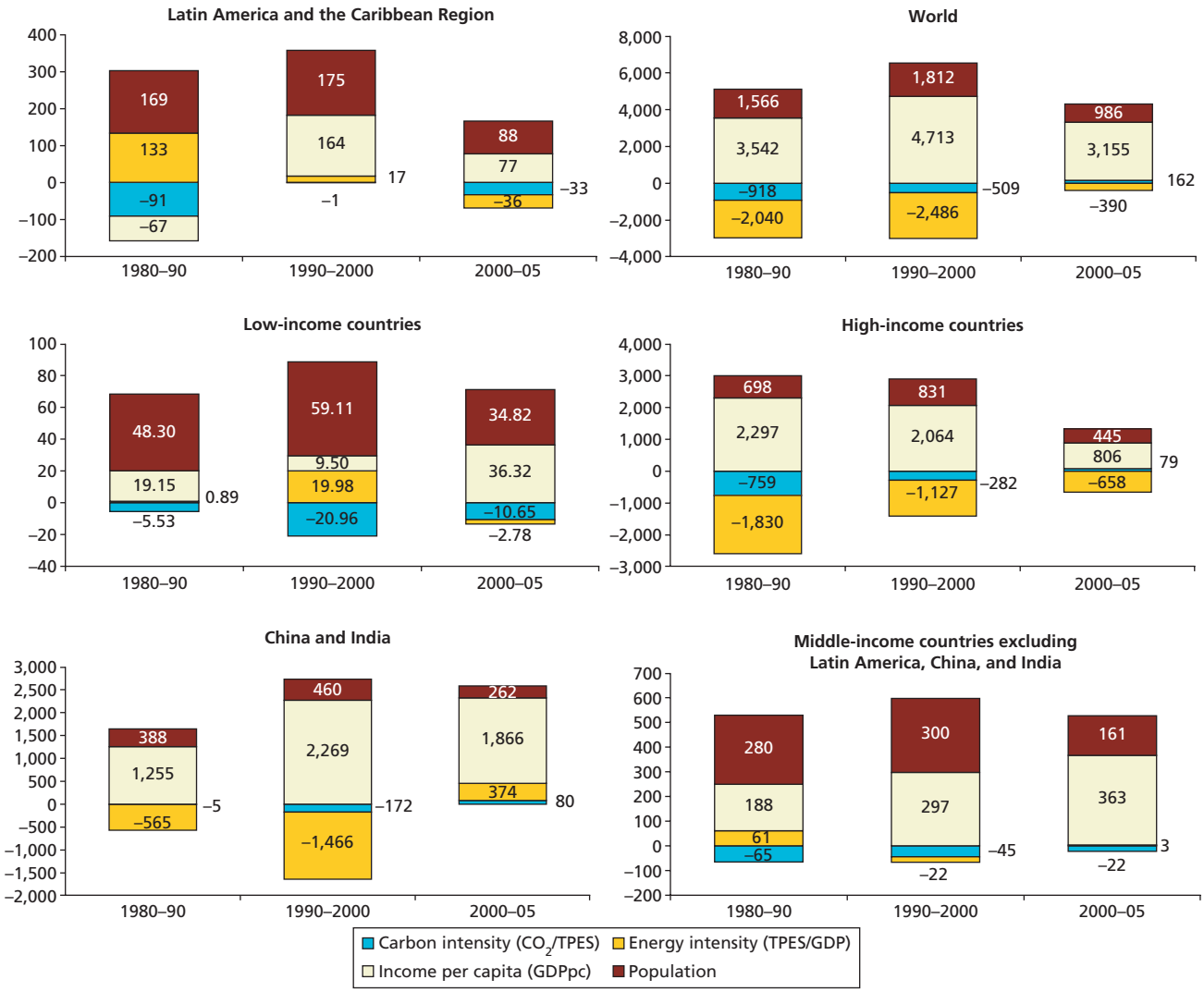
Summary Kaya Decomposition of Changes in Fossil Fuel CO_2 Emissions, 1980–2005



Sources: For primary energy consumption: Energy Information Administration (2005); for CO_2: Energy Information Administration (2005) and Marland, Boden, and Andres (2007); for GDP and population: World Development Indicators (World Bank).

FIGURE 5.20

Kaya Decomposition of Changes in Fossil Fuel CO_2 Emissions, by Subperiods, 1980–2005



Sources: For primary energy consumption: Energy Information Administration (2005); for CO_2: Energy Information Administration (2005) and Marland, Boden, and Andres (2007); for GDP and population: World Development Indicators (World Bank).
Note: Emissions are expressed in thousands of metric tons of carbon.

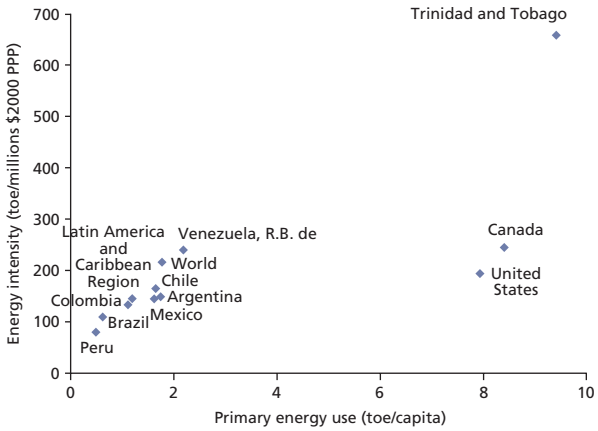
region's emissions was small. During the present decade, there was a reversal of the previous trend, with energy use per unit of GDP actually contributing to reduce the region's total emissions. As for the reduction in the carbon intensity of energy, most of it occurred during the 1980s and to some extent during the first half of the present decade, with very little progress achieved during the 1990s. A different time pattern is found, however, in other regions of the world. In China and India, for example, after significant reductions in energy intensities during the 1990s and a smaller reduction in the carbon content of energy, the present decade has seen considerable increases in energy usage per unit of output and an increase also in the carbon intensity of energy. As for industrialized countries, large reductions in energy and to a lesser extent in carbon intensity indexes were achieved during the 1980s, with smaller reductions in energy usage and a relatively stable carbon intensity index observed afterward.

Comparing the main drivers of LCR emissions across decades, figure 5.20 shows that during the 1980s the increase in the energy intensity of output was more than compensated by reductions in the carbon intensity of energy and per capita GDP. During the 1990s, the resumption of income growth had a strong impact on the LCR's emissions, together with population growth. Changes in the level of energy consumption and in the carbon intensity of energy had a very small impact on overall emissions. Finally, during the first half of the 2000s, income and population growth have continued to grow at similar rates, but about half of their impact on emissions has been compensated by falling energy usage and decreasing carbon intensity of energy.

The fact that developed countries have been able to reduce their energy intensity during the past 25 years, while the LCR has not shown significant improvements, can to a large extent be explained by differences in primary energy use and economic development. As shown in figure 5.21, the LCR's energy intensity, at about 150 tons of oil equivalent (toe) per million GDP, is still below the averages for the world and developed countries, such as the United States and Canada, which are in range of 200 to 250 toe per million GDP. The consumption of primary energy per capita in the latter industrialized countries is about five times greater than in the LCR. However, those countries have been able to reduce their energy intensity through an increase of the service sector's share in their economies and a decline in the industrial sector's participation. In contrast, countries in the LCR still exhibit a larger share of energy intensive industries and their per capita primary energy use is still growing thanks to rising incomes and increased electricity coverage.

FIGURE 5.21

Energy Intensity and Primary Energy Use, 2004



Source: Dussan (2008).

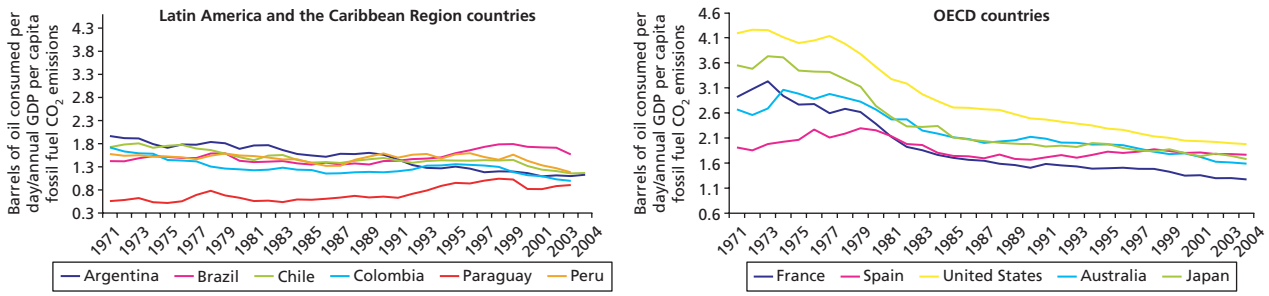
A limited reaction to increasing oil prices

Oil price fluctuations have generally had a significant effect on the intensity of oil consumption and energy use per unit of GDP for oil importing countries. That, however, has not been the case in the LCR. In contrast with the evidence for the OECD, the oil and energy intensities of Latin American countries (excluding oil exporters) have not been affected by higher oil prices as shown by Alaimo and Lopez (2008). To use a more technical lexicon, they are not "Granger-caused" by higher oil prices. This finding is consistent with the evidence presented in the last section of this chapter on the limited reductions in energy intensities observed in the LCR in comparison to other regions of the world.

This is illustrated in figure 5.22, which shows that over the period from 1971 to 2004 the barrels of oil consumed daily per unit of annual GDP have evolved in a very different fashion in the LCR and the OECD. Indeed, oil intensities have declined only moderately in Latin America, with the median intensity for Latin America falling from 1.6 barrels per day per million dollar produced (bpdpmd) in the early 1970s to 1.3 in the early 2000s. The only exception would be Panama, where intensities declined from 2.8 to close to 1.7 bpdpmd. With regard to the rest of Latin American countries, one can observe a few modest declines and some increases. In contrast, in the OECD, oil intensities have declined much more markedly. For example, over the period under consideration, the United States reduced its oil intensity from about 4.2 barrels per day per million dollar produced to about 2.1 bpdpmd. Similarly, whereas in 1971 Japan and France had oil intensities of, respectively, 3.6 and 3.1 barrels per day per million dollar of GDP, by 2004 both countries had oil intensities of about 2 bpdpmd. The median oil intensity for the OECD countries in this sample declined from 2.9 bpdpmd in the early 1970s to 1.7 in the early 2000s.

FIGURE 5.22

Oil Intensities of Selected Latin America and the Caribbean Region and OECD Countries



Source: Alaimo and Lopez (2008).

However, the levels of oil intensities of LCR countries now appear very similar to those found in the OECD, ranging mostly between 1.1 and 2.1 barrels per day per million dollar of GDP.

As shown by Alaimo and Lopez (2008), about two-thirds of the reduction in oil intensity in OECD countries was achieved by 1985, which corresponds to the end of the second oil crisis. Japan, for example, cut oil intensities from 3.6 to 2.2 bpdpmd by 1985, whereas between 1985 and 2004 the decline was much more modest (from 2.2 to about 2 bpdpmd). The United States, where by 1985 intensities had been cut to 2.7 bpdpmd, is another case in point. To a large extent that was the result of improved home insulation, better gasoline mileage, and streamlined production processes that led to a reduction in the use of oil per unit of output. Since then, progress in reducing oil intensities has continued, albeit at a much slower pace, probably because of the lower level of prevailing real oil prices.

Is the low pass-through from oil to gasoline to blame for LCR's stable energy intensity?

Alaimo and Lopez (2008) argue that the limited reaction of oil intensities observed in the LCR—and for that matter in other middle-income countries—even in the aftermath of large increases in oil prices may be due to governments' decisions to reduce the pass-through of international oil prices to final consumers. In many middle income-countries and particularly in Latin America, energy prices are heavily regulated and energy price changes tend to be a sensitive topic. While, on the one hand, this can protect consumers by isolating them from price fluctuations especially when facing price increases, it may, on the other hand, fail to send the appropriate market signals. Indeed, this means consumers will have a tendency not to adjust their energy consumption to changes in oil prices.

Existing estimates of price pass-through from oil to gasoline suggest that price pass-through is higher in oil importing countries and limited in oil exporting countries. Bacon and Kojima (2006), for instance, compute the ratio between the change in domestic prices (gasoline, diesel) and the change in oil prices[1] from 2004 to 2006 for eight Latin American countries. Findings show that República Bolivariana de Venezuela, Argentina, and Mexico have negligible pass-through. In contrast, Bolivia and Honduras would have a pass-through of about 60 percent for gasoline and 80 percent for diesel. Finally, Guatemala, Nicaragua, and Chile have the highest pass-through of their sample with coefficients ranging from .95 to 1.15 (table 5.1).

These findings are to a large extent consistent with those of the World Bank (2006), which estimates the degree of pass-through as the coefficient from a regression of the overall price index of gasoline prices on energy prices. This study concludes that in Argentina, Ecuador, Mexico, and República Bolivariana de Venezuela, there is no pass-through. On the contrary, in Brazil, Colombia, the Dominican Republic, El Salvador,

TABLE 5.1

Pass-Through Estimations of Previous Studies

	Gasoline		Diesel
Authors	Bacon and Kojima, 2006	World Bank, 2006	Bacon and Kojima, 2006
Years covered	2004–06	mid-90s, 2000s	2004–06
Argentina	0.02	None	0.11
Bolivia	0.64		0.84
Brazil		Complete	
Chile	1.15		1.11
Colombia		Complete	
Dominican Rep.		Complete	
Ecuador		None	
El Salvador		Complete	
Guatemala	0.93		0.99
Guyana		Complete	
Honduras	0.60	Complete	0.87
Mexico	0.15	None	0.11
Nicaragua	0.95		0.88
Venezuela, R. B. de	0.00	None	0.00

Sources: Bacon and Kojima (2006); World Bank (2006).

TABLE 5.2

Average Gasoline and Diesel Prices in Latin America and the Caribbean Region, 2005–07

(US$/gallon)

	Premium gasoline	Regular gasoline	Diesel	Obs.
Argentina	0.89	0.79	0.67	36
Bolivia	0.82	0.56	0.56	30
Colombia	n.a.	0.96	n.a.	36
Costa Rica	1.25	1.20	0.88	29
El Salvador	1.14	1.08	0.95	29
Guatemala	1.14	1.12	0.91	29
Honduras	1.24	1.17	1.02	29
Mexico	1.01	0.83	0.65	36
Nicaragua	1.19	1.14	1.02	29
Panama	2.32	n.a.	n.a.	36
Paraguay	1.19	1.07	0.99	36
Peru	n.a.	1.23	n.a.	36
Uruguay	1.59	1.55	1.27	20

Source: Alaimo and Lopez (2008).

and Guyana the pass-through appears to be complete. On the whole, the picture that emerges from these studies is mixed. Typically, net importing countries allow oil price fluctuations to pass through to final consumers. In contrast, net exporting countries show a clear disconnect between domestic and international price changes. By isolating final consumers from price fluctuations, net exporting countries do not allow energy consumption to be affected by market prices.

Do these conclusions still hold in the more recent period, where crude oil prices are reaching record levels? To address this question, Alaimo and Lopez (2008) collected data for 13 countries from January 2005 to December 2007. Table 5.2 provides the average price of three oil products: premium gasoline, regular gasoline, and diesel in each country, measured in dollars per gallon. Net oil exporter countries have lower prices than net oil importers. For example, a gallon of regular gasoline was less than a dollar in Argentina, Bolivia, Colombia, and Mexico from 2005 to 2007, while it averaged 1.19 US$/gallon for net oil importers. Alaimo and Lopez (2008) show that oil price changes are positively and significantly correlated with changes in premium and regular gasoline prices in net oil importer countries even though the correlation is very modest: US$0.22 for premium and $0.16 for regular. On the contrary, oil prices do not appear to be correlated with diesel at the pump regardless of net importer or net exporter status or even with gasoline prices in net exporter countries.

New pass-through estimates for the period between 2005 and 2007 are summarized in table 5.3 by Alaimo and Lopez (2008). The results indicate that net oil exporters fall into the "no pass-through category" with regard to all types of fuels. For example, Peru does not show signs of pass-through for regular gasoline.[2] Similarly, Paraguay appears not to have pass-through in the case of regular gasoline, but does show signs of low pass-through for premium gasoline and diesel, amounting to 15 percent and 23.7 percent, respectively. Costa Rica stands out as the only Central American country with no pass-through for two types of derivatives, premium and diesel, even though it does translate oil price changes into regular gasoline prices at a 44 percent rate. In addition to Uruguay, the remaining Central American countries show evidence of medium or high pass-through. In particular, estimations suggest that Nicaragua and Uruguay have high pass-through for premium and regular gasoline prices and medium pass-through for diesel prices. El Salvador also shows evidence of high pass-through for regular gasoline. Finally, Guatemala and Honduras

TABLE 5.3

A Taxonomy of Pass-Through by Country

Level of Pass-through	Premium Gasoline	Regular Gasoline	Diesel Gasoline
None (*)	Argentina, Bolivia, Costa Rica, Mexico	Argentina, Bolivia, Colombia, Mexico, Paraguay, Peru	Argentina, Bolivia, Costa Rica, Mexico
Low (<.33)	Paraguay		Paraguay
Medium (.33–.66)	El Salvador, Guatemala, Honduras, Panama	Costa Rica, Guatemala, Honduras	El Salvador, Guatemala, Honduras, Nicaragua, Uruguay
High (>.66)	Nicaragua, Uruguay	El Salvador, Nicaragua, Uruguay	

Source: Alaimo and Lopez (2008).
(*) None means that either the coefficients for oil price changes were not significant or they were significant but negatively related to the gasoline price change.

are classified as countries with medium pass-through for regular gasoline, premium gasoline, and diesel.

Cross-country differences in emission trends

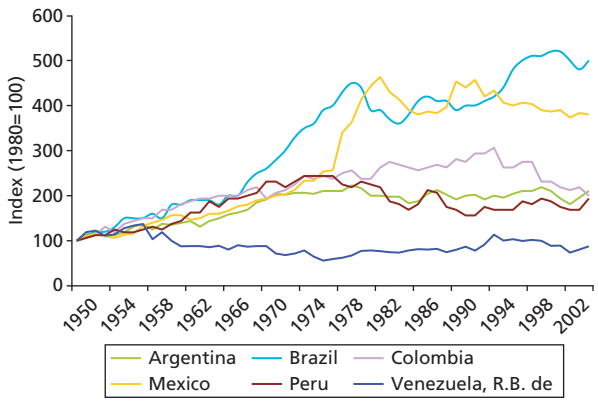
Figure 5.23 reports historic rates of growth of fossil fuel CO_2 emissions in selected LCR countries. The fastest rates of growth are found in Brazil and Mexico, with a 300 percent increase in emissions between 1950 and the early 1980s. While in Mexico, emissions have been relatively stable after that period; in the case of Brazil, another spur is evident during the past decade, with emissions reaching 500 percent of their initial 1950 level by the mid-2000s. Trends have proven to vary across the other four large LCR emitters. In the case of Argentina, Colombia, and Peru, emissions during the present decade were about twice their 1950 level, with most of the growth having taken place before the 1980s. The picture is slightly different for República Bolivariana de Venezuela, which has managed to stabilize its emissions over the past 50 years, albeit at much higher levels than in the case of the other five large LCR emitters presented in figure 5.23.

When emissions are expressed as a ratio to GDP, República Bolivariana de Venezuela and Brazil are the only countries among the LCR's largest emitters with intensity of fossil fuel CO_2 emissions higher in 2005 than in 1980. The increase was relatively small in Brazil, where emissions per unit of GDP were about 15 percent higher by the mid-2000s than they were in 1980 compared to an increase of more than 40 percent in the case of República Bolivariana de Venezuela. In marked contrast, emission intensities have been falling during the past decade in Colombia, Mexico, and Peru, and, to a lesser extent, in Argentina. By 2005, emission intensities in Argentina were about 3 percent below their 1980 level. Peru, Mexico, and Colombia achieved larger reductions of 15, 20, and 34 percent, respectively, in the same period of time (figure 5.24).

The drivers of changes in fossil fuel emission intensities have been different across LCR countries (figure 5.25). For instance, in Brazil, the increase in its rate of emissions per unit of GDP has been driven mainly by the rising intensity of energy consumption over GDP. However, as the right side shows, this increase has been partially compensated by the falling carbon intensity of energy. A similar pattern has been

FIGURE 5.23

Trends in Per Capita Fossil Fuel CO_2 Emissions for Selected Latin America and the Caribbean Region Countries

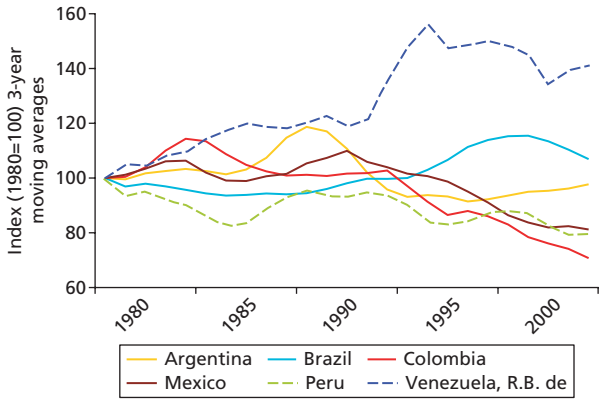


Source: Marland, Boden, and Andres (2007).

observed in Argentina, although in this case the reduction in the carbon intensity of energy, which amounted to 20 percent by the mid-2000s, has more than compensated the country's increasing energy intensity. Thus, Argentina was more successful in balancing the increase in energy intensity it witnessed with a substantial reduction in the carbon intensity of energy.

FIGURE 5.24

Intensity of Fossil Fuel CO_2 Emissions Per Capita GDP, Selected Latin America and the Caribbean Region Countries, 1980–2005



Sources: For CO_2 and primary energy consumption: Energy Information Administration (2005) and Marland, Boden, and Andres (2007); for GDP and population: World Development Indicators, World Bank (2005).

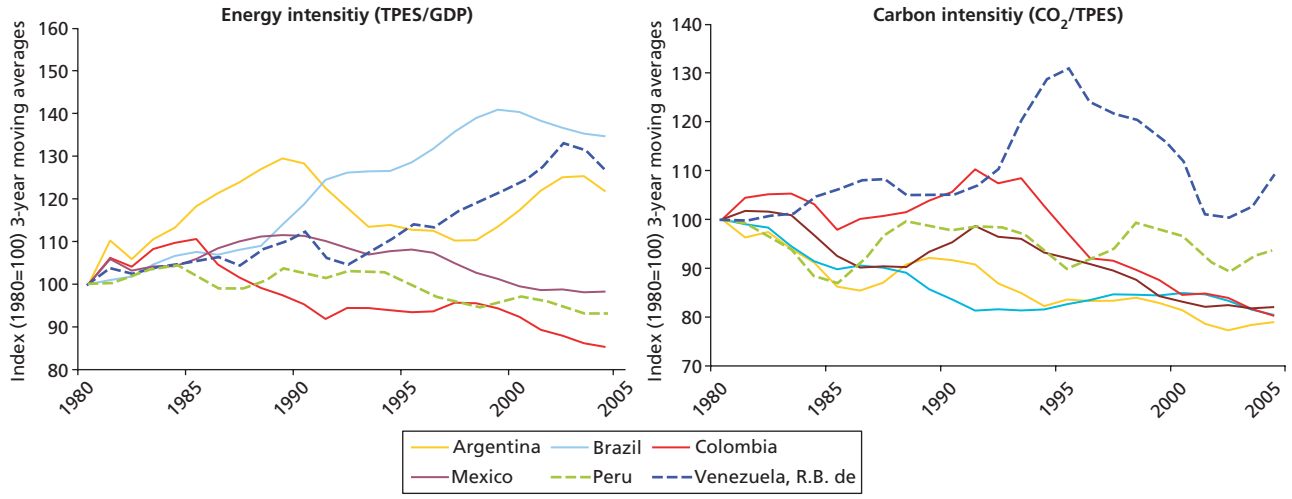
A different pattern is apparent in República Bolivariana de Venezuela, which has experienced both a higher level of energy consumption and an increasing ratio of emissions per unit of energy. Finally, when considering the whole period, Colombia, Mexico, and Peru's energy intensities have been either declining or stagnating. Allied to the falling carbon intensities of energy, these trends have been driven by a reduction in overall ratios of energy consumption to GDP. These patterns are visible in the "Kaya decompositions" reported in figure 5.26. Noticeably, Brazil achieved sizable reductions in the carbon intensity of energy during the 1980s, followed by Mexico and Colombia since the 1990s. The figure also illustrates the considerable amount of emissions that were driven by increases in energy intensities during the 1980s in Argentina, and between 1990 and 2000 in Brazil and República Bolivariana de Venezuela.

Projected Growth in Fossil Fuel CO_2 Emissions

Energy demand is the main driver of world emissions' growth predictions. The World Energy Outlook (IEA 2007) predicts that under a business-as-usual scenario, in 2030 the world's energy needs will be 55 percent higher than today, increasing at an approximate annual rate of 1.8 percent. As much as 74 percent of the

FIGURE 5.25

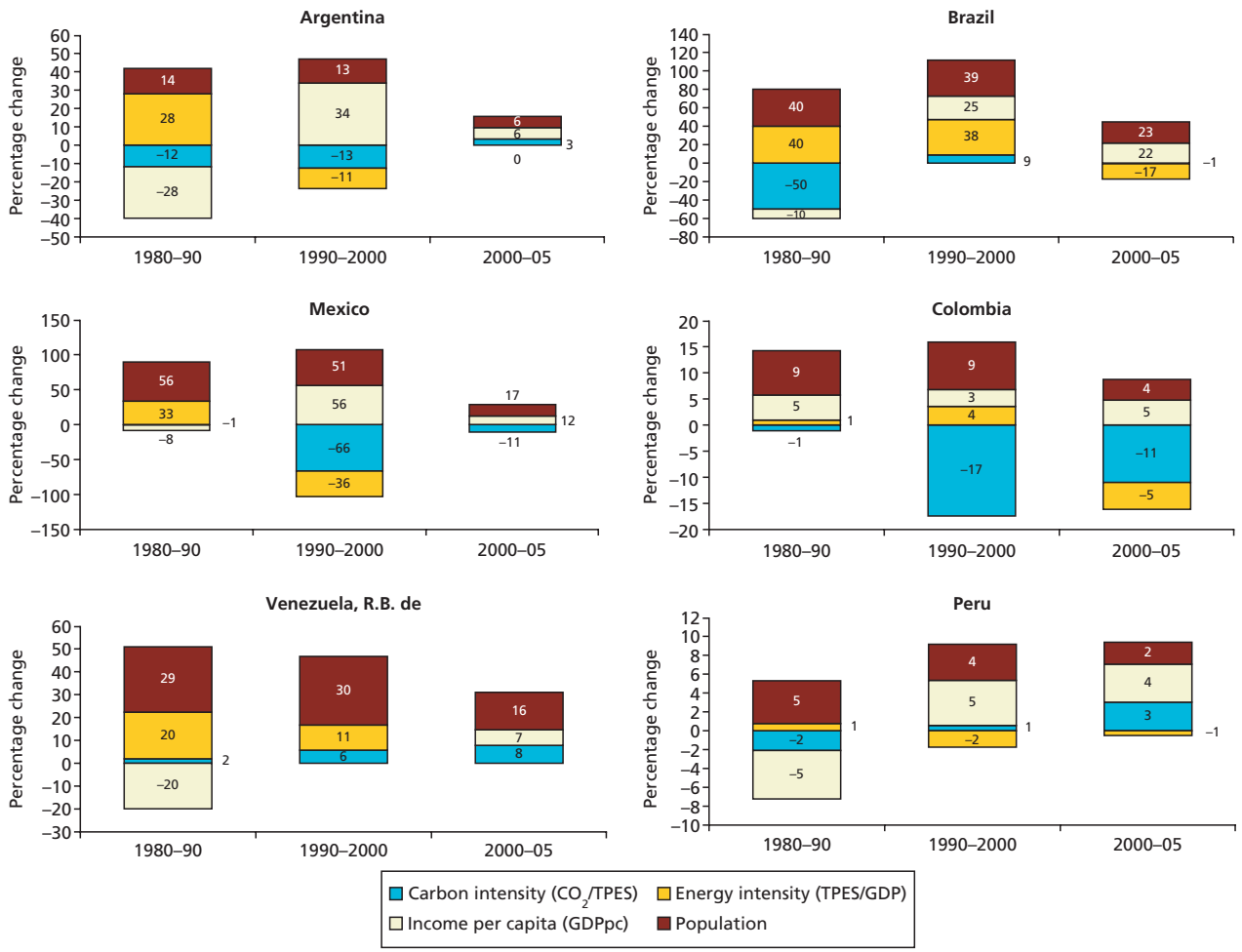
Intensity of Energy Use and Carbon Intensity of Energy, Selected Latin America and the Caribbean Region Countries, 1980–2005



Sources: For CO_2 and primary energy consumption: Energy Information Administration (2005) and Marland, Boden, and Andres (2007); for GDP and population: World Development Indicators, World Bank (2005).

FIGURE 5.26

Kaya Decomposition of Projected Changes in Fossil Fuel CO_2 Emissions, by Subperiods, Selected Latin America and the Caribbean Region Countries, 1980–2005



Sources: For CO_2 and primary energy consumption: Energy Information Administration (2005) and Marland, Boden, and Andres (2007); For GDP and population: World Development Indicators, World Bank (2005).
Note: Emissions are expressed in thousands of metric tons of carbon.

growth is projected to occur in developing countries. In fact, by 2030, developing countries will account for more than half of the global energy market, up from 41 percent today. However, it is important to note that China and India are the primary growth nations, accounting for 45 percent of the total increase in world demand.[3] In terms of global energy supply, fossil fuels are expected to continue to dominate. Indeed, fossil fuels will account for 84 percent of the overall increase in energy demand under the business-as-usual scenario. Because energy needs are predicted to increase substantially due to rising demand in developing countries, fossil fuels are predicted to maintain significant weight as an energy supply. For these reasons, the business-as-usual scenario considers a substantial increase in GHG emissions as imminent.

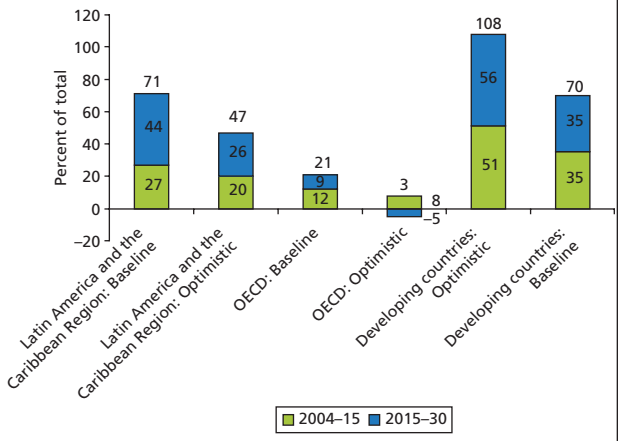
In addition to being a relatively low emitter from energy-related sources, the LCR's projected growth in annual emissions remains considerably lower than that of other developing countries. According to the IEA's World Energy Outlook 2006, energy-related CO_2 emissions in Latin America are expected to

grow by 27 percent between 2004 and 2015 and by 71 percent between 2004 and 2030 (figure 5.27). However, the increase in Latin American energy related CO_2 emissions is more modest than in the rest of the developing world, where they are expected to more than double, increasing by 51 percent in 2015 and by 108 percent in 2030. In comparison, the OECD's fossil fuel emissions are projected to climb by 21 percent between 2004 and 2030, of which 12 percent will be attained by 2015.

In its baseline business-as-usual scenario, the International Energy Agency takes into account all those government policies and measures that were enacted or adopted by mid-2006, even if many of them had not been fully implemented by that time. The IEA also considers a more optimistic alternative policy scenario in which countries would adopt all of the policies that they were considering in 2006 related to energy security and energy-related CO_2 emissions. The result is a projection of future emissions growth that is about 33 percent lower for developing countries, including the LCR, and almost 90 percent lower for the OECD. In this scenario, by 2030 emissions from the OECD would be only 3 percent above their 2004 level, while the LCR would increase its emissions by only 47 percent and the rest of the developing world by 70 percent.

FIGURE 5.27

Projected Increases in Fossil Fuel CO_2 Emissions, Baseline, and Optimistic IEA Scenarios for Latin America and the Caribbean Region, OECD, and Other Developing Countries, 2004–30



Source: IEA (2007).
Note: Mexico is included with the OECD countries, not with the Latin America and the Caribbean Region countries.

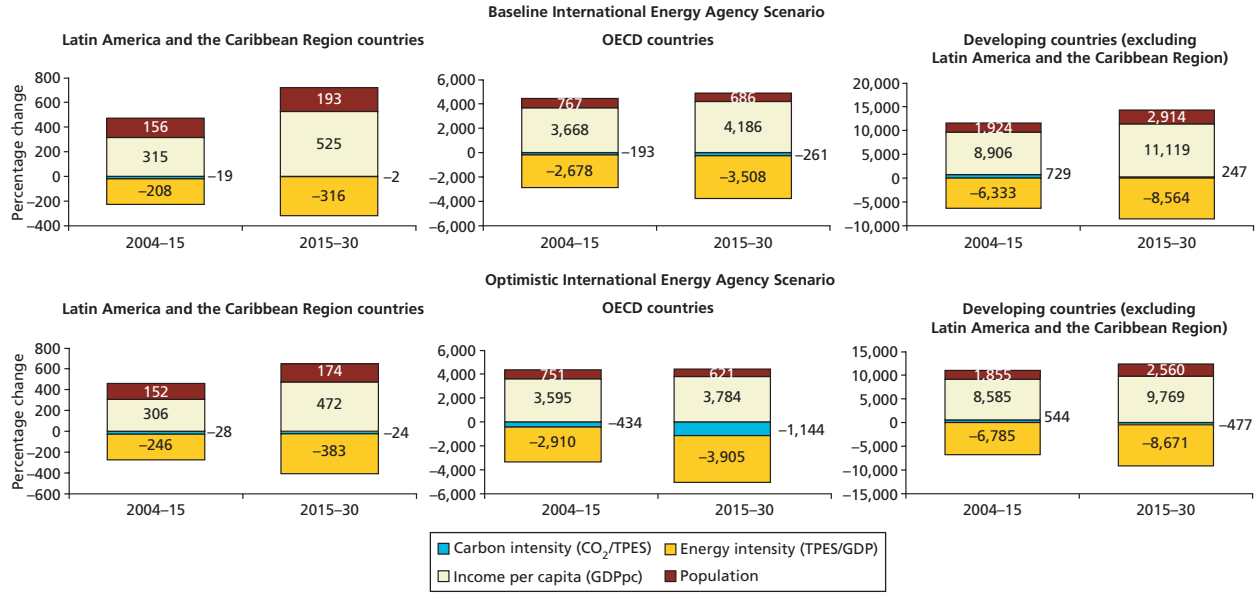
The slower growth of energy-related emissions projected by the IEA for the Latin America and the Caribbean Region is driven to a large extent by the assumption that output in the region will grow at a slower pace than in the rest of the developing world. For instance, the LCR's output would grow at a rate of 3.2 percent compared to 4.7 percent per year for other developing countries and 2.2 percent for the OECD. Given these expected rates of GDP growth and the assumption that population growth will be close to 1 percent per year in developing countries and 0.4 percent in the OECD, the IEA supports the projected rates of emission growth that have been described, with assumptions regarding drastic reductions in energy intensity indexes.

Indeed, as illustrated in figure 5.28 through "Kaya decompositions" of the IEA's projected changes in emissions, no significant contributions are expected to come from reductions in the carbon intensity of energy, neither in the LCR nor in the OECD. For other developing countries, the IEA actually expects the volume of emissions per unit of energy to increase, especially in the 2004–15 period. Nevertheless, significant reductions in energy intensity are expected in the baseline scenario, especially in developing countries. In the LCR, those reductions would contribute to reducing emissions by an amount equivalent to 94 percent of the region's 2004 emissions, compared to 59 percent in the OECD. In other developing countries similar reductions would lead to a 243 percent decrease in emissions.

The IEA's optimistic alternative projection attributes an increased role to possible reductions in the carbon intensity of energy. Projected reductions in carbon intensity would contribute to emission reductions by an amount equivalent to 6 percent of the region's 2004 emissions. A larger contribution of 12 percent is expected in the OECD. In the case of the LCR, what underlies these projections is an expected increase in the share of gas fuels in the region's total primary energy supply, from 20 percent to 29 percent during the 2004–30 period. This increase would take place mainly at the expense of oil and biomass, with the share of other energy sources, such as coal, hydro power, and other renewables, remaining basically constant (figure 5.29). In

FIGURE 5.28

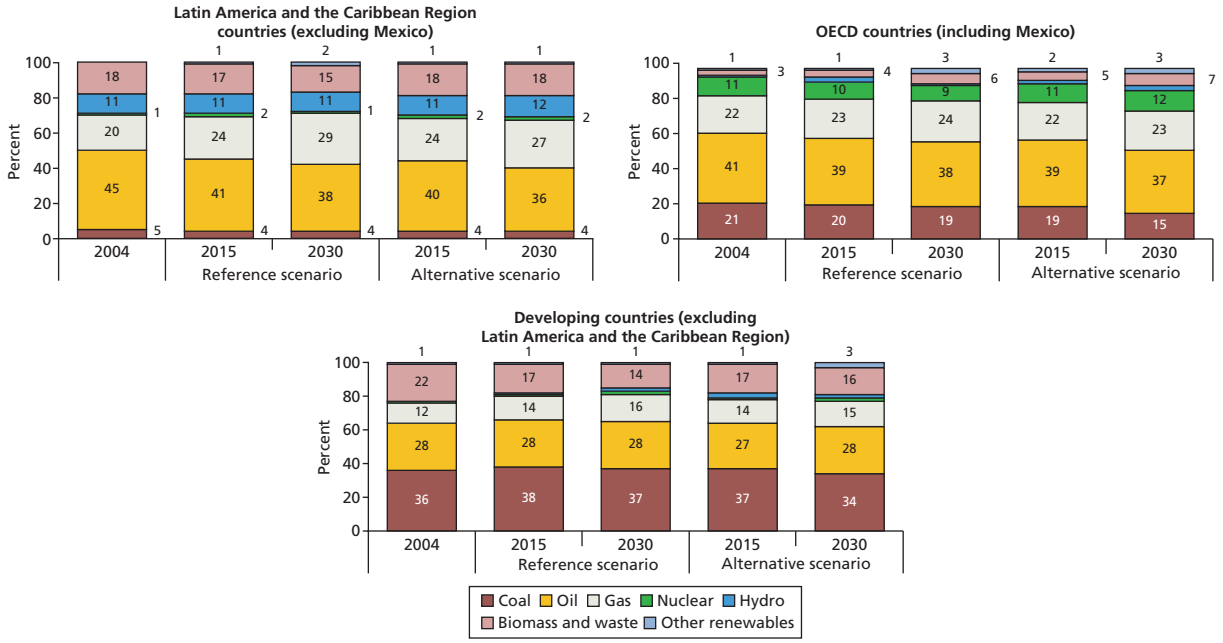
Kaya Decomposition of Projected Changes in Fossil Fuel CO_2 Emissions, Baseline, and Optimistic International Energy Agency Scenarios for Latin America and the Caribbean Region, OECD, and Other Developing Countries, 2004–30



Source: IEA (2007).
Note: Mexico is included with the OECD countries, not with Latin America and the Caribbean Region countries.

FIGURE 5.29

Projected Total Primary Energy Supply under Baseline and Optimistic IEA Scenarios for Latin America and the Caribbean Region, OECD, and Other Developing Countries, 2004–30



Source: IEA (2007).
Note: Mexico is included with the OECD countries, not with Latin America and the Caribbean Region countries.

the more optimistic scenario, hydro power, nuclear power, biomass, and other renewables would reach 35 percent of total primary energy supply by 2030, compared to 30 percent in 2004. As for the OECD, the IEA's optimistic scenario envisages a reduction of 10 percent in the share of coal and oil, with corresponding increases in renewable energy sources. As opposed to the LCR, the rest of the developing world is expected to continue relying heavily on coal, oil, and, to a lesser extent, gas, even in the most optimistic IEA scenario (figure 5.29).

Notes

1. The domestic fuel price and oil price change ratios are both measured in dollars.
2. Gasoline is the only type of fuel available in their sample.
3. IEA (2007).

CHAPTER 6

Climate Change Mitigation in the LCR: No Regrets and Beyond

As shown in chapter 5, the LCR has relatively low GHG emissions from energy consumption both in absolute terms and in the carbon intensity of energy use, due in part to the historically large role of hydroelectricity. However, emissions from the LCR rise significantly when agricultural and land-use changes are considered, and deforestation remains the largest single source of GHG emissions. But energy consumption in Latin America has been growing faster than the world average, and at current growth rates energy-related emissions would increase by 70 percent by 2030. In this context, this chapter assesses the potential for reduction of GHG emissions from the main contributing sources: energy consumption, transportation, agricultural and waste management, and forestry. The mitigation options with the largest potential can often be implemented with existing technologies and at relatively low capital costs, including avoided deforestation, energy efficiency, urban transport, and waste management, but this will require new policies and institutional development to overcome high transaction costs. Fortunately, there are multiple nonclimate change benefits for many of these mitigation options, which, if combined with the flow of international carbon payments, can help to significantly reduce Latin America's overall GHG emissions.

Introduction

As the global community moves closer toward committing itself to global emissions reductions to avoid potentially catastrophic impacts associated with global climate change, it is incumbent upon all countries—both industrial and developing—to take actions to reduce greenhouse gas emissions. The LCR has shown its commitment to shouldering its share of emissions reductions through the early signing of the UNFCCC and the Kyoto Protocol along with the vast majority of countries. Mexico has adopted a proactive climate change policy that—besides demonstrating its leadership among middle-income countries—it hopes will deliver other economic and social benefits, and the government is currently evaluating the priorities for both adaptation and mitigation. The LCR has unique capacities and opportunities for reducing GHG emissions, but what has not been entirely clear is the relative priority of different mitigation measures and the "net" costs of their implementation.

As argued in chapter 1, in order for the global response to the challenge of mitigating climate change to be efficient, it is critical to take advantage of the low-cost opportunities existing in the LCR and other regions of the developing world. However, for global mitigation efforts to also be equitable, it is key that the cost of undertaking the corresponding projects be shared by the global community, including by means of an expanded and reformed CDM (as outlined in chapter 4) and the progressive rollout of low-carbon policies in the developing world. However, a further motivation for LCR countries to pursue a lower-carbon development path has to do with the fact that many of the policies needed to advance in that direction also have other advantages, including financial gains (for

example, when using less costly low-carbon energy sources or increasing energy efficiency) and potential improvements in energy security. In addition, there are social protection and biodiversity conservation benefits from improved land use and forestry management. The objective of this chapter is to identify the main climate mitigation opportunities that exist in the region and to prioritize those options in terms of their relative contribution to emissions reduction, technology and implementation costs, and co-benefits. In addition, the chapter explores the policy challenges in overcoming various implementation barriers and the potential synergies that may provide additional motivations for pursuing them.

GHG Emissions and Projections for the LCR

The LCR is a relatively small contributor to global emissions—6 percent of energy emissions and 12.5 percent of total GHG emissions—but faces disproportionate impacts of climate change (chapter 2). The mitigation potential is largest in the sectors that contribute most GHG emissions in the LCR today and in those sectors whose emissions are expected to experience high growth. Thus, an assessment of the most promising areas for mitigation begins with a close look at the emissions profile in the LCR. It is strikingly different from the global emissions profile, with deforestation and agriculture accounting for the bulk of total emissions, followed by emissions associated with energy use and electricity consumption in the industrial and residential sectors. By contrast, energy use in these two sectors is the leading source of GHG emissions in the world, and transportation contributes a substantially higher share to total emissions globally than in the LCR (chapter 5). Another specific aspect of LCR's emissions profile is the particularly high share of the agricultural sector in total non-CO_2 emissions—more than 70 percent compared to the global average of 55 percent. Methane from enteric fermentation in the livestock sector and nitrous oxide from soils are the bulk of non-CO_2 emissions in the LCR and they are projected to rise in absolute value as well as remaining high in relative terms.

Depending on some assumptions about the magnitude of future emissions from land-use change, they could become so large in the future as to far outweigh the contribution from other sectors—or could remain at the level comparable to emissions from the energy sector. This uncertainty comes about from the dependence on the actual emission levels from deforestation or forest degradation on tree species, end-use of timber products, and several other factors. For example, using harvested timber for furniture stores carbon, whereas burning forests immediately releases carbon into the atmosphere. Keeping in mind that uncertainty, recent estimates suggest that emissions from deforestation in the LCR may have been declining since the early 1990s from more than 3 $MtCO_2$ in 1991 to less than 2.5 $MtCO_2$ in 2005 (Houghton 2008). If that trend continues while energy sector emissions grow, the relative contribution to total GHG emissions from the energy sector in the LCR may indeed become comparable to the importance of the emissions from land-use change in the future.

What do the current pattern of emissions and their expected future trajectory imply for the mitigation opportunities in the LCR? The region may make the highest contribution to the global mitigation efforts by reducing emissions from deforestation—and this is high on the global agenda—but curbing the growth of energy-related emissions, particularly in the industrial and residential sectors, will emerge as another priority area on the mitigation agenda for LCR as well as globally.

Energy—Relatively Low-Carbon Intensity in the LCR Today but on a Rising Path

The energy sector contributes a lower share of total emissions in the LCR than in the world because of the region's much lower carbon intensity of energy supply and its comparatively low per capita energy use (table 6.1). Low-carbon intensity is the result of a low share of coal and a relatively high share of renewable energy—particularly hydro—in the LCR's energy supply. However, both indicators—carbon intensity and per capita energy use—are on the rise in the region, and this trend will continue unless measures are taken to tap the large potential of low-carbon energy supplies and expand energy efficiency measures in the region. Although the LCR is starting from a low emissions

TABLE 6.1

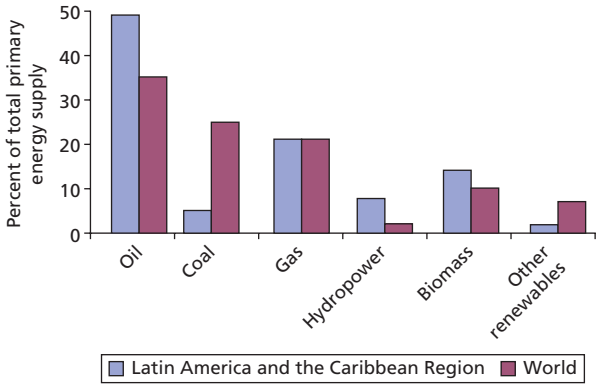
Lower Carbon Intensity but Higher Energy Demand Growth in Latin America and the Caribbean Region than Globally

	LCR	World
Energy use (toe/capita)	1.19	1.77
Emissions (tCO_2/capita in 2004)	2.4	4.2
Carbon intensity of energy use (tCO_2/toe)	1.98	2.38
GDP (US$ 2000 PPP/capita)	7,267	8,191
Primary energy supply growth (% per year 1990–2004)	2.5%	1.8%
Energy related CO_2 emissions growth (% per year 1990–2004)	2.6%	1.8%

Source: Dussan (2008).

FIGURE 6.1

Low Reliance on Coal and High Reliance on Hydro-Electric, Oil, and Biomass in Latin America and the Caribbean Region, 2005



Source: IEA online data services, http://data.iea.org/ieastore/statslisting.asp.

base, energy-related CO_2 emissions grew at a faster pace during 1990–2004 than the global average mainly because of the higher than average growth in energy supply. If this trend continues, emissions in the LCR would double by 2030.

The composition and evolution of the primary energy matrix in the LCR during the past 25 years shows some similarities but also significant differences with the world. The share of natural gas in the primary energy supply had risen to about 21 percent by 2005, the participation of low-carbon energy (hydro, nuclear, and small renewable) had risen to about 10 percent, and the share of oil was high but declined by about 10 percent during this period. LCR has a cleaner generation mix relative to the world average, with a much lower contribution of coal and a relatively high share of hydro (figure 6.1). The contribution of traditional biomass is also higher in the LCR than in the world, although it has decreased as electricity coverage and access to other modern energy sources (liquefied petroleum gas, solar) have risen, displacing the use of firewood.

A high but declining share of renewables in electricity generation

Electricity generation is cleaner in the LCR as a whole than on average in the world, but that could change. In 2004, LCR produced 6 percent of the world's electricity but only contributed about 3 percent of electricity sector emissions worldwide, implying that the carbon intensity of electricity generation in the LCR was about half the world average (table 6.2). However, CO_2 emissions from electricity generation grew at a faster pace in the LCR relative to the world or industrial countries in the period 1980–2004. The main reason for LCR's relatively low carbon intensity is the large share of hydro and natural gas in the region's power sector fuel mix. Though mitigation of CO_2 emissions was not an explicit policy objective at the time, the development of hydroelectric projects was very effective in keeping the carbon intensity of electricity generation low.

An analysis of the drivers and dynamics of CO_2 emissions in the power sector reveals major differences between countries in the LCR in terms of the carbon intensity of electricity generation. While Brazil generated only 87 grams of CO_2 per unit of electricity (gCO_2/kWh), Mexico emitted 552 gCO_2/kWh, a level similar to the United States. The Caribbean, which relies primarily on small thermal generation units, produced 712 gCO_2/kWh. South America and Central America, with a relatively large base of hydroelectric generation, had a carbon intensity below 250 gCO_2/kWh, a level similar to Canada. Despite the relatively clean generation mix in the LCR, the high growth rate of emissions has important implications for climate change. Although the region starts from a low base of carbon intensity, it is likely that this index

TABLE 6.2

CO_2 Emissions from Electricity Generation

	Annual growth (1980–2004), %		Carbon intensity (2004), gCO_2/kWh	Increase in carbon intensity (1990–2004), %
	Emissions	Electricity generation		
World	2.5	3.1	500	10
United States	1.5	2.3	555	−4
Canada	2.1	1.9	205	2
LCR	3.7	4.7	262	3
Central America	4.9	5.3	302	217
Caribbean	5.1	5.6	712	−9
South America	2.7	4.6	165	0
Brazil	5.8	4.3	87	57
Argentina	1.5	3.5	332	−20
Venezuela, R. B. de	0.6	4.7	252	−24
Chile	6.6	6.2	356	−16
Colombia	2.3	3.9	169	−21
Peru	2.4	3.8	206	7
Mexico	4.8	4.9	552	−3

Sources: Emissions (IEA online data services), generation (EIA).

and the share of total energy-related emissions from the power sector will increase in the future.

The share of renewable energy in the generation mix is expected to gradually decrease, as evident from the reference planning scenarios (see table 6.3).[1] Despite substantial growth in the use of renewable resources, that growth is not fast enough to keep pace with the rising demand for energy. As a result, CO_2 emissions from electricity generation in the region are expected to continue to grow at annual rates of about 3.9 percent. Relatively low carbon intensity levels are maintained in the scenarios mainly because most thermal expansion is based on natural gas; however, carbon intensity is expected to increase in countries where the share of hydro and other low-carbon sources is already high (Brazil) and decrease in countries with substantial thermal generation (Mexico).

Great potential for renewable energy—but addressing the environmental concerns

As a whole, LCR is endowed with substantial energy resources to meet future electricity needs. The hydroelectric potential is about 687 gigawatts (GW) spread throughout Mexico and South and Central America, of which only 26 percent will be utilized by 2015, according to current expansion plans. There are substantial natural gas reserves in República Bolivariana de Venezuela, Trinidad and Tobago, and Bolivia, which are partially used in regional pipeline markets (Bolivia) or in the liquefied natural gas (LNG) market (Trinidad and Tobago). There are substantial reserves of good quality steam coal in Colombia, which are increasingly attractive to the region as oil prices rise.

Developing small-scale renewable projects is also a promising prospect in the LCR from the purely technical point of view. Countries rich in large hydroelectric resources also have a significant potential of small hydroelectric projects. Many countries have areas with excellent wind conditions, with a wind power class equal or higher to 4; there is high potential for solar energy with radiation levels of more than 5 kWh/m2 in large areas of the Southern Cone, Mexico, and the Caribbean; many countries are located in volcanic areas with geothermal resources; and sugarcane bagasse already contributes about 6 percent of primary energy. However, information about the potential of renewable energy that could be developed economically, and consolidated at a regional level, is fragmentary and incomplete. The fact is that in 2005 the installed capacity of renewable energy (not including hydro) for electric power was only about 6,800 MW, representing less than 3 percent of total generation capacity in the region.

TABLE 6.3

Latin America and the Caribbean Region-Generation Expansion 2005–30: Reference Case Generation Mix and CO_2 Emissions

	IEA World Energy Outlook 2007 (LCR except Mexico)			OLADE-Energy Prospective (LCR)		BRAZIL-National Energy Plan 2030 (only Brazil)			MEXICO-CFE POISE 2008–17 (only Mexico)	
	2005	2015	2030	2008	2018	2005	2020	2030	2006	2017
Share of renewable energy	71%	63%	58%			86%	79%	78%	16%	11%
Medium and large hydro	68%	60%	53%			82%	73%	68%	13%	9%
Other renewables	2%	3%	4%			4%	7%	9%	3%	3%
CO_2 emissions (in million tons CO_2/year)	179	263	412	302	438	21	48	83	117	178
Carbon intensity of generation (grams CO_2 /kWh)	198	192	200	249	241	57	67	78	519	464
Annual rate of growth										
Generation		4.2%	2.7%		4.1%		4.7%	3.9%		5.0%
Emissions		3.9%	3.0%		3.8%		5.7%	5.6%		3.9%

Source: Dussan (2008).

The region has significant potential for low-carbon energy, especially medium and large hydroelectric plants, but also wind and biomass that are competitive today in some countries and that could play a major role in future electricity expansion plans.

Different implications of a menu of renewable energy policies

Legal, regulatory, institutional, and financing schemes to promote the use of renewables for electricity generation are at different stages of development in the region. These policies have recently been implemented in many countries due to the drop in investment in natural gas infrastructure, high cost of fossil fuels, and El Niño– and La Niña–related droughts that showed how susceptible hydro generation can be to climate variability. Many countries have enacted renewable energy legislation recently in response to high fossil fuel prices. The policies implemented in the region fall into four categories: tax exemptions and credits, mandates, tariff and subsidy support for renewables, and resource laws. Furthermore, some support measures, such as guaranteed purchase prices (feed-in prices), are more advantageous under relatively uncertain economic conditions, while other instruments, such as mandates, perform well when price uncertainty is not a major factor in investor decisions (box 6.1).

Challenges for expanding hydropower with few environmental and social impacts

Hydropower potential in the LCR is very significant. Yet the development of more than 100,000 MW of medium and large hydroelectric projects in South America and some Central American countries, which are included in the generation expansion plans by 2015 and 2030, face many difficulties and may not be realistic (figure 6.2, table 6.3). Many of the most attractive hydroelectric projects require the construction of large reservoirs to regulate the substantial seasonal variations in river inflows and provide a reliable source of energy. However, the construction of large dams has been at the heart of the opposition that has typically accompanied large hydroelectric projects in Latin America over the past 25 years due to population displacement, including indigenous groups and ethnic minorities, inundation of vast amounts of land and the loss of biodiversity, and adverse impacts on aquatic habitats and other ecosystems. Climate change raises risks for hydroelectric plants through greater variation in rainfall or runoff patterns that may require modifications to hydropower designs and plans. Although the environmental and social impacts can be managed in many cases by appropriate environmental impact assessment studies and mitigation plans, the environmental licensing process is often inefficient and ineffective at achieving the environmental objectives, and

BOX 6.1

Supporting Policies Have Different Effects on Incentives, Investment Certainty, and Costs

Tax exemptions and credits. In an effort to stimulate investments in renewable energy projects, countries may elect to reduce or eliminate certain taxes—such as income and import taxes and depreciation allowances—for a set number of years of project operation. The incentive laws of Argentina, Colombia, the Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, Panama, and Peru are of such a nature. Another instrument, a production tax credit (PTC), helps renewables compete with other types of generation technologies by compensating renewable energy producers for the difference in generation costs relative to fossil fuels. But PTCs can also be a detriment to an industry if they are not consistently supported by the federal government. In the United States the PTC for wind generation has expired and been renewed several times, causing a boom and bust in the wind industry. If a developer begins the preparatory studies and applies for permits but is unable to begin generation on the site before the PTC has expired, he is not eligible for the credit. In the region, only Argentina has adopted a PTC.

Tariff and subsidy support. Feed-in laws require distributors to buy renewable energy at a fixed rate that is higher than the average wholesale market price and usually close to the retail price of electricity. A feed-in tariff is an associated incentive structure to encourage the adoption of renewable energy through government legislation, in which regional or national electricity utilities are obligated to buy electricity generated from renewable sources at rates set by the government at levels above the market rate. This incentive mechanism for renewables has been adopted in Costa Rica, Ecuador, and Peru. Feed-in laws are effective at promoting renewables since developers can get loans for projects as uncertainty about power purchase prices is reduced. However, feed-in tariffs provide little incentive for innovation or cost minimization since generators are not competing against each other, as under energy auctions. A further disadvantage is the difficulty of phasing out feed-in tariffs even if economic conditions change, as typical of any subsidy.

Renewable energy mandates. A renewable energy mandate requires existing and new generators to produce a certain percentage of their generation from renewable sources by a given target year. Binding mandates typically involve fees for noncompliance. Renewable energy mandates help attain production efficiency as they allow market pressures to lower the cost of generation. Generators still compete against each other to provide the least-cost energy and are selected and contracted by power providers in power purchase agreements. This situation differs from a feed-in tariff, which provides generators with a fixed purchase price for renewable energy from specified sources and does not encourage innovation to lower generation costs. However, mandates that are not well-structured may promote cherry-picking of technologies rather than preserving the level playing field for diverse technologies. Chile has adopted a renewable energy mandate in terms of a percentage of generation that must be sourced from renewables, whereas mandates in Brazil and Uruguay are in the form of specified MW capacity additions by target years.

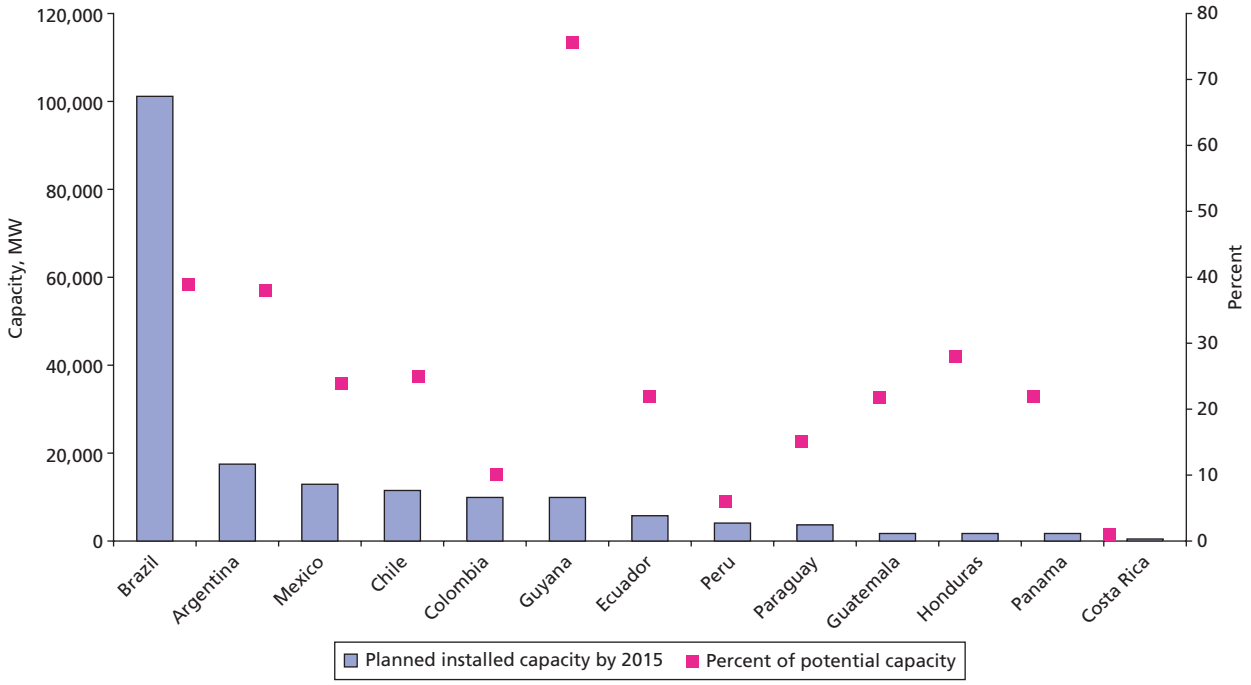
Renewable energy resource laws. Using renewable resources to generate electricity requires specific legislation that governs their use. For example, tapping geothermal resources for power generation is more successful when governed by a geothermal resources law than under generic mineral or water acts. Geothermal resource laws, such as those in El Salvador, Guatemala, Nicaragua, and Peru, address such matters as drilling rights, resource concessions, and environmental protection that is unique to the industry. Similar policies need to be formulated for hydropower, wind, and biomass resources.

when the licensing process is lengthy, risky, and expensive, it causes delays in the preparation and execution of the projects, raising project risks and costs. The challenge is to make the process of environmental impact assessment and licensing both more effective at attaining environmental objectives and efficient from the economic viewpoint (box 6.2).

In most countries that have adopted a competitive electricity market with private participation, investors have avoided hydro projects because of high project

FIGURE 6.2

Hydroelectric Potential in Latin America and the Caribbean Region



Source: Dussan (2008).
Note: This figure shows planned installed capacity by 2015 as a percent of potential capacity. MW = megawatt.

BOX 6.2

More Effective and Efficient Environmental Licensing Is Needed to Unleash the Region's Potential for Hydropower

Minimizing adverse environmental and social effects of hydropower and other clean-energy projects that involve large infrastructure works requires strategic planning at the sector and subsector levels, an effective regulatory framework, environmental information, and institutions that can monitor and enforce standards and regulations.

The environmental licensing process for hydropower projects in the LCR needs to become more efficient—impose lower-costs on the economy—and, at the same time, more effective at achieving environmental protection objectives. The primary instrument for managing the environmental implications of hydropower investments is the Environmental Impact Assessment (EIA) whereby an environmental agency issues licenses. Using complementary instruments—including zoning and Strategic Environmental Assessment (SEA)—will improve infrastructure planning and assessment of environmental impacts. The advantage of SEA is the possibility to assess cumulative effects (for example, impacts of building several rather than one hydropower plant in the same river basin) and compare alternatives that are not assessed in the standard EIA process. Zoning plans can also be instrumental for selecting the sites for hydropower plants and dams and helping avoid critical wildlife habitats. This approach can be used in planning hydropower investments, and it has been successfully applied in other sectors with potentially high environmental impacts. Planning roads as a network in the Tocantins state in Brazil helped avoid critical habitats while at the same time increasing the economic and social benefits. Using these complementary instruments of environmental management can enhance the EIA process, improve its efficacy, and reduce the regulatory costs and delays, thereby helping overcome the main obstacles to realizing the potential of the region to meet a large share of the growing energy demand from low-carbon sources.

risks: high capital cost, need for expensive and time-consuming feasibility studies, higher construction risks, long execution and amortization periods, and protracted and politically sensitive processes to obtain environmental licenses. Development of large hydro projects requires strong government support to help manage these risks or the participation of financially solid state-owned enterprises that are willing and capable to assume these risks. Because of these risks, many institutions (including multilateral banks) have reduced their involvement in hydroelectric projects over the past 20 years.

Even Brazil, a country that has been very successful in developing a large potential of low-cost hydroelectric generation, has experienced delays in the development of new hydro projects. Brazil has been using public auctions since 2004 to award long-term energy supply contracts, and one of the hopes of the program was that it would facilitate the delivery of hydroelectric projects. However, the participation of hydro in the auction process was constrained by delays in obtaining environmental licenses, and only about 50 percent of the hydro projects that intended to participate in the first auction in late 2005 received an environmental license and were able to submit a proposal (World Bank 2008a). Consequently, the awarding of contracts for hydroelectricity in new generation capacity to be commissioned in 2008–10 has been lower than envisaged in the indicative generation expansion plans, and, as a result, the share of fossil fuel plants has increased.

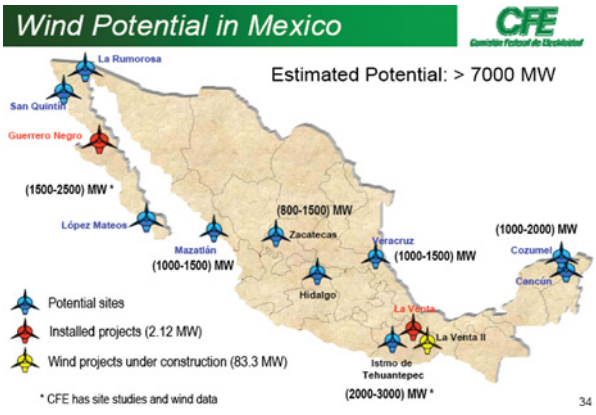
Hydropower projects do not necessarily have to produce negative environmental consequences. Mainstreaming environmental considerations in project design at an early stage can significantly reduce infrastructure's environmental footprint. This can be achieved through avoiding critical natural habitats in infrastructure siting, minimizing damage to other (noncritical) natural habitats, and through such mitigation measures as careful engineering design and ecological compensation programs.

Opportunities for wind—difficulties competing with low and unstable energy prices

The wind power potential in the LCR is considerable, with the best wind resources located in Mexico, Central America and the Caribbean, northern Colombia, and Patagonia (both Argentina and Chile). Mexico's CFE (Federal Electricity Company) has estimated the feasible potential of wind at between 7 to 12 GW, in comparison to the current installed capacity of 51 GW, with detailed wind resource studies completed for Baja Peninsula (1,500–2,500MW) and the Isthmus of Tehuantepec centered in Oaxaca (2,000–3,000MW) (figure 6.3).

Wind power tends to be competitive in locations with a favorable policy environment, resource endowments, available infrastructure, and without low-cost alternative sources of energy. Wind power operating with high capacity factors and close to a transmission grid is becoming competitive for most countries in Central America and the Caribbean that generate a large share of their electricity with oil, do not have access to low cost hydroelectric generation, and have introduced legislation to promote development of small renewable power. In this case, wind projects can be competitive and cover their levelized generation costs at the marginal costs of new capacity.[2] Wind is also likely to be quite competitive in Chile and Mexico, where marginal generation costs are high based on natural gas, fuel oil, or imported coal or LNG. In Colombia, another area with good wind resources, wind is less competitive. In countries with access to low-cost generation (hydro or gas-fired), including Brazil, Colombia, and Peru wind projects cannot

FIGURE 6.3
Wind Power Potential in Mexico



cover their levelized generation costs. In the presence of low-cost generation sources, as in these cases, revenues from energy sales at marginal generation costs, projected to be in the range of 25 to 70 US$/MWh, are low and that makes it difficult for higher-cost wind power to compete.[3]

Private developers of wind projects—as with other long-term investments, such as hydro—typically require long-term contracts with stable energy prices sufficient to recover their fixed costs. While wind may be competitive today in certain countries in comparison to fossil fuels, the opportunity cost may drop in the future to levels that do not cover their costs, and many wind developers do not have deep pockets. To address these hurdles, in some countries, like Honduras, the developer can use a long-term contract to lock current high marginal costs in the energy price. Additional revenues from the sale of CERs would help but are still small at current carbon prices.[4]

As an alternative example, Brazil established a quota-based incentive program (PROINFA) for the development of wind, biomass, and small hydro, considered as three different markets, each one with its own energy price. In the first phase of the program a capacity of about 1,423 MW was awarded to wind power at a much higher energy price than biomass or small hydro. In 2007, the government decided to apply the scheme of public auctions with a ceiling price to purchase energy from small renewable power, but the results were not positive. With a ceiling price of about US$77/MWH, only 638 MW were awarded, 85 percent to biomass and the rest to small hydro (World Bank 2008c), probably an indication that wind and most small hydro projects cannot compete at that price.

Over the past three years the increasing demand for wind, especially in the United States and other industrial countries, has resulted in a short-term shortage and an increase in price of wind turbines and other equipment, with installed costs increasing by as much as 17 percent in 2006. Even with these cost increases, Mexico (and specifically Oaxaca) remains among the lowest-cost regions for wind generation with recent bids in the range of US$64/kWh (table 6.4).

TABLE 6.4

Levelized Generation Costs of Wind Power

	US$/MWh
Brazil	126
Canada	78.4–116.2
China	57.4–68.6
Costa Rica	72.8
Estonia	74.2
Mongolia	89.6
Sweden	91
Mexico	64.3

Sources: World Bank staff estimates; *Wind Power Monthly,* January 2008, with prices in euros converted to US$ at US$1.4/euro.

Bioenergy—identifying sustainable liquid biofuels to avoid perverse outcomes

The use of bioenergy from agriculture, forestry, and municipal solid wastes represents a potentially large mitigation source in the efforts to combat climate change when feedstocks for bioenergy can be collected and produced in a sustainable manner. Fuelwood continues to provide a large share of the world's and LCR's energy needs. However, given the unsustainable nature of much fuelwood production, particularly when it drives deforestation, and the health costs associated with inefficient fuelwood stoves for cooking and heating (and the global warming potential of incomplete combustion), traditional fuelwood use is not a feasible option for reducing GHG emissions. While bioenergy includes all biomass used as fuel, there has recently been a lot of interest in liquid biofuels, especially in the LCR.

Liquid biofuels are one of few alternative fuels for transport—a sector whose emissions are rapidly rising in tandem with economic growth and improving living standards in developing countries. With oil prices in 2008 reaching record highs, Brazil, the European Union, and the United States, among others, are actively supporting the production of liquid biofuels from agriculture—usually maize or sugarcane for ethanol and various oil crops for biodiesel. The share of biomass consumption in the total energy basket in the LCR is on the decline, while the share of biofuels is higher than in any other region—thanks to the large production potential in Brazil—and is rising (table 6.5).

TABLE 6.5

Shares of Energy Consumption in Latin America and the Caribbean Region by Energy Source

	Industry		Transport		Residential, services and agriculture	
	2004	2030	2004	2030	2004	2030
Coal	7	6			0	0
Oil	23	21	90	84	28	25
Gas	25	25			11	15
Electricity	19	26			31	40
Heat	0	0			0	0
Biomass and waste	26	21			30	19
Other renewables	0	0			0	1
Biofuels			6	10		
Other fuels			4	6		
Total	*100*	*100*	*100*	*100*	*100*	*100*

Source: IEA (2006).
Note: This table shows the shares of energy consumption in the LCR by energy source under the IEA reference scenario. In the IEA's alternative policy scenario, the shares of coal, oil, gas, electricity, and heat are projected to decrease by about 10 to 16 percent for all sectors (and an over 20 percent reduction of oil consumption by the transport sector) relative to the reference scenario, while the share of other renewables would increase by 110 percent compared to the reference scenario. The share of biofuels in transport would increase by 24 percent relative to the reference scenario.

The global economic mitigation potential of biomass from agriculture is estimated at about 640 to 2,240 Mt CO_2e per year, with additional mitigation potential from biofuels.[5] However, uncertainty about land availability and future yields result in a very broad range of estimates. Furthermore, the way in which biomass is used—unsustainable harvesting and combustion in inefficient and polluting stoves—limits its potential to contribute to GHG reduction. The mitigation potential of biofuels is even more contentious as the implications of biofuels' use on GHG emissions vary depending on the type of feedstock, process, and the environmental impact of cultivating a specific feedstock.

Brazil and the United States accounted for almost 90 percent of global ethanol production—50 billion liters—in 2007. In the same year, the EU countries produced nearly 60 percent of the world's total biodiesel output of 9.6 billion liters. Brazil is an ethanol pioneer, with production starting in the 1930s; it remains the world's most competitive producer, as well as the lowest-cost sugarcane producer. Half of Brazil's sugarcane is now devoted to ethanol, for which a market has been guaranteed by legislation requiring ethanol-gasoline blends. The United States used 24 percent of its maize crop to produce ethanol in 2007–08, and extends generous support to the industry through tax incentives and subsidies for biofuel production and consumption, coupled with consumption mandates. Many developing countries are launching biofuel programs that rely on molasses, sugarcane, and oil-rich crops, such as soybeans, oil palm, and jatropha. In the LCR, Argentina, Central America, Colombia, and Paraguay are some of the new emerging players on the biofuels markets, although their production volumes are far lower than in Brazil. According to some estimates, more than 40 million additional hectares of arable land that is suitable for sugarcane cultivation can be brought into production in Brazil. Despite this large untapped potential, important social and environmental trade-offs need to be considered.

To make biofuels financially viable, most governments extend financial and policy support to the industry. Feedstock costs account for more than half the costs of producing biofuels. Despite remarkable reductions in production costs in Brazil and elsewhere, the biofuels industry has struggled until recently. It has been able to stand on its own in purely economic terms in just a handful of cases, such as Brazil in 2004–05 (but not 2006 when international

sugar prices skyrocketed) and 2007–08. Elsewhere, biofuels production has not been financially viable without government support and protection. Domestic producers in the European Union and the United States receive additional support through high import tariffs on ethanol.

Possible environmental and social benefits, including mitigation of climate change and contribution to energy security, are cited as the main reasons for public sector support of the rapidly growing biofuels industry. Yet despite the potential of biofuels both as a renewable energy resource and a source of support for agricultural producers, there is mounting evidence that they carry social and environmental risks. These include upward pressure on food prices, intensified competition for land and water, and land-use change that increases greenhouse gas emissions. The climate mitigation potential of biofuels, in particular, depends on the type of feedstock and production process used, as well as on the indirect emissions resulting from land-use change.

Without changes in land use, Brazilian sugarcane is estimated to reduce GHG emissions compared to gasoline by about 90 percent. In contrast, the reduction of GHGs for ethanol from maize in the United States is only in the range of 10 to 30 percent before taking into account the indirect GHG emissions from land-use change.[6] By some estimates, the cost of reducing one ton of carbon dioxide emissions through the production and use of maize-based ethanol could be as high as $500 a ton, or 30 times the cost of one ton of CO_2 offsets in the European Climate Exchange.[7]

For biodiesel, the emission reductions are estimated in the range of 50 to 60 percent—again, without considering land-use changes—with the economic value of reductions much lower than the subsidies typically given to biofuels. At the prices forecast in carbon markets—between US$8 and US$20 per metric ton: CO_2 equivalent—the value of GHG reductions is likely to fall between US$0.01 and US$0.04 per liter of biofuel.[8,9] In many cases, demand-side and efficiency measures in the transport sector are likely to be much more cost-effective than biofuels in reducing GHGs.

If feedstock production in one part of the world prompts another region to change its land-use practices, global GHG emissions may actually rise. Life cycle analysis—which is a way to account for the total emissions of GHGs throughout the entire process of cultivation of feedstocks and production of biofuels—indicates a 20 percent annual savings in CO_2 emissions relative to oil when ethanol is produced from maize in the United States. However, a recent study estimates that land conversion in the United States and elsewhere to produce more maize may actually result in a doubling of GHG emissions over 30 years and increase GHGs for 167 years.[10]

Benefits can fall further after accounting for environmental impacts associated with production of biofuels: depletion of natural resources, razing of forests and peat surfaces to open land for cultivation, and damage to ecosystems. Environmental costs of nearly half of these biofuels, including the economically most important ones—such as U.S. maize ethanol, soy diesel, and Malaysian palm-oil diesel—may have greater environmental costs than fossil fuels. The ranking of biofuels by their overall environmental impact depends crucially on whether the cultivation of feedstocks results in direct or indirect land-use change. Conversion of forest areas as a consequence of the expanding biofuels production can occur indirectly as sugarcane or soy plantations displace crop areas and pastures, which, in turn, expand into forest areas. This type of indirect land-use change is particularly difficult to measure and because of that complexity it is often overlooked in sustainability assessments of biofuels.

The findings of very high environmental costs of land-use change are corroborated by studies that look at specific regions and assess the "carbon payback time," or time that it takes for the annual reductions in emissions when biofuels replace fossil fuels to compensate for the one-time emissions of carbon from land conversion to biofuels. Conversion of peat land or tropical forests to cropland to cultivate feedstocks for biofuels, whether first- or second-generation, will cancel out any of the emissions reductions for decades. Production of annual biofuel crops, such as maize, cassava, or soybeans, on deforested land with first generation technologies

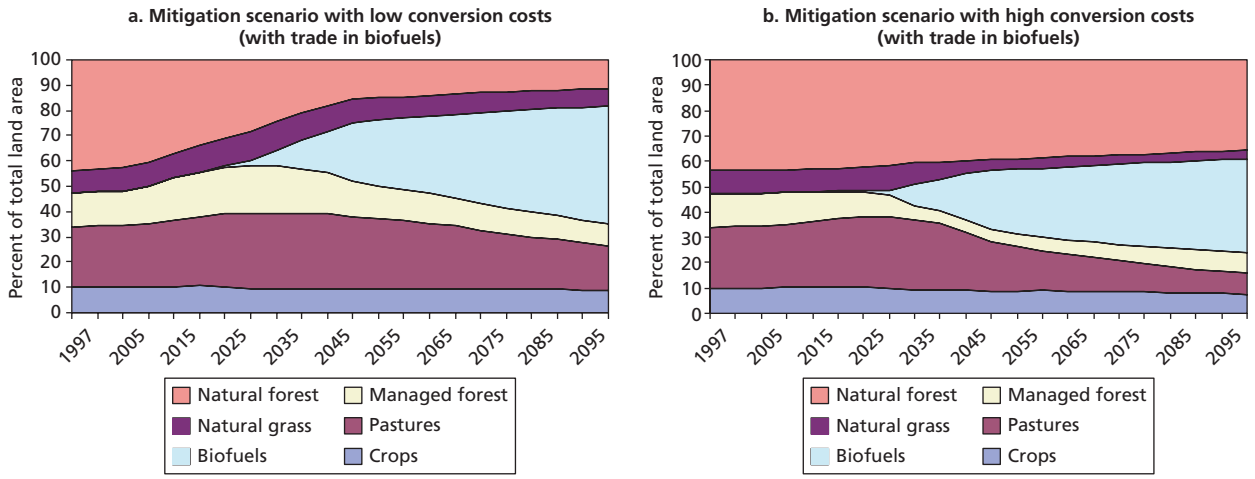
requires approximately 300–1,500 years of biofuel carbon savings to reach a carbon breakeven point. Biodiesel compensates for forest carbon losses only after 30–120 years for nonpeat soils and after more than 900 years for forest growing on peat lands in South Asia.[11] Carbon flows from initial land clearing and from carbon savings associated with the replacement of fossil fuels with biofuels occur at different time periods and they need to be discounted, which would somewhat reduce the carbon payback periods, but the choice of an appropriate discount rate for carbon is surrounded by political controversy and few studies have addressed this issue.[12] If forests or grasslands are not converted for the production of biofuels—including indirect impacts—the carbon payback would be significantly less. Brazilian researchers estimate that the carbon payback from producing ethanol from sugarcane grown on former pasture land would be less than four years.

In the policy discussions, high hopes rest with second-generation biofuels and the expectation that their advent would reduce the pressure on land. Yet results from one of the few studies that assess the interactions between land use and biofuels production on the global scale do not support that hope. Policy simulations from a scenario of costless land conversion suggest that as much as 40 percent of land currently under natural forests around the world may be converted to biofuels production by 2100 relative to 2000 even with second-generation biofuels.[13] Forest conversion is much lower when forest conversion is more costly (figure 6.4b) than with low conversion costs (figure 6.4a). These results underscore the importance of implementing conservation policies and incentives for forest preservation that would increase the relative cost of land conversion from forests to agriculture. Although the study uses regionally disaggregated data within a general equilibrium framework, the results should be treated with some caution because of the global focus of the study and the understandable general nature of the conclusions. Assessments of the likely direct impact of biofuels on land use within a general equilibrium framework and a high level of regional disaggregation, with a focus on specific countries and regions, are much needed to aid policy design.

Second-generation biofuels may require less additional land insofar as they would utilize crop residues and waste or energy crops grown on poor quality

FIGURE 6.4

Conversion of Natural Forest to Second-Generation Biofuels in Latin America and the Caribbean Region



Source: Gurgel et al. (2008). The disaggregated results for the LCR were provided by the authors.
Note: Results are from the general equilibrium modeling mitigation policy scenarios, which allow unrestricted conversion of natural forest and grassland (as long as conversion costs are covered by returns), and for costly conversion (assuming the same costs as what had been observed in the past). The two models represent what might be considered the two extremes of land conversion, and the magnitude of future conversion is likely to lie somewhere between the results of these two models.

land that is not suitable for other agricultural production. The extent to which GHG emissions can be avoided using marginal and degraded land or waste products is debated. Even if truly excess croplands are used, biofuels would still not avoid the emissions as these croplands would convert either to forest or grassland and start sequestering carbon if they were not used for biofuels. The net emissions depend on carbon sequestration by biofuels crops compared to the alternative land cover. Furthermore, cultivation of energy crops on marginal and degraded land would likely require fertilizer and irrigation, with such possible environmental impacts as fertilizer runoff and groundwater depletion. Waste products—as they would not cause land-use change—have been identified as a truly sustainable raw material for biofuels.[14]

Minimizing potential environmental risks from large-scale biofuels production could be possible through certification schemes to measure and communicate the environmental performance of biofuels (for example, a Green Biofuels Index could reflect the production path and contribution to GHG reductions).[15] Similar standards already exist for organic products and for the sustainable production of timber, pulp, and forest products (Forest Stewardship Council). From the point of view of reducing environmental risks from biofuels, however, only worldwide certification of most biofuels that is effectively enforced may have a reasonable chance of making a difference. This would argue for rapidly building a consensus on what would be a realistic way forward to ensure global environmental sustainability. Assessment of the indirect impact of biofuel production on land-use change will be challenging or nearly impossible even if such a certification scheme could be implemented.

The conflict between food and fuel is another important economic and social risk posed by production of some biofuels. Rising energy prices, among several factors, have contributed to food price increases, but biofuel production has also pushed up feedstock prices. The clearest example is maize, whose price rose by 87 percent from January 2005 to December 2007. Driven by subsidies, mandates, and import barriers, a rapidly rising proportion of the U.S. maize crop is devoted to ethanol production, coinciding with a sharp drop in U.S. maize reserves. Biodiesel production in the European Union—again driven by subsidies and mandates—and elsewhere, among other factors, has contributed to similar price increases for vegetable oils (canola, soybean, and palm). The increased demand for feedstock crops by biofuel industries, by some estimates, has accounted for about 20 percent of the overall increase in real rice and wheat prices and about 40 percent for maize from 2000 to 2007.[16] On the contrary, Brazil's ethanol production from sugarcane has not contributed appreciably to the recent increase in food commodity prices.[17] Rising food prices have hit many food-importing countries hard, causing significant welfare losses for the poor, many of whom are net buyers of staple crops.

Second-generation technologies could enable a shift from reliance on food crops to dedicated energy crops using a range of feedstocks, including agricultural, municipal, industrial, and timber wastes, thus attenuating the trade-offs between food and biofuels production. This could reduce pressure on food crop prices, but only if producing these alternative feedstocks and raw materials requires less land than that used for biofuels at present. Among the most promising second-generation technologies are lignocellulosic ethanol that can use a range of biomass feedstocks and oils derived from algae. Such technologies are not yet commercially viable—and will not be for at least several more years. Bridging this gap with research investments, by both private companies and public authorities, should be a priority.

Biofuels trade liberalization would increase competition in the sector. This would improve efficiency, bring down costs, and enable the world's most efficient producers to expand their share of the biofuels market. But for this to deliver net gains in welfare for developing countries, efforts to remove trade barriers must be accompanied by a commitment by rich countries to reduce or eliminate domestic protection of feedstock producers and biofuels industries. A level playing field for biofuels would resolve some of the dilemmas, attenuate the risks, and clarify the choices for policy makers seeking welfare gains from biofuels.

Biofuels promotion policies such as agricultural subsidies and tax exemptions not only distort international

trade patterns, but also impose large costs on their own populations. Interactions among different policies can magnify these costs. De Gorter and Just (2008) analyze the interaction between agricultural policy (loan deficiency payments for corn) and biofuels policy (tax credits), using the U.S. program as an example. With the rates for both programs used in the years 2004–07, they estimate average annual taxpayer costs of about $4.83 billion, with reduction in social welfare of $1.66 billion per year. These findings underscore the need to base policy design on sound economic analysis.

The choice of policy instruments in support of biofuels has very important and mostly overlooked consequences for the financial cost of that support—the environmental and distributional outcomes. In the LCR, Argentina, Brazil, Colombia, the Dominican Republic, Peru and Uruguay have defined consumption targets for ethanol from sugarcane; Argentina, Brazil, and Paraguay, for biodiesel from soy; and Bolivia and Colombia, for biodiesel from palm oil.[18] Consumption mandates for biofuels are a preferred policy instrument on the grounds of efficiency and the environmental impacts.[19] Combining mandates with tax credits—a common approach around the world, including the United States—has perverse consequences because of a unique interaction between the quantity and price-based incentives in the biofuels markets (box 6.3). These unintended adverse consequences need to be brought out into the public debate in the LCR and other developing countries so that these countries can benefit from the experience of the suboptimal biofuels policies of the European Union and the United States. If consumption targets in the LCR become binding mandates, combining them with tax credits for biofuels would reduce or eliminate the possible beneficial economic, social, and environmental impacts of the mandates.

The rising market share of biofuels in the global energy basket can help mitigate global climate change if GHG emissions fall after a full accounting of fossil energy use and land-use change throughout the production cycle. The local environmental impacts will on balance be positive if the contribution of biofuels to reduce local air and water pollution outweighs the adverse environmental effects caused by the production of feedstocks. And the social and distributional effects will be positive if job creation and employment outweigh the loss of access to land and adverse changes in cropping patterns by the poor and vulnerable households with insecure land tenure. The challenge for the governments in the LCR is to assess biofuel strategies using integrated cross-sectoral approaches that fully account for the location- and feedstock-specific environmental and social impacts. At the international level, it is essential that trade in biofuels is liberalized so that they are produced in the most efficient manner and make the maximum contribution to climate change mitigation.

The rising role of coal and the costs of switching away from it

High natural gas prices and concerns about the social and environmental impact of large and medium hydroelectric projects are becoming barriers to the development of other sources of clean or low-carbon energy in the region. Carbon capture and storage, which is not yet commercially available, could be a long-term option for the region. In the meantime, coal-fired generation, a technology with a high carbon footprint, is becoming a preferred option in several countries in the region.

Coal-fired generation is a cost-competitive option in countries with high-cost or scarce hydroelectric potential (Mexico, Central America, and the large Caribbean islands) or countries with indigenous coal reserves that do not have access to international markets (Brazil and Colombia). The generation cost of coal-fired plants for base load operation, using imported coal, is estimated to be in the range of 50 to 70 US$/MWh, and for coal-fired plants in Brazil and Colombia, between 45 and 50 US$/MWh (figure 6.5). The development of coal-fired generation raises environmental concerns and is of course a threat to the abatement of CO_2 emissions of electricity generation in some countries in the region—its emission factor in tons CO_2/MWh doubles the factor for a gas-fired CCGT. However, it is an option that cannot be ignored as long as it remains attractive financially. For example, the Dominican Republic is in the process of developing 1,200 MW in coal-fired generation by

BOX 6.3

Unintended Consequences of Combining Biofuel Mandates with Tax Credits

Since December 2007, the new mandate signed into law in the United Staes requires the use of at least 36 billion gallons of biofuels in 2022, a fivefold increase over the current Renewable Fuel Standard (RFS) levels in the recently passed Energy Independence and Security Act. By 2022, biofuels could represent more than 20 percent of U.S. automobile fuel consumption. At the same time, the new legislation calls for the continuation of the federal biofuel tax credit of US$0.51 per gallon which, when combined with state tax credits, will potentially cost taxpayers over US$26 billion by 2022.

An economic model developed by de Gorter, Just, and Kliauga (2008) shows the effect of tax credits compared to biofuel mandates on gasoline and biofuel production and consumption and gasoline and ethanol prices, and the combined effect of tax credits implemented simultaneously with consumption mandates. As this model demonstrates, any beneficial effects on energy security and the environment of the new RFS may be completely offset by the tax credit that is in place.

The key difference between tax credits and mandates is the way they affect fuel consumption, mileage, gasoline, and ethanol prices and who the captures the subsidy. Tax credits by themselves encourage ethanol production as a replacement for oil-based gasoline consumption. Compared to tax credits that achieve the same level of ethanol consumption, a mandate results in higher fuel prices and lower fuel consumption (although a mandate can generate an increase in fuel consumption). This means a mandate is preferred to a tax credit when there is a suboptimal gasoline tax, like in the United States. A mandate also saves taxpayer costs and does not incur the deadweight costs of taxation. Mandates are more efficient than tax credits for the same level of ethanol production because mandates result in relatively higher gasoline prices and lower CO_2 emissions and miles traveled. Gasoline producers always lose from a mandate, ethanol producers gain, while fuel consumers can gain or lose.

A further disadvantage of tax credits compared to mandates is the additional instability that tax credits bring to the corn markets and therefore the agricultural and food markets in general. Tax credits create an incentive to drastically change ethanol production in response to a large fluctuation in oil prices. In addition, de Gorter, Just, and Kliauga (2008) show that trade restrictions through an import tariff in the United States have a smaller negative impact on world ethanol prices with a mandate compared to a tax credit.

Combining mandates with tax credits leads to a perverse outcome, unexpected by policy makers. With binding mandates in place, the tax credits will unintentionally subsidize gasoline consumption. This contradicts the energy bill's stated objectives of reducing dependency on oil, improving the environment, and enhancing rural prosperity. Because of the unique way in which mandates reverse the market effects of a tax credit, the intentions of policy makers cannot necessarily be faulted. Furthermore, combining mandates with tax credits is a worldwide error of judgment as most countries use both instruments simultaneously. The policy implication is clear: allow the mandate to work by itself, eliminate the tax credit, and save billions to taxpayers.

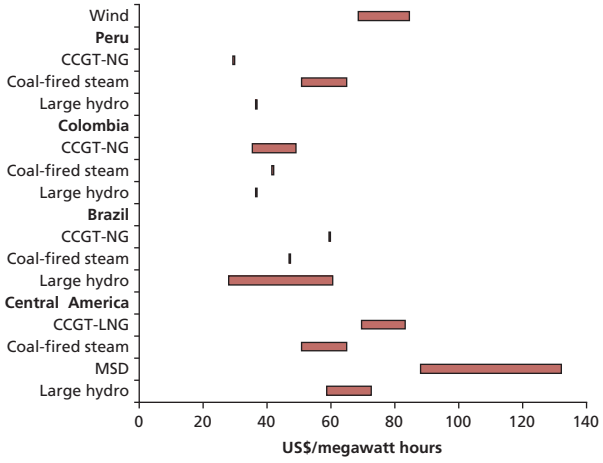
Source: Adapted from De Gorter, Just, and Kliauga (2008).

2013 (for a projected peak load demand of about 3,000 MW), because of high oil and LNG prices. By comparison, large hydro can be developed at a lower cost than coal (as in Brazil, Colombia, and Peru) and sometimes also lower than gas (as in Brazil, Colombia, and Central America) as long as the environmental and social costs that impede hydropower development can be minimized.

The expansion of coal-fired generation in the LCR raises environmental concerns, not only in the increase in CO_2 emissions and the raising of the carbon intensity, but also for local environmental concerns—water, land, and air pollution due to the transport, processing, and burning of coal. As noted above, coal is currently a bargain compared to oil-fired generation, and in some cases is competitive compared to hydro and natural gas. However, least-cost generation expansion plans usually do not take into account the externality cost of CO_2 (nor adequately account for the cost of local pollutants such as PM, SO_2 or NO_x), estimated in the range

FIGURE 6.5

Generation Costs of Hydro Are Often Lower than for Gas and Coal-Based Power



Source: Dussan (2008).
Note: CCGT-NG = combined cycle gas turbine from natural gas; CCGT-LNG = CCGT from liquefied natural gas; and MSD = medium-speed diesel. The levelized generation costs were calculated based on typical investment and operation costs for generation expansion planning in the region, and based on two fuel price scenarios (assuming an oil price of 60 US$/bbl and a high price case of 100 US$/bbl). Imported coal and LNG prices are consistent with the two oil price scenarios. Coal and natural gas prices in local markets are the prices used in generation expansion plans in producer countries.

of 16 to 105 US$/ton CO_2.[20] As an alternative to the evaluation of social carbon costs, one can calculate the "switching cost," the price paid for carbon that will make a developer indifferent between developing a high-carbon and the next best lower-carbon alternative. Thus, "switching costs" are a benchmark for assessing competitiveness of low-carbon alternatives with fossil fuels.

Table 6.6 shows the results of a simplified analysis of switching prices for some selected countries in the region. For example, the table shows that in Central America, at a price of carbon of US$8.8/ton CO_2, it would be possible to switch from a coal to a hydro plant, but the cost would rise to US$38.2/ton CO_2 to switch to a combined cycle natural gas turbine. Likewise, hydro is already the preferred alternative to coal in Brazil, Colombia, and Peru assuming a medium value of levelized costs for hydro. The large range in switching prices for some power sources is due to the large range in estimated levelized costs (figure 6.5).

TABLE 6.6

Switching Costs from More to Less Carbon Intensive Energy Sources (US$/MWh)

	Central America	Brazil	Colombia	Peru
Coal to large hydro	8.6 to 8.8	0 to 15.3	0	0
Gas to large hydro	0	0 to 2.9	0 to 2.3	17.5
Coal to gas	37.2 to 38.2	25.5	0 to 15.3	0

Source: Dussan (2008).
Note: Calculations assume carbon intensity of 896 tCO_2/GWh for coal-based generation, 404 tCO_2/GWh for gas, and zero for hydro. The ranges are for the medium (the first number in the range of switching costs) and high levels (the second number in the range) of generation costs that correspond to the costs shown in figure 6.5.

However, these results underestimate the difficulties and implicit costs that many countries face when developing hydroelectricity. In terms of the analysis, a delay of one year in the commissioning of a hydro project in Central America will increase the switching costs from coal to hydro by about 6.5 US$/ton CO_2. At a price of US$100/barrel of oil and a cost of CO_2 of US$20/ton, the rate of return for the Jepirachi wind power project in Colombia increases from 9.6 percent to more than 11.1 percent (ESMAP 2008 forthcoming).

Tapping the Potential of Energy Efficiency—One of the Most Promising Options

By any measure, there is substantial untapped energy efficiency potential worldwide and in Latin America that could reduce greenhouse gas emissions at low cost. Globally, more than half of the energy related potential to abate GHG emissions within the next 20–40 years is attainable through improvements in energy efficiency.[21] Countries in the LCR could reduce energy consumption by 10 percent over the next decade by investing in energy efficiency at a cost that is US$37 billion less than the cost of investing in new electricity generation capacity.[22] Improving energy efficiency has important benefits beyond climate change mitigation: lowering energy demand, delaying the need to install new generation capacity, raising competitiveness, and reducing consumption of fossil fuels along with a reduction in air pollution. Energy efficiency is

particularly important for countries facing energy supply constraints.

An array of energy efficiency measures can be undertaken in a wide range of sectors (table 6.7). Some measures are best associated with new construction (such as building design), while others can be effectively retrofit with existing equipment or structures (new boilers or windows). With many measures in the building sector, the additional cost of incorporating efficiency measures at the planning stage is typically a fraction of the cost of retrofitting it later (Dernbach 2008).

So if energy efficiency has such a large potential and has large financial and economic benefits irrespective of its greenhouse gas benefits, why has there been a slow uptake of energy efficiency investments? The core problem in many countries, both developing and industrial, is the perceived high risk associated with energy efficiency projects, high transaction costs associated with many small but replicable investments, and difficulties in structuring workable contracts for preparing, financing, and implementing energy efficiency investments.

Efficiency vs. conservation

Energy efficiency measures are typically defined as technological switches that provide the same output with less energy, such as replacing an old inefficient boiler with a more efficient one or an incandescent light bulb with a compact fluorescent. In Mexico, an energy savings trust fund (FIDE) has helped finance energy efficiency investments over the past decade. Energy conservation can be defined as changes in behavior whereby consumers use less energy without changes in technology or the capital stock. An example of an effective energy conservation program was Brazil's response to the electricity supply crisis in 2001 (box 6.4). Both efficiency and conservation can be driven by market forces and government policies, with the latter of particular importance given a variety of market failures and externalities that inhibit the "market" for efficiency and conservation.

Prices drive the incentives for efficiency improvements

Energy prices—such as electricity tariffs or gasoline prices—can significantly affect the incentives that consumers have for undertaking energy efficiency or conservation measures. Recent surges in petroleum prices have made it more attractive for companies to implement energy efficiency investments and to look for alternative fuels where possible. Over the past decade, average real electricity tariffs in Brazil have increased significantly, providing additional incentives for improving efficiency (figure 6.6).

However, some consumers remain insulated from higher energy prices, such as electricity consumers

TABLE 6.7

Energy Efficiency Opportunities and Measures in Key Consuming Sectors

Sector	Energy efficiency improvement opportunities
Buildings	Integrated building design and measures such as better insulation, advanced windows, energy efficient lighting, space conditioning, water heating, and refrigeration technologies
Industry	Industrial processes, cogeneration, waste heat recovery, preheating, efficient drives (motor, pump, compressors)
Cities and municipalities	District heating systems, combined heat and power, efficient street lighting, efficient water supply, pumping, and sewage removal systems
Agriculture	Efficient irrigation pumping and efficient water use, such as drip irrigation
Power Supply	New thermal power plants: combined cycle, supercritical boilers, integrated gasification combined cycle, and so forth. Existing generation facilities: refurbishment and repowering (including hydro), improved operation and maintenance practices, and better resource utilization (higher plant load factors and availability). Reduced transmission and distribution losses: high voltage lines, better insulated conductors, capacitors, efficient and low-loss transformers, and improved metering systems and instrumentation
Transport	Efficient gasoline/diesel engines, urban mass transport systems, modal shifts to inter- and intracity rail and water transport, improved fleet usage, compressed natural gas vehicles
Households	Lighting, appliance efficiency, improved cook stoves

Source: World Bank staff.

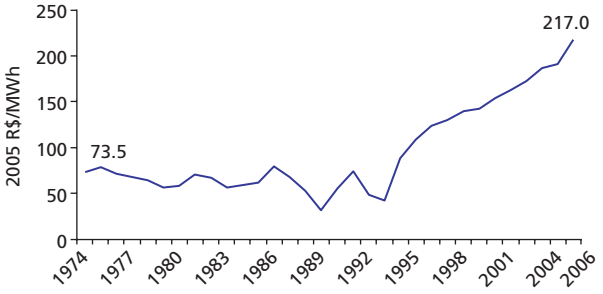
BOX 6.4

Conserving Electricity in Brazil

In 2001, Brazil experienced a severe power supply shortage as a result of a prolonged drought that reduced the supply of hydropower (which accounted for nearly 90 percent of total installed capacity) and due to the underinvestment in new generating capacity. In response, the government instituted an aggressive energy rationing system that consisted of monthly energy consumption targets for almost all consumers and a set of rules for trading quotas among users, setting bonuses for overachievers, and penalties for violators. As a result of the program, from June to December 2001 there was a 20 percent reduction in electricity demand compared with the previous year's consumption level. The quota system effectively minimized the damage of the crisis by not resorting to blackouts. There is also evidence that some of the energy efficiency measures adopted by consumers became permanent—nearly three quarters of the consumers who replaced incandescent bulbs with compact florescent lamps (CFL) during the crisis continued using CFLs thereafter according to the market survey by the Brazil National Electricity Conservation Program. Among the lessons from Brazil's rationing program is that there is significant "slack" in electricity consumption that can be reduced through a system of rewards and penalties and without resorting to forced blackouts or sacrificing basic needs provided by electricity.

FIGURE 6.6

Average Electricity Tariff in Brazil, 1974–2006



Source: IPEA (Institute of Applied Economic Research, Government of Brazil), ELETROBRÁS, adjusted to inflation rates by IPC-FIPE in Johnson et al. (2008).

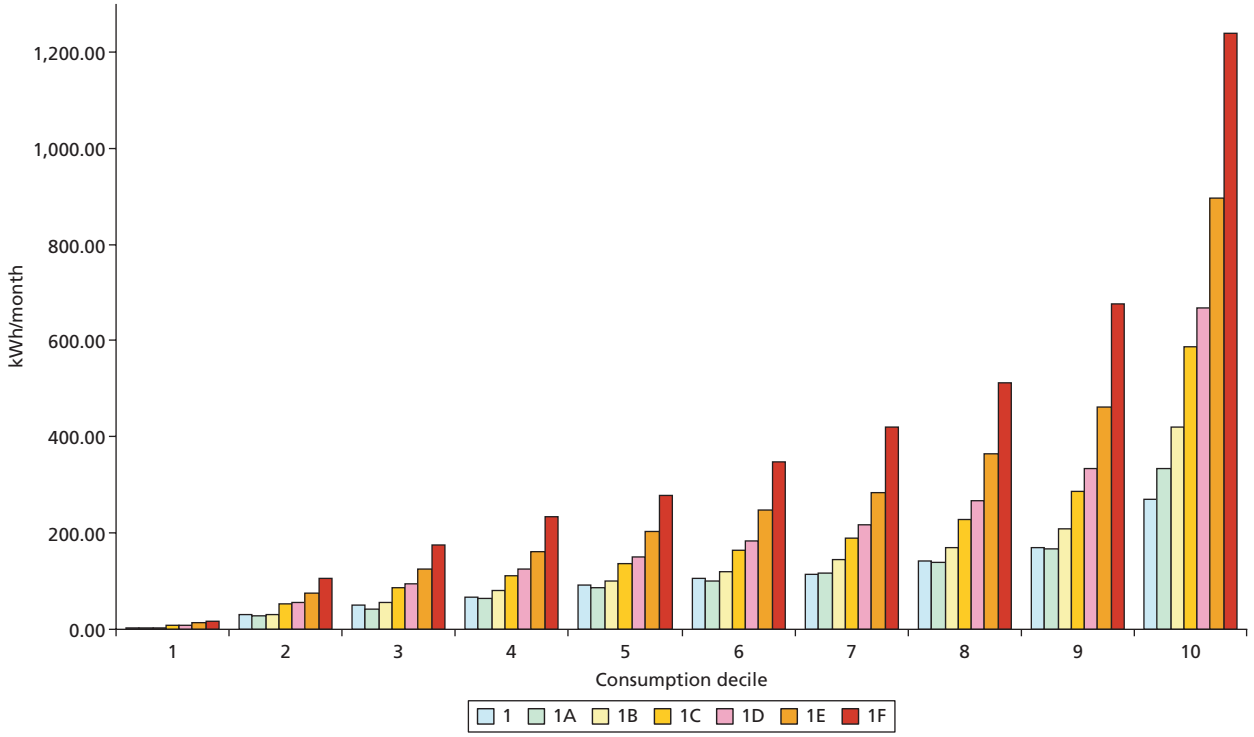
who enjoy subsidized tariffs or gasoline prices that are controlled at below-market levels. In República Bolivariana de Venezuela, prices of gasoline remain highly subsidized, leading both to high demand and giving rise to smuggling between neighboring countries such as Colombia with much higher gasoline prices. In Mexico average residential electricity tariffs cover only about 40 percent of the cost of supply, with less than two percent of customers paying tariffs above the marginal cost of supply. As a result, electricity consumption (and the consequent subsidy share) among residential consumers in Mexico is significantly higher for those people in the most highly subsidized tariff categories (categories 1E and 1F) and among higher income groups (figure 6.7). While raising residential electricity tariffs can be an effective mitigation measure from the climate change perspective, tariff reforms are difficult to implement because of the affordability concerns and their sensitivity on the political agenda.

Supply-side efficiency improvements may be the most palatable way to improve efficiency

Improving energy efficiency is probably the most economic and effective way to mitigate CO_2 emissions from power generation. The menu of measures includes the repowering of existing generation plants to produce more electricity using the same amount of primary energy, reducing electricity losses, developing cogeneration and distributed generation, and using high efficiency technologies for thermal generation. At high fossil fuel prices, improving the efficiency of thermal plants can produce strong financial returns for electric power generators. These efficiency improvements coupled with the increasing share of natural gas generation are the main determining factors of carbon intensity of electricity generation in the LCR. Reducing distribution losses is also good business for power companies and can reduce generation needs and CO_2 emissions.[23]

FIGURE 6.7

Mexico's Tariff Structure and Electricity Consumption



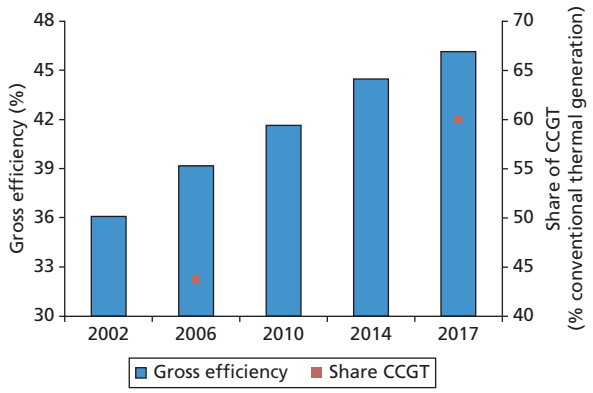
Source: Komives et al. (2009).
Note: Electricity subsidies were first introduced in Mexico in 1973 in response to persistent inflation, when the single electricity tariff was changed into a three-part, increasing block tariff, with subsidized rates for the first two blocks. The first "summer subsidy" (Tariff 1A) was introduced in 1974, providing additional subsidized rates to customers living in hotter areas (1A was defined as regions with more than four months of average temperatures above 25 degrees Celsius [°C]). Successive climate-based tariffs with increasingly subsidized rates over larger volumes were introduced in 1988 (Tariff 1B > 28 °C; 1C > 30 °C), 1990 (1D > 31 °C), 1995 (1E > 32 °C), and 2002 (1F > 33 °C). Today, Mexico has an extremely complex tariff system with over 112 different billing possibilities for residential consumers.

Mexico continues to reduce carbon intensity from a high level by replacing old and inefficient plants and expanding thermal generation from high-efficiency natural gas plants (combined-cycle gas turbines). The average thermal efficiency of conventional thermoelectric plants is expected to increase from 39 to more than 65 percent in 2006–17, consistent with an increase of the participation of CCGTs in that group from 43 percent to 60 percent (figure 6.8).

Energy efficiency programs in the LCR and elsewhere typically focus on the residential and commercial sector, often through the provider of electricity in what are known as utility demand-side management (DSM) programs. Such programs have the advantage of being able to target a large number of consumers, with utilities able to reach all of their customers, for example through education programs or concessional financing of energy-efficient equipment. The drawback of DSM programs is that electric utilities do not naturally have an incentive to reduce their sales of electricity, which is the ultimate goal of energy efficiency or energy conservation programs.[24] The most popular type of DSM program is where the utility promotes the purchase of more energy-efficient equipment—such as lighting and appliances—and provides the financing of such equipment with repayment through the consumers' electric bill. Mexico has had success with numerous DSM programs, including a new program that would promote energy efficient refrigerators and air conditioners through the national utility, CFE, and its energy saving trust fund, FIDE (box 6.5).

FIGURE 6.8

Mexico—Improvements in Thermal Generation Efficiency



Source: CFE (Comisión Federal de Electricidad) (2008b), *Programa de Obras e Inversiones del Sector Eléctrico 2008–2017*. Available at: tinyurl.com/poise2017.

BOX 6.5

Energy Efficiency in Mexico

The Private Trust Fund for Electricity Savings (Fideicomiso para el Ahorro de Energía Eléctrica, FIDE) was created in 1990 as a nonprofit institution with the purpose of investing in energy efficiency. As of 2007, FIDE had completed 25,917 energy audits, and concluded 3,899 electric energy saving projects, with direct electricity savings of 13,191 GWh and 1,566 MW in installed capacity (mostly by reducing the peak demand). These savings are equivalent to about 3 percent of total installed capacity and 7 percent of electricity consumption, or the same as the domestic consumption of five Mexican states: Nuevo Leon, Jalisco, Tamaulipas, México, and Aguascalientes. In terms of GHG emissions, these measures reduced approximately 8 million tCO_2, or 2 percent of CO_2 emissions (not including land-use change).

Source: Authors.

Public sector energy efficiency—another very promising area

The energy savings potential in the public sector is large and typically cost effective but often suffers more than other sectors from a lack of incentives to undertake energy efficiency measures. Energy savings in the public sector—including all levels of government and all public services and infrastructure, such as water and sanitation, public street lighting, public transit, and vehicle fleets—can exceed 20 percent of energy use; rates of return for energy efficiency investments typically range from 20 to 30 percent. The public sector typically constitutes between 10 and 20 percent of the national economic product, and is often the largest buyer of energy-using equipment.[25]

One of the promising public sector areas for energy efficiency improvement is the water supply and sanitation (WS&S) sector. Energy consumption (mainly electricity for pumping) is typically the largest variable cost item for a water utility after personnel. Energy efficiency can be improved directly through a number of technical and operational measures, such as improving the efficiency and sizing of pumps and other equipment, and reducing excessive water pressure in the distribution system. Utilities can often save considerable money simply by moving pumping operations to off-peak times. In addition, energy as well as all inputs can be reduced by the reduction of physical water losses—every liter of water, whether it reaches the final consumer or not, requires significant amounts of inputs, including the energy used for extraction, treatment, and distribution. A survey of some of the largest and better-performing WS&S utilities in Brazil found that the majority of these utilities had non-revenue water[26] ranging from 35 to 40 percent.

Despite the substantial benefits of public sector energy efficiency programs, many governments have been reluctant to undertake such programs due to several types of barriers, including: (1) public procurement rules and annual budget cycles that make the implementation of energy efficiency programs difficult; (2) the lack of incentives and information for the public sector endusers; and (3) tight budgets and limits on debt. For example, a public hospital or school may receive a budgetary allocation for its energy expenditures from a municipal or state budget and has little or even a negative incentive to reduce its energy consumption.[27] The municipality or state agency, in turn, may not be in a position to know or be able to identify the opportunities for energy efficiency and as such does not allocate the necessary capital budget.

One way of promoting energy efficiency investments in the WS&S sector is through the use of

energy performance contracts (EPC) where a private sector company carries out an energy efficiency investment, typically providing financing, guaranteeing the performance of the investment (that is, the savings) and is remunerated based on its performance. The performance guarantee reduces the risk for the host enterprise, in this case a water utility, while also overcoming financing barriers. In 2007, the water utility serving São Paulo in Brazil, SABESP, signed an EPC contract with a private firm, the first such contract in the water sector in Brazil. Under the contract, a Brazilian energy service company (ESCO) provided the entire financing (US$4 million) to improve the efficiency of a wastewater treatment plant, which has a simple payback period of 3.7 years.

Transforming Transport

Global emissions from the transport sector are expected to rise from about one-third to one-half of total emissions from energy use. Historically, the dominance of emissions by the transport sector has been more characteristic of industrial countries than developing countries, but in the LCR, the transportation sector has accounted for a large share of energy sector emissions for a number of years, reflecting the rapid growth of private vehicle fleets in many countries: Argentina, Brazil, Colombia, Mexico, and República Bolivariana de Venezuela. In Mexico—the second largest country in the region after Brazil in terms of the absolute level of transport sector emissions—car ownership is expected to increase at an annual rate of 5 percent from a fleet of 24 million in 2008 to 70 million vehicles in 2030.[28] In addition, traffic congestion in urban areas and a large share of highly polluting and inefficient vehicles on the road has meant that transport is also the leading cause of air pollution in Latin American cities. The rapidly rising emissions and large benefits from local environmental improvements mean that the transportation sector in the LCR offers significant potential for mitigation—especially when institutional barriers can be overcome—while at the same time delivering important auxiliary benefits.

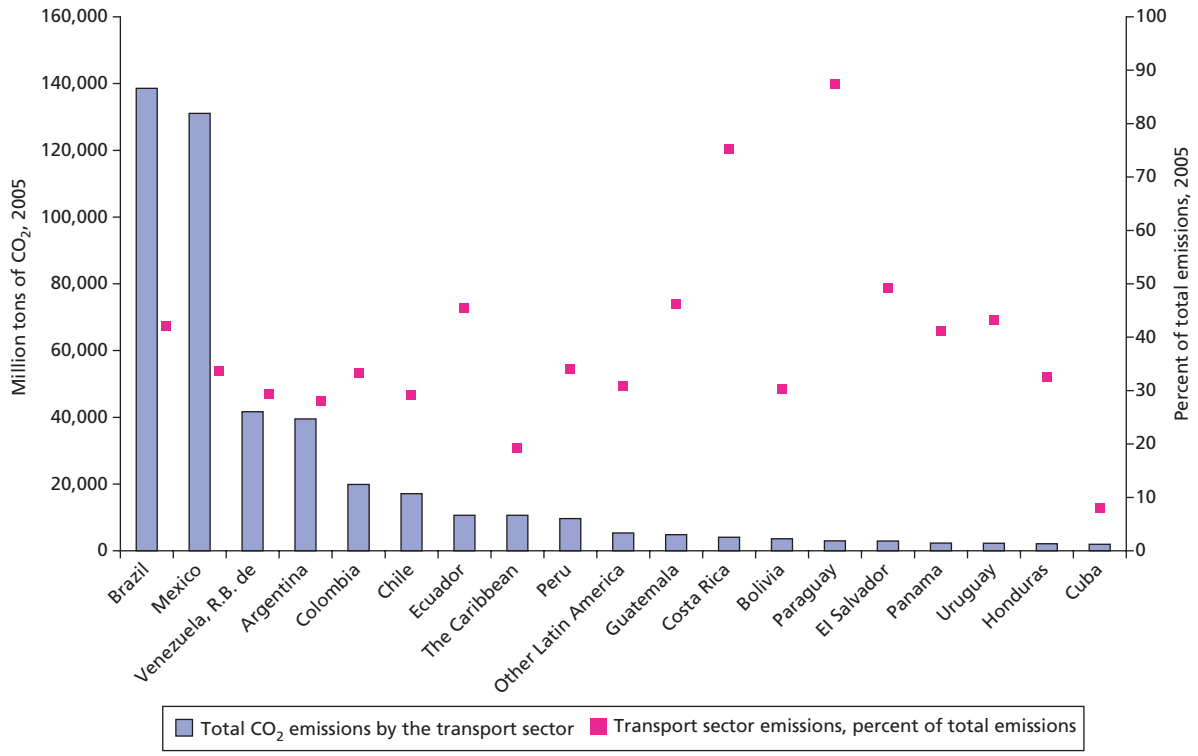
It is not surprising that the LCR has one of the highest motorization rates in the developing world, with a few large countries responsible for the bulk of the sector's emissions. With an average of about 90 vehicles per thousand people, the motorization rate in the LCR exceeds Africa, Asia, and the Middle East, but it is less than half of that in Eastern Europe and a fraction of the OECD countries' motorization rate of nearly 500 vehicles per thousand people.[29] In absolute terms, 2005 emissions from the transport sectors of Brazil and Mexico were much higher than elsewhere in the region (figure 6.9). More than 90 percent of these emissions and fuel consumption of the transport sector were from road transport, with the exception of slightly lower shares in Bolivia and Ecuador. A few countries contribute most of the emissions, but this does not imply that mitigation efforts in the sector need to focus only on those countries. Significant health benefits from improvements in air quality, time savings, and reduced congestion from some of the interventions may justify the implementation of a wide range of mitigation measures in the smaller countries as well.

Realizing the sector's mitigation potential and the complementary local benefits requires a thorough understanding of the factors behind the rising emissions trend: (1) the increasing number of vehicles, (2) the distance traveled by each type of vehicle, and (3) the emissions of each type of vehicle per kilometer traveled. The LCR's transport sector is fast growing in terms of GHG emissions because of the rapid economic growth and the associated rise in car ownership and use, a modal shift away from public transportation to private vehicles, and the rising length and number of trips per vehicle as cities sprawl. The corresponding strategies to reduce emissions fall within these three categories (figure 6.10).

A decomposition of emissions in a recent assessment of the transport sector in the region from 1980–2005 shows that income growth has been the leading cause of rising emissions in the sector in some countries or regions (Argentina, Brazil, Costa Rica, Peru, and Uruguay). The rising energy intensity of the transport sector—possibly as a result of low energy efficiency and rising congestion—has been the dominant factor in the others (Bolivia, Caribbean, Cuba, Ecuador, Guatemala, Honduras, Panama, Paraguay) during most years in the study period; and in the remaining countries (Chile,

FIGURE 6.9

Transport Sector Emissions in Latin America and the Caribbean Region



Source: IEA (2007) as reported in Timilsina and Shrestha (2008).

FIGURE 6.10

Emission Levels Can Be Determined by Three Variables

Emissions	=	Number of vehicles traveling	X	Distance traveled	X	Emissions of each type of vehicle per km traveled
		– Modal shift – Increase load factor – Congestion pricing – Economic incentives		– Zoning practices – Density of housing – Mixed land use – Transport corridor densification		– Fuel type – Vehicle technology – Weight of vehicle – Maintenance – Driver behavior – Congestion – Mobility management – Operational design

Source: Authors.

Colombia, El Salvador, Mexico, Nicaragua, and República Bolivariana de Venezuela) both factors have been important.[30] The main challenge in terms of reducing GHG emissions from the transport sector is to decouple emissions from rising incomes, despite higher rates of vehicle ownership that has accompanied income growth in the region.

With the current growth in vehicle ownership and use, especially in urban areas, there is a pressing need to address issues related to emissions from private vehicles. The focus of an emission reduction strategy should be vehicle usage and not ownership. However, ownership and emission levels are in fact closely correlated for several reasons. First, approximately one-third

of a vehicle's lifetime emissions stem from the upstream manufacturing process of the vehicle. Second, once a vehicle is purchased, the convenience of use induces additional travel (Gilbert 2000). Third, in the developing world, many vehicles purchased are highly polluting, secondhand vehicles.

The energy efficiency of transport vehicles is likely to improve, but these improvements are expected to be more than offset by a combination of increases in the number of vehicles and in average vehicle utilization. While ethanol in Brazil has replaced about fifty percent of gasoline consumption by the light-duty vehicle fleet, the rest of the transport sector in the LCR will continue to depend overwhelmingly on petroleum-based fuels for the foreseeable future. As such, changes in the carbon intensity of transport fuels are seen to have a minor impact on transport-related GHG emissions, and what will be more important are the efficiency of transport fleets and the share of different transport modes.

A growing middle class has helped spur the demand for private vehicles. A study in 2005 of low-income families in four former *favelas* in São Paulo found that 29 percent of families owned a car.[31] Over the years, efficiency improvements and competition have led to a slow decline in vehicle prices with vehicles becoming more accessible to larger groups of people. There is an increased competition from inexpensive vehicles from Asia and the secondhand vehicle market is also growing. Vehicle sales in Latin America are breaking records and are expected to continue to post solid gains, buoyed by economic growth. Brazil and Mexico are the largest auto markets in Latin America, but Peru is the region's fastest-growing market. During the first three quarters of 2006, vehicle sales in Peru soared by 41 percent. The latest trends worldwide have vehicle manufacturers developing sturdy and inexpensive vehicles, specifically and successfully advertised to the middle and lower-middle-income classes. For example, in São Paulo the fleet is growing at a rate of 7.5 percent per year, with almost 1,000 new cars bought in the city every day, and this has accelerated motorization rates in already congested cities and caused a rapid deterioration of the existing transport systems and infrastructure. The result is deteriorating air quality, numerous traffic deaths and injuries, millions of hours of lost productivity, and increased fuel consumption and consequently rising GHG emissions. According to *Time* magazine, São Paulo has the world's worst traffic jams.[32] In 2008, the accumulated congestion reached an average of more than 190 kilometers during rush hour, and on May 9, 2008, the all-time record was set at 266 kilometers, which meant that 30 percent of the monitored roads were congested.

In the LCR, there has been a steady trend of people switching to more polluting and less efficient vehicles. As income and car and motorbike ownership have increased, people have preferred the use of these vehicles over the public and mass transport systems, both of which have much lower pollution levels per kilometer per passenger. Although walking is still important, especially for the poor, the infrastructure investments and spatial growth of cities have favored motorized mobility and inhibited the access by foot to health care, jobs, education, and other services. The recent rapid increase of motorbike ownership in many cities is particularly worrisome, as it often occurs at the expense of public transport users and further affects the efficiency of the overall transport systems. Increased traffic jams and motorization further deteriorate the attractiveness and competitiveness of public transportation competing with the same road space as private vehicles. This creates a vicious circle of declining public transport quality and use and growing motorized travel.

Urban sprawl in Latin American cities is probably the fundamental factor behind the rapid growth of vehicle emissions. As cities sprawl, the length and number of trips rises. Latin American cities are sprawling and as new transport infrastructure is being developed, origins and destinations are further apart from each other. Like many cities around the world, the large urban centers in Latin America present acute challenges in terms of arranging economic activities across space. Most new development occurs at the periphery of large cities and at relatively low densities. These are the areas where the land is cheapest; however, these are also the areas where service provision, including transportation, will be most expensive. At the same time, the main cities continue to be magnets for people and jobs, forcing commuters to travel longer

distances. Public transport services, however good in frequency and coverage, are not competitive in sprawling suburban areas and only attracts residents that have no other choice. Congestion is aggravated by the fact that the different modes often compete for the use of the same road space.

Finally, a large number of highly polluting and old vehicles are still driven in cities. While the transport fleet, both public and private, is quickly growing and new technologies are being introduced, the vehicle fleet in use is steadily growing and deteriorating. Although better technologies exist and are being purchased, the highly polluting in-use and secondhand vehicles are not scrapped and continue to be widely used in Latin America. These vehicles disproportionately contribute to high air pollution levels and climate change and governments often lack effective instruments and policies to restrict or ban their use. Furthermore, due to frequent breakdowns, these vehicles affect the traffic flows and contribute to congestion in cities.

GHG emission mitigation in the transport sector—low hanging fruit and no regrets

In order to deliver the highest environmental, social, and economic benefits, transportation policies need to integrate issues like transit oriented land-use planning, private vehicle mobility management, improvements in mass transportation and integration with nonmotorized modes of transport, freight transportation, and related infrastructure development planning. Transparent assessments of needs, benefits, and realistic options can ensure truly sustainable transportation policies.

Such an integrated approach has been adopted in Mexico's recent assessment of the mitigation potential and marginal abatement costs through interventions that affect the transport sector's emissions.[33] Mitigation strategies span spatial and sectoral boundaries and include a series of options that fall under the broader categories of land-use planning—so as to address the issues of longer travel times associated with urban sprawl; fuels and technology; public, nonmotorized, and cargo transport; and transport demand management.

Among the policies that are beneficial for transport management and which provide large GHG emission reductions are developing high quality and integrated public transport systems, nonmotorized transportation, urban and spatial planning to reduce transport demand, improving the efficiency of both new and used vehicles through standards and inspection and maintenance programs, and freight management. Such measures can be effective climate change mitigation measures, especially when they are designed as part of an integrated strategy.

Development of High Quality Mass Transportation Systems. LCR cities still have relatively high public transport ridership, but public transport shares are gradually decreasing. Therefore, there is an urgent need to prioritize the development of high quality public transportation systems. Ensuring local government investments to support projects that seamlessly integrate motorized and nonmotorized transportation infrastructure is the first and most critical step. At the same time, it is necessary to integrate and optimize the many components of public transportation systems through a series of measures, such as improved organization and management practices, setting reasonable fares, preferential traffic flow for public transport, improved safety, outreach incentives, and training for system operators and planners. Curitiba and Bogota popularized the "bus rapid transit" system that mimics the efficiency of metro systems through dedicated bus lanes along key transport corridors but at a fraction of the cost of rail systems. Today, dozens of cities in the LCR and worldwide have established similar systems based on the successful experiences of Curitiba and Bogota.

Establishment of Integrated Transportation and Land Use Planning Systems. Cities can implement policies and incentives to mix land uses and increase density along major transport corridors so as to help the accessibility to mass transport systems or reduce the need to travel altogether. In the 1970s Curitiba Brazil established an integrated land-use and urban planning system that gave priority to public transportation and the location of industry, schools, and residences in close proximity to convenient transport. The popularity of Curitiba's Bus Rapid Transit (BRT) system has attracted motorists, despite a high rate of automobile ownership relative to the rest of Brazil. A 1991 travel survey reported that about 28 percent of "direct bus" users previously

traveled by automobile. BRT service resulted in 27 million fewer automobile trips each year and about 27 million fewer liters of fuel annually. Curitiba uses about 30 percent less fuel per capita because of its heavy transit usage, and its ambient air pollution is one of the lowest in Brazil. In the 1990s, Colombia passed national legislation that is considered a model for rational land-use in high-density urban areas, with public transportation being a central pillar of the legislation (box 6.6). These policies can ensure a reduction in emissions of both conventional pollutants and greenhouse gases by placing transportation considerations at the center of development. By considering transportation needs and challenges as an integral part of land use planning, cities can avoid unchecked sprawl, decrease the need for travel in personal vehicles, and allow for low-cost, high-volume alternative transportation options.

Enhancement of Nonmotorized Transportation. Walking is still the prevalent mode of transport in many Latin American cities and, surely, the one that the poor have access to. Latin American cities could significantly benefit from better and expanded nonmotorized transportation infrastructure. Establishing measures designed to encourage walking and cycling, as well as improving intermodal integration with high capacity transport systems can have an important benefit in terms of quality of life and reduction of emissions. A number of cities have promoted bicycles as an alternative to motorized transportation, including Bogota, Rio de Janeiro, and Santiago, both for short trips and as commuter vehicles and through "park-and-ride" arrangements linking to public transportation. Many other cities in Latin America are starting to follow these examples and promoting bicycle use.

Control of Private Vehicles. None of the above policies will be truly effective in reducing GHG emissions without some measures to reduce or restrict private vehicle use in highly congested urban areas. As a complement to improving the public transport systems, Latin American cities need to design policies to better manage private vehicle mobility. Systems that impose one or more of the following measures have been successfully implemented in other parts of the world. Some of these measures include the implementation of Intelligent Transport Systems technologies to redirect traffic, control roadway congestion and provide information to drivers, and help plan and manage urban transport systems;[34] implement varied parking rates; create incentives for intermodal integration between private vehicles and public transport stations in the suburbs and increase occupancy rates of vehicles; and better regulation of motorcycle mobility in cities.

BOX 6.6

Examples of Transport and Land-Use Planning in Bogotá, Colombia

In 2000 and 2005 the Transmilenio Company conducted censuses of urban activity along the corridors of Phase I: Caracas Avenue, Autonorte, and 80th Street. Every property along the corridors was surveyed thus diminishing statistical error. The main findings regarding the impacts on land use are the following:

First, the census showed that in 2000, 96 percent of the buildings had five stories or less. By 2005 this number had dropped by 91.2 percent. Consequently, the share of buildings with more than five stories more than doubled in five years, suggesting a considerable densification of the corridor. Part of the reason for the increasing density relates to the higher rental rates along the corridor. In essence, as urban rents increase, more units per unit area are needed in order to cover the higher value of land, thus increasing density. Second, the number of housing units along phase I increased by 12 percent in the five years between the two censuses. Third, and related, people who live in the corridors of phase I chose to stay longer in their housing units. In 2000, 48 percent of residents had lived six years or longer in their housing units and by 2005 this number had increased to 52 percent. Again, because it was a census, the results are significant. Fourth, more people own their housing unit along the corridors (46 percent in 2000 and 52 percent in 2005), showing higher willingness to invest in properties along phase I. These results are partially explained by increased accessibility and also a higher perception of security.

Freight Transport Management includes strategies to increase the efficiency of freight and commercial transport. Better logistics is a way to develop more efficient freight management, including transportation practices (for example, vehicle type, shipment size, frequency, and so on), facility siting, and related activities. Although logistics is focused on increasing efficiency and minimizing transportation costs, it can also help in reducing congestion and pollution impacts. An important measure is to encourage rail and water transport rather than truck for longer-distance shipping. Trucking uses much more energy per unit of transport than rail or water (10 times as much in many situations), although only certain types of goods and deliveries are suitable for such shifting. To accomplish this, there is a structural need to improve rail and marine transportation infrastructure and services to make these modes more competitive with trucking. There is also a need to organize regional delivery systems, especially in metropolitan regions, so fewer vehicle trips are needed to distribute goods (for example, using common carriers that consolidate loads, rather than company fleets) and use smaller vehicles and human powered transport, particularly for distribution in urban areas. Improved maintenance and operation as well as training to encourage more efficient driving also have proven to be very cost-effective in reducing fuel consumption and GHG emissions. Truck design improvements and new technologies can also help increase efficiency. Simple and cost-effective measures that are already being implemented in a number of cities are limiting freight transport and avoiding delivery during traffic peak hours in cities.

The complexity of transport systems requires taking into consideration a range of criteria, such as increasing volume of passenger and vehicle flows, travel time, accessibility, safety, environmental, and equity impacts. Where many of the easy choices have already been made, increasingly intricate transport decisions aim to achieve an optimal balance between sometimes conflicting interests. While transport cost and energy consumption have always been important objectives, climate change is becoming increasingly important. The inclusion of climate change offers a significant opportunity to revisit the relationships between alternative objectives to better understand synergies and trade-offs.

Transportation initiatives have many co-benefits. Reductions in emissions result in GHG decreases but also in improvement of the local air environment, with important health benefits. Promotion of mass transit systems and nonmotorized transport, while lowering emissions, also contribute to poverty alleviation through providing improved mobility and access for poorer segments of society. Reduction in fuel usage and improvement in the efficiency of transport systems, while contributing to decreases in emissions, also represents improvements in the operation of transportation networks. Improving the flow of traffic to combat congestion, while resulting in lower emissions from idling vehicles, also reduces accident rates.

Thus, many mitigation measures in the transport sector are no-regrets options, which can be implemented not only at a low cost but result in large savings even before considering the co-benefits. But institutional and regulatory obstacles as well as collective action problems affect the feasibility of their implementation. A comprehensive approach extending beyond the transport sector itself is the cornerstone of a long-term vision to effectively address the three drivers of emissions—the number of vehicles, distance traveled, and vehicle emissions rate—and benefit from the sizable positive externalities (box 6.7).

Quantification of these co-benefits and an assessment of the feasibility of implementation is an important component of an overall evaluation of alternative—and sometimes complementary—mitigation options. Apart from the Mexico: Estudio sobre la Disminucion de Emisiones de Carbono (MEDEC) (Low-Carbon Study) study, a series of other studies assessing the mitigation potential and costs (or benefits) associated with the mitigation measures in different sectors have recently been completed by the local universities and research centers for Argentina, Brazil, Chile, Colombia, and Peru; and other efforts have previously been implemented as part of some of the national climate change mitigation strategies in the region.[35] The availability of cross-country information on the potential to reduce emissions in the transport sector is an important contribution to facilitate the setting of priorities in sectoral mitigation

BOX 6.7

Cost-Benefit Analysis of Mitigation Measures in Mexico's Transport Sector

An analysis of transport mitigation options in Mexico demonstrates that there are numerous co-benefits of transport options, including financial, time savings, and local environmental improvement. Among the options that may provide the largest GHG reductions in Mexico are vehicle inspection and maintenance programs, optimized transport planning, vehicle efficiency standards, and densification policies. The economic benefits resulting from these interventions include the financial benefits compared to alternative means of transportation, time savings to individuals, for instance by reducing congestion, and the local health benefits due to decreased local air pollution emissions (accruing to both commuters and to local inhabitants)—which leads to negative costs for reducing GHG emissions for many of the interventions evaluated. As is typical of such studies, other important costs that are difficult to estimate are not quantified, such as the costs of implementing monitoring systems, overcoming information failures, or policy or regulatory changes, however, these costs were assessed by transport experts qualitatively and were viewed to be "surmountable."

Some types of interventions are expected to have very large estimated co-benefits in Mexico. By reducing the distance of urban commuting, a program to encourage dense urban development would not only cause emission reductions of up to 117 $MtCO_2$, but also a cumulative reduction of particulate matter (PM 2.5) by 11,800 tons and nitrous oxides by 855,000 tons over the 2009–30 period. Implementing efficiency standards would result in a cumulative reduction of 195 $MtCO_2$ and a significant reduction in the emission of pollutants on the order of 8,000 tons of PM 2.5 and 1,134,000 tons of nitrous oxides. Transport options with high mitigation potential in Mexico—promotion of urban public transportation—would not only result in very significant reduction in air pollution. They would also bring about time savings and other social benefits, as long as these measures are well integrated into an overall strategy that ensures efficient connection between different transport modes and sufficient urban density that would make these options viable.

Source: Center for Sustainable Transport (2009), background report prepared for the World Bank MEDEC low-carbon study.

policies, but estimates from the available studies are not directly comparable because of divergent and sometimes unclear assumptions. In the transport sector, these assessments need to evaluate the mitigation potential and the benefits from energy savings, reduction in local air pollution, and time savings using consistent methodologies to ensure comparability across countries. Because of its public good, provision of this type of information in developing countries needs to be harmonized at the global or at least the regional level.

Waste Management—Significant Local Benefits of Mitigation Options

Globally, GHG emissions from solid waste and wastewater contribute only about 3 percent of the total emissions but they constitute as much as 18 percent of the anthropogenic methane emissions. Even though emissions from waste and wastewater also are relatively low in the LCR, they are projected to increase in tandem with the rising population and the level of economic activity. Waste generation tends to increase in proportion with GDP per capita—as much as 3 percent per year in periods of sustained economic growth.[36]

Throughout the LCR, solid waste management is an important priority, primarily because of the local health and environmental benefits, but obtaining sustainable finances and full public cooperation is a challenge. Municipal waste collection is generally acceptable, particularly in larger cities in the region. On average, cities of more than 500,000 inhabitants collect more than 80 percent, while technical and financial difficulties result in a lower collection rate of about 69 percent in smaller cities. Waste disposal in the LCR is generally deficient. Only 23 percent of the waste collected is disposed of in sanitary landfills, another 24 percent goes to controlled landfills,

with the remainder ending up in open dumps or bodies of water. Overall, 62 percent of the waste generated in the LCR is burned or ends up in unknown disposal sites.[37]

Apart from proper waste disposal in sanitary or controlled landfills, recycling and composting help minimize the volumes of waste for disposal. Only about 2 percent of municipal waste is estimated to be formally recycled in the region, even though some countries or cities do so; Mexico and Chile report that about 10 percent of their urban waste stream is recycled.[38] In addition, an estimated 500,000 waste pickers in the LCR operate in the informal recycling sector.

In addition to the disamenities from a failure to collect and properly dispose of waste for aesthetic reasons, it has important health and environmental consequences. Inadequate waste collection and the resulting clandestine dumping of waste in cities increases the risk of flooding when waste blocks urban waterways and drainage channels; burning of waste on city streets or in open dumps emits carcinogenic dioxins and furans because of incomplete combustion and other contaminants; garbage dumps are a major source of leachates to surface and groundwater and they proliferate the spread of vector-borne diseases by insects, rodents, and birds. Solid waste disposal sites that do not have gas management systems accompanied by flaring or energy recovery are major sources of methane discharges, and leaking methane gas can explode in people's houses or in public areas.

Methane emissions from solid waste landfills are expected to increase in the LCR due to the growth of solid waste generation rates caused by the increase in population and economic activity, and the improvements in landfill operational practices that are expected to increase anaerobic conditions in landfills. Compost practices may contribute to a reduction in methane generation, but it is extremely difficult to predict the potential of composting practices in the short and medium term. Nevertheless, policies and financial incentives could accelerate the capture and flare or use of the methane in the short term, decreasing the net effect of the increase of methane emissions.

Financial and institutional obstacles impede faster progress toward improved collection and disposal of solid waste in the LCR. Sanitary landfills are a more expensive solution than open dumps because of the higher upfront investment and maintenance requirements. Sanitary landfills operate with a system of pipes that capture methane gas which is then flared, emitting carbon dioxide which does not pose the risk of explosion and is 19–20 times less potent than methane in terms of the global warming potential. To prevent free dispersion of methane into the atmosphere, waste needs to be periodically covered with a layer of soil.

But management of solid waste tends to be an unfunded public mandate in the realm of municipal governments, and it has been challenging to secure sustainable sources of financing in the sector despite the clear public good and positive externalities from proper waste collection and disposal. Furthermore, proper waste management in small cities often requires cooperation with other municipalities to achieve the necessary economies of scale for more advanced technical solutions. Social opposition to the placement of landfill sites and the failure of collective action by municipalities and stakeholders throughout the entire chain of waste management add further complexity. Integrated waste management strategies that sometimes cross municipality boundaries are the first important step toward ensuring the long-term objectives.

For example, a solid waste management strategy launched in 1993 in Belo Horizonte, Brazil, succeeded in establishing a fully functional waste management system in just four years. It included a technological component for differentiated collection, recycling, and disposal systems of different types of waste materials; construction of recycling plants; and a human resources development program. Other components of the strategy promoted citizen participation and modernization of the municipal waste management agency. In this sense, despite the low priority of solid waste management in the LCR as a GHG mitigation option because of the low even if growing contribution of the sector to total emissions, many interventions are the "low-hanging fruit" that would receive strong political support and result in very significant local benefits.

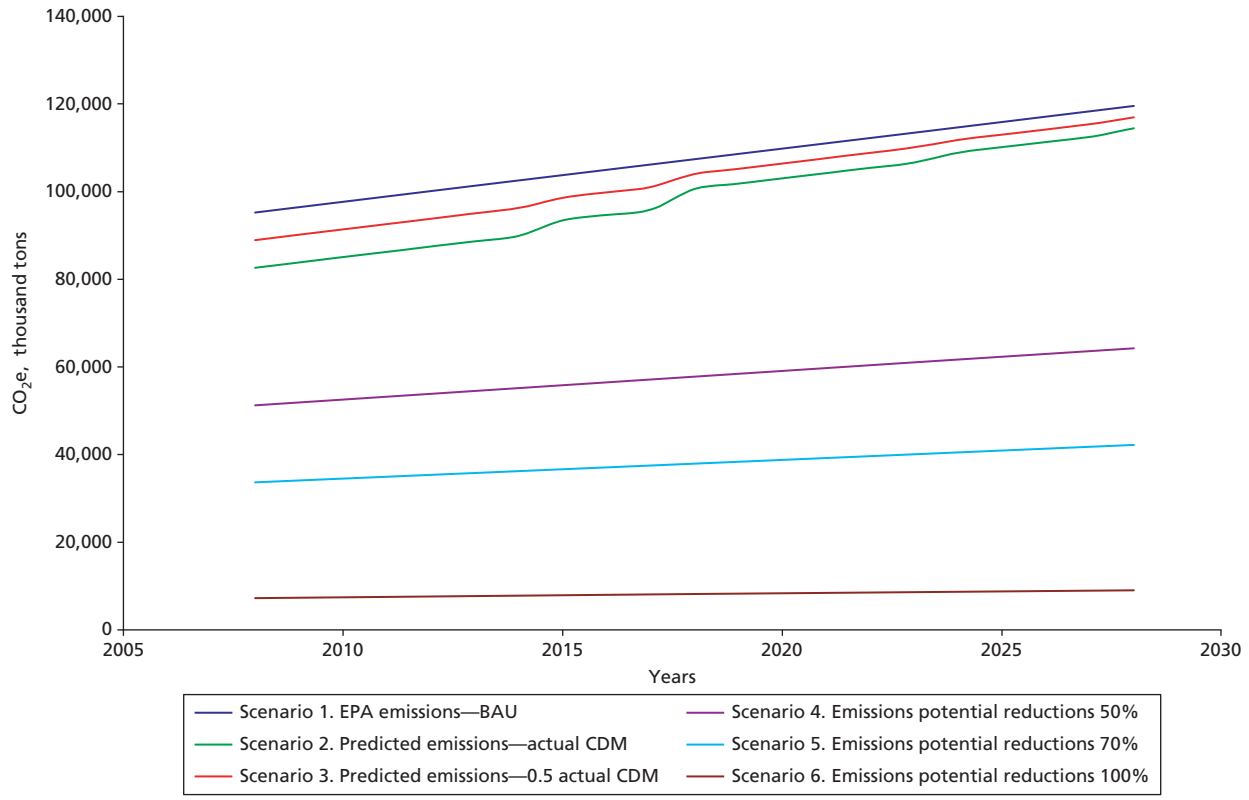
Total methane emissions from the landfilling of solid waste in the LCR are projected to rise from

about 92 Mt CO_2e per year in 2005 to 109 Mt CO_2e in 2020.[39] Capturing and burning the methane gas emitted from waste sites can make a substantial contribution to mitigation of climate change, even though the efficacy of landfill gas (LFG) projects depends on the quality of waste management. Lack of adequate compaction, poor leachate management, waste procedures different from the original project design, and inappropriate parameters used to estimate emission reductions have meant that actual reductions were lower than originally anticipated in many LFG projects. In practice, less than 100 percent of emissions are mitigated. Scenarios of potential emission reduction through the CDM in a range of scenarios show that emissions from landfill gases in the LCR could be drastically reduced (figure 6.11). Potential emission reductions from landfill gas projects that could be included in the CDM range from about 51 Mt CO_2e per year by 2020—assuming that half of all emissions in cities with more than 500,000 inhabitants can be mitigated—to 71 Mt assuming that 70 percent can be mitigated. For comparison, current landfill gas projects registered in the CDM for the LCR would result in a reduction of waste-related emissions by 4 to 15 percent.

The ancillary benefits associated with carbon finance activities in the management of solid waste are significant, and usually outweigh the additional incremental costs. For example, a sanitary landfill, which is a prerequisite for LFG recovery projects under CDM, eliminates problems associated with common dumps,

FIGURE 6.11

Six Scenarios Estimating Technical Potential to Reduce Latin America and the Caribbean Region's Emissions through Landfill Gas Projects in the CDM



Source: U.S. EPA.
Note: Scenario 1 presents the predicted emissions by the EPA in the business-as-usual (BAU) scenario. Scenario 2 presents the predicted emissions by the EPA taking into account the reductions with the actual registered CDM projects, assuming that 100% of the predicted CERs are captured. Scenario 3 presents the predicted emissions by the EPA with 50% of the estimated reductions with the actual registered CDM projects; this is based on World Bank experience. Scenario 4 presents the predicted emissions by the EPA, including the estimated potential reductions from 50% of the cities with more than 500,000 inhabitants. Scenario 5 uses the potential reductions from 70% of the cities with more than 500,000 inhabitants, and scenario 6 uses the potential reductions by 100% from cities with more than 500,000 residents.

such as odors; ground- and surface water contamination; and reduces the spread of diseases and the risk of methane explosion.

In terms of policy, the region needs to start working on various fronts. The first priority in the medium term is making the burning of landfill gas mandatory for security and sanitary reasons. Another priority for the countries in the region is to initiate assessments of current and projected markets for recycled products and pilot initiatives to test the feasibility of promising waste minimization and recycling programs. Practices that minimize the generation of waste (reduction, reuse, recycling) and enhance the generation of compost need to be instituted for sanitary, environmental, and economic reasons. Recycling of paper, metal, and glass can be a major source of energy savings since the amount of energy needed to process recycled materials is a fraction of that required for producing virgin materials. There can also be important social co-benefits of recycling programs on the welfare of waste pickers, for whom waste collection and sorting for recycling is a major source of income.

Mitigation Potential of Agriculture—Large and Location Specific

The global technical mitigation potential from agriculture by 2030 is very significant; it is estimated at about 5,500–6,000 Mt CO_2e per year for all greenhouse gases, including the emissions from land-use change. About 70 percent of this potential reflects mitigation opportunities in developing countries, and a further 10 percent in countries with economies in transition, with particularly high mitigation potential in the LCR (map 6.1). The mitigation opportunities fall into three broad categories: (1) reducing emissions through better management of fluxes of carbon dioxide, methane, nitrogen dioxide, and other greenhouse gas emissions through agronomy and improved livestock management; (2) removing emissions through enhancing carbon storage in soils or vegetative cover through such measures as conservation tillage and restoration of degraded lands; and (3) displacing emissions through bioenergy feedstocks and the avoided cultivation of new lands under forest and other vegetative cover.

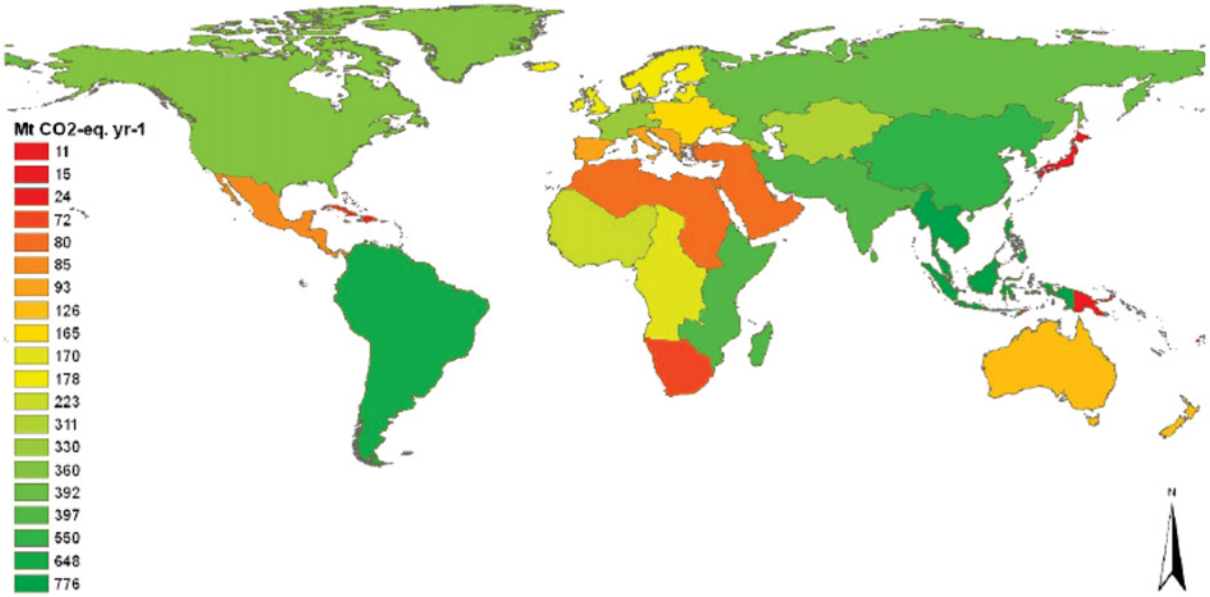
The economic mitigation potential both globally and in the LCR is much lower than the technical potential due to a multitude of economic, institutional, political, educational, and cultural constraints that prevent the implementation of mitigation measures. At full biophysical potential, agriculture could offset nearly one-third of total annual CO_2 equivalent emissions from all sources. However, the full technical potential would only be realized with exceptionally high prices for CO_2 equivalents, while it is estimated that lower prices of 0 to 20, 0 to 50, and 0 to 100 US$ per ton of CO_2e would deliver 35, 43, and 56 percent, respectively, of agriculture's total mitigation potential by 2030.[40] Obstacles to implementation that are specific to the agricultural sector include the issues of permanence of GHG reductions (particularly for carbon sinks), slow response of natural systems and varying time profile of emissions, and high transaction and monitoring costs. As a result, it is likely that less than 30 percent of the biophysical mitigation potential may be achieved in agriculture by 2030 unless a broad range of climate and nonclimate policies is effective at overcoming these barriers to implementation.

The emissions profile of the agricultural sector varies by region. Globally, N_20 emissions from soils dominate other sources, but in the LCR the largest share of emissions is methane from enteric fermentation. Other important sources are nitrogen dioxide and methane emissions from soils and biomass burning (figure 6.12).

Global forecasts project a significant increase in greenhouse gas emissions from agriculture due to the escalating demand for food. Higher nitrogen fertilizer use and increased production of animal manure are the main driving factors behind the projected increase in agricultural emissions of about 35 percent to 60 percent between 2005 and 2020. In tandem with the rising global food demand, livestock related emissions would increase by 60 percent up to 2030 relative to 2005 if CH_4 emissions are assumed to grow proportionally to an increase in livestock numbers; or by 15 to 21 percent with improved feeding practices and manure management. The LCR is expected to contribute a substantial share of the global increase in agricultural emissions by 2020, particularly for nitrogen

MAP 6.1

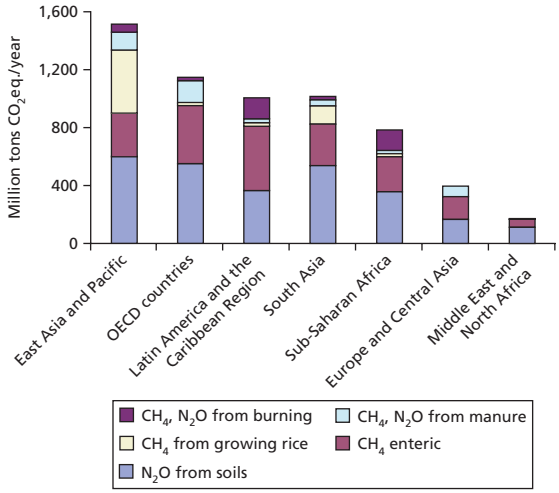
High Mitigation Potential of Latin American Agriculture



Source: Smith et al. (2008).

FIGURE 6.12

Agricultural Non-CO_2 Emissions by Region and Source, 2005



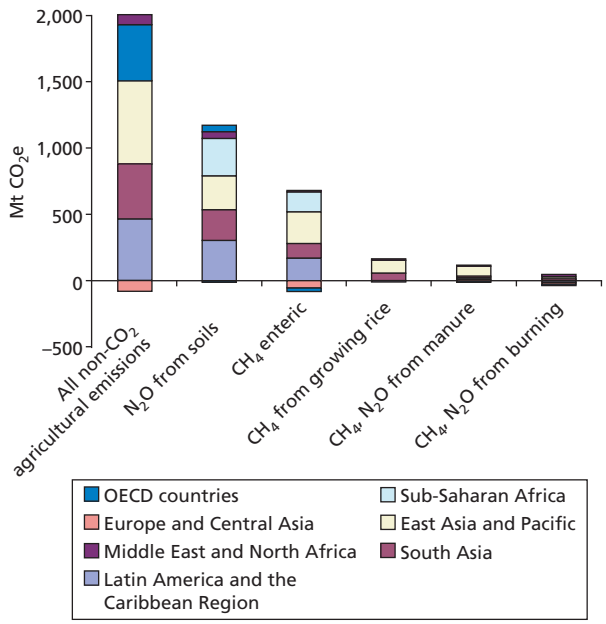
Source: Adapted from U.S. EPA (2006).

dioxide emissions from soils and methane from enteric fermentation (figure 6.13). This is not surprising given the importance of the agricultural sector and particularly cattle farming in the region's economy and the recent dramatic increase in cropland areas and application of nitrogen fertilizers.

The broad range of mitigation measures in agriculture ranges from cropland and grazing land management to restoration of degraded lands; management of organic soils—or previously flooded soils that store greenhouse gases until they are drained; and livestock and manure management. Emissions from cropland can be reduced through improved agronomic practices, such as using improved crop varieties; extending crop rotation; and reducing reliance on nitrogen fertilizers by using rotation with legume crops or improving the precision and efficiency of fertilizer applications. In certain climatic and soil conditions, conservation or zero tillage can be effective at improving crop yields, restoring degraded soils, and enhancing carbon storage in soils. Methane emissions from ruminant livestock, such as cattle and sheep, are a major source of agricultural emissions in the LCR. Measures to reduce emissions from livestock involve a change in feeding practices, use of dietary additives, and breeding species and managing livestock with the objective of minimizing emissions per unit of animal products.

FIGURE 6.13

Projected Cumulative Emissions from Agriculture, by Region, 1990–2020



Source: Adapted from U.S. EPA (2006).

The effectiveness and cost of mitigation measures from this palette of agricultural practices vary by climatic zone and socioeconomic conditions. Conservation or zero tillage—an agricultural practice that has been successfully applied over nearly 45 percent of cropland in Brazil—is a case in point (box 6.8). In contrast to conventional tillage, zero tillage involves no plowing of soils and incorporates the use of rotations with crop cover varieties and mulching (application of crop residues). The result is an increase in the storage (sequestration) of carbon in soils. Carbon is sequestered in zero-till systems due to lower decomposition rates of organic soil matter in undisturbed soil—a process whereby carbon is emitted—and the recycling of organic matter through the use of mulching. Lower fuel requirements for plowing operations that are no longer needed are another source of greenhouse gas reductions. However, application of nitrogen fertilizers to counteract nitrogen depletion, which often occurs in the first few years after conversion from conventional to zero tillage, may negate some of the reductions in GHG emissions.[41]

Zero tillage can make a substantial contribution to mitigation of climate change, although the extent of greenhouse gas reductions varies by climatic conditions and is a subject of scientific debate. The potential to use zero tillage to mitigate GHG emissions varies depending on the soil characteristics, water availability, and other climatic conditions; it is higher in warm and moist climates than in cool or dry ones. Compared to other cropland management practices, per-hectare benefits in terms of carbon sequestration may be modest, but zero tillage also has significant local benefits, especially in areas that are affected by soil erosion or that are particularly well-suited for zero tillage. Furthermore, these modest per-hectare reductions could occur over large cropping areas still under conventional tillage.

Just as the effectiveness of agricultural practices in reducing emissions varies between climate zones and within regions, the costs of mitigation are also specific to individual agricultural systems with particular ecological and socioeconomic conditions. This means that proposed practices need to be evaluated within these specific settings and there is no universally acceptable list of preferred interventions.[42] Furthermore, competition for land among different uses means that many solutions are more effective at achieving reductions in emissions and more cost effective when they are implemented as part of an integrated strategy that spans agricultural subsectors and forestry. Nevertheless, it is informative to compare the magnitude of the cost of mitigation measures across agricultural practices. These global averages point to the generally higher cost of mitigation measures in the livestock sector (livestock feeding and breeding) than such measures as tillage management, restoration of degraded soils, and the avoided deforestation (set aside/land-use change). Livestock additives, such as antibiotics and halogenated compounds, appear as a cost-effective way to reduce emissions, but their effect on emissions may be transitory and some of the additives have been banned in the European Union.[43] Another possibly promising venue is research to develop low-cost vaccines against methanogenic bacteria; they have been developed but are not yet commercially available. In the LCR, Mexico has incorporated improved production efficiency through higher quality grazing systems and forages and improved feed management as the key measure to

BOX 6.8

Severe Soil Erosion Precipitates the Adoption of Zero Tillage in Brazil

Despite significant challenge in the application of zero-tillage practices, particularly in areas with shallow, acidic, or compact soils, zero tillage has become progressively more widespread throughout the world in such countries as Argentina, Australia, Brazil, Canada, and the United States. Globally, the area under zero-till systems has expanded to more than 72 million hectares. In Brazil—the most frequently cited success story and the leading nation in terms of the adoption of this technology—zero tillage has exploded from less than 1,000 hectares in 1973–74 to nearly 22 million, or 45 percent of total cultivated land, in 2003–04. The rapid spread of the zero-till technology in Brazil precipitated from severe soil degradation in the late 1960s and 1970s in subtropical southern Brazil that resulted from the expansion of soybean and winter wheat cultivation with intensive plowing and burning of residues. By some estimates, for each kilogram of soybean harvested, 10 kilograms of soil were lost because of soil erosion using conventional tillage. The technology has spread to Paraguay and the *cerrado*—or tropical wet-dry savannah—region of Brazil. Brazil is one of the few countries if not the only one with a substantial area under zero-till in the tropics and with a high adoption rate by smallholder farmers; as many as 90 percent of southern Brazil's smallholders have switched to zero tillage although not all of them have switched permanently and adopted the full range of technology.

Source: Bolliger et al. (2006).

reduce GHG emissions from enteric fermentation; the use of high quality forages may reduce methane emissions there by 50 percent compared to mature pastures.[44]

As the efficacy of a range of mitigation measures and the magnitude of co-benefits varies by gas, region, site specificity, and time profile of emissions, a universal recipe for reducing emissions does not exist for the LCR as a whole or even for specific regions. Ecosystem complexity further adds to the heterogeneous response of emissions to agricultural investments and practices. Some mitigation measures impact more than one GHG, involving synergies or trade-offs between the emissions. Thus, a practice that is highly effective in one region may be counterproductive in another. Nevertheless, several priority subsectors stand out because of their high contribution to the overall emissions from agriculture, particularly in the future development scenarios, and high mitigation potential. These priority areas are the reduction of greenhouse gas emissions from soils and methane emissions from enteric fermentation, and enhancing carbon sinks in soils and vegetative cover.

As identified by a regional model, "low hanging fruits" in the mitigation of GHGs in LCR's livestock sector include improvements of animal productivity and use of additives to improve feed conversion and intensification of livestock production systems.[45,46] Altogether, the cumulative reduction potential in the livestock sector in the region by 2020 is estimated at about 90 Mt CO_2e per year, or 10 percent of the livestock sector's baseline emissions. In the cropping sector, the reduction potential is lower in absolute terms (about 15.5 Mt CO_2e per year) and there are complex interactions between CO_2 reduction from zero tillage—the option with the most significant potential and lowest costs—and other GHG emissions, especially nitrous oxide. Taking these interactions into account, the main "low hanging fruits" are the introduction of zero-till systems in Argentina (for maize and wheat) and in Mexico (for maize).[47]

Many agricultural mitigation options, just like in other sectors, have negative costs and it is difficult to assess whether important costs have been omitted or if barriers to adoption exist that are not accounted for in these estimates (figures 6.14a and 6.14b).[48] Accounting for adoption barriers and market failures which may prevent broader adoption, to gain a more complete picture of greenhouse gas mitigation potential is an important area for future research.

FIGURE 6.14a

Marginal Abatement Cost of Reducing Latin America and the Caribbean Region's Livestock Sector Emissions

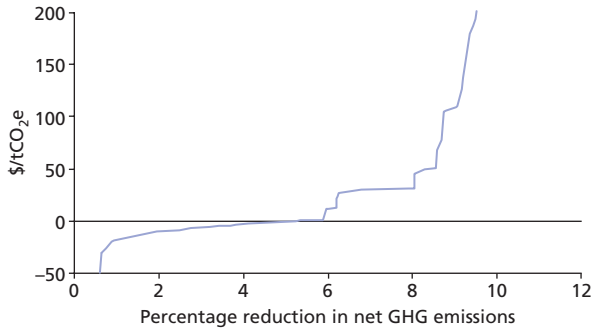
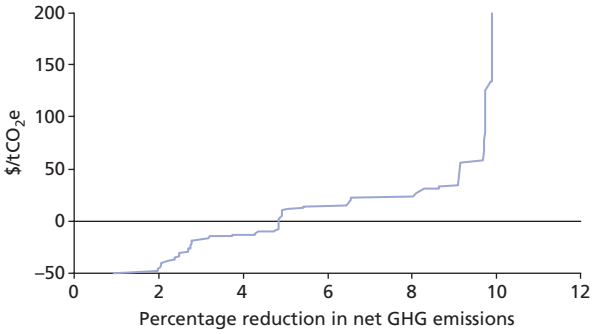


FIGURE 6.14b

Marginal Abatement Cost of Reducing Latin America and the Caribbean Region's Emissions through Soil Management



Source: Elaboration for Latin America and the Caribbean Region based on Beach et al. (2008) and provided by the U.S. EPA, personal communication, 2009.

The actual potential is much lower than the technical potential because of high implementation costs and other economic, social, and political barriers. These implementation issues in agriculture range from the difficulties in estimating the profile of carbon sequestration and emissions over time (permanence of emissions reductions), verifying the reductions, uncertainty about the complex biological processes and feedback mechanisms, and leakage, whereby production can shift from regions with the agreed upon GHG emissions caps to regions without such constraints. High monitoring and transaction costs stand out as particularly significant barriers to implementation. While the magnitude of monitoring costs in agriculture is still debated, innovative technological solutions—such as remote sensing and measuring soil bulk density—and measurement methodologies will likely alleviate this barrier as technologies develop. Transaction costs—or the amount of money farmers receive for implementing mitigation practices—remain a formidable challenge and a large fraction of the market price of carbon under the CDM. Because transaction costs tend to decrease with the size of the contract, small farmers will continue to face high barriers to participation in the program. For smallholder farmers, transaction costs may amount to a quarter of the market price of carbon.[49] The creation of producer organizations and smallholder cooperatives is a promising venue for overcoming this barrier.

Soil carbon sequestration and reduction of emissions from enteric fermentation are areas with high mitigation potential that need to be addressed through additional research, adaptation of practices to the local conditions, and the global sharing of technologies. Although the CDM currently does not support carbon sequestration in soils, emerging markets in Canada and the United States are beginning to trade carbon offsets in these types of projects. Their experience will prove vital for its inclusion in future carbon trading schemes and realizing the large untapped potential of the LCR in this area. Nonclimate policies, ranging from nonclimate UN Conventions to trade, macroeconomic, and environmental policies and relative price changes of agricultural products, can have an even greater bearing on land use and emissions of GHGs from agriculture.

Land-Use Change and Forestry—The Pillar of Mitigation in the LCR

Land-use change and forestry are the single largest source of GHGs in the LCR. More than half of those emissions are from Brazil, followed by Peru and República Bolivariana de Venezuela with less than one seventh of the level of Brazil's emissions. Large-scale expansion of agricultural production since the 1960s and forest clearing by other agents have led to a rapid increase in deforestation and emissions from tropical forests in Asia and the LCR; and 65 percent to 69 percent of the total deforestation in the LCR from

1990–2005 is estimated to have occurred in Brazil[50] (figures 6.15a and 6.15b). Recent estimates suggest that emissions from land-use change and forestry have begun to decline in the LCR, although it is unclear to what extent that trend has also been observed in Brazil (Houghton 2008).[51] The available estimates of emissions from land-use change are affected by a high margin of error in projections of deforestation rates and even greater uncertainty about how that translates into carbon emissions, as the level of emissions also depends on the final use of timber products. Depending on the true level of emissions from deforestation and degradation in tropical forests given significant uncertainty in their estimation, they could dwarf emissions from other sectors in the LCR or those emissions could become comparable with the future—and rising—emissions from the energy sector.

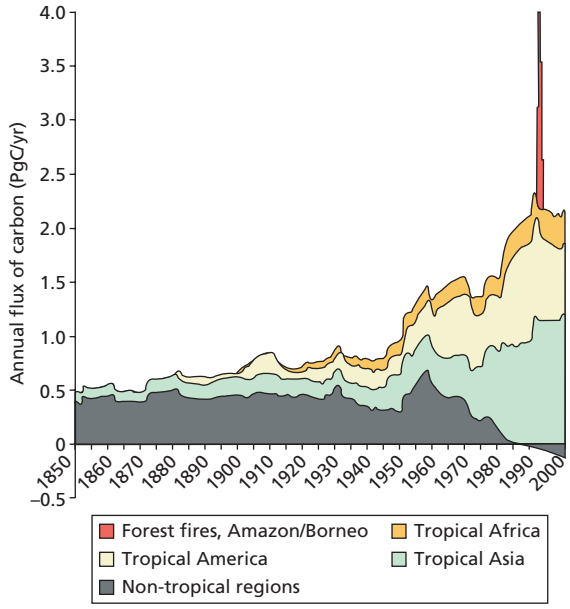
As argued, exploring the large mitigation potential associated with land-use change and forestry should be a priority for the LCR. While reductions in emissions from energy consumption could be potentially significant if appropriate policies and projects are implemented, the largest potential for drastically reducing GHG emissions in the LCR is associated with reducing deforestation and other land-use change emissions. Policies to reduce deforestation have been put in place in a number of countries. However economic forces, such as an increase in soybean or beef prices can overwhelm forestry conservation policies. Domestic and international policies to avoid deforestation and land degradation can reduce future GHG emissions from the LCR and should be among the highest priority policies for climate change mitigation for the region.

Effective domestic forest policies are the cornerstone of mitigation efforts in the sector

Many countries in the LCR have designed good laws and regulations in the forestry sector, but effectively implementing them and ensuring that they achieve forest conservation objectives is challenging. Management of forest lands is intricately linked to the issues of land tenure, restrictions on the use of forest areas, and the trade-offs and synergies between sustainable forestry and poverty. Effective implementation of forest policies may give rise to social conflicts when

FIGURE 6.15a

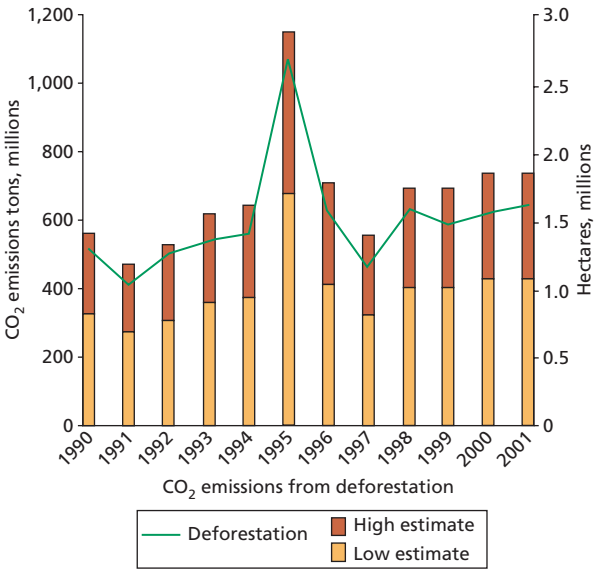
Carbon Emissions from Deforestation



Sources: Elaboration for Latin America and the Caribbean Region based on Beach et al. (2008), and provided by the U.S. EPA (2008); Houghton et al. 2005b.
Note: PgC/yr = petagrams of carbon/year.

FIGURE 6.15b

Annual Deforestation in the Amazon, 1990–2001



Sources: UNEP (1999); La Rovere (2000); Cramer (2004).

restrictions on the use of forest lands negatively affects the local communities whose sources of livelihood depend on forest income. Implementation of forest policies can also have high economic costs and be demanding in terms of human capacity because of the need for monitoring and enforcement of forest regulations. Assessing feasibility of particular management strategies from an economic and social perspective—including the consideration of the opportunity costs for alternative uses of forest areas and the social impact of restrictions on the use of forests—is an important element of developing national forest policies. Another crucial element is institutional capacity to implement those policies.

Two prominent approaches to management of publicly owned forests are protected areas and regulated concessions on privately owned land. Privately owned forests include areas managed by local communities, local governments, or individual owners. Management of a relatively small but growing share of forests in the LCR is being decentralized to local governments and indigenous communities, especially since the recognition of indigenous land rights has found particularly strong resonance in this region. The share of privately owned forests in the LCR far exceeds private forest ownership in other regions, with 56 percent in Central America; 17 percent in South America, excluding Brazil; and 15 percent in the Caribbean compared to the global average of 13 percent.[52] Community-based forest management in Mexico has reached a scale unmatched anywhere else in the world; an estimated three-fourths of Mexican forests are communally owned either by *ejidos,* or indigenous communities.

Land tenure over forest land and trees matters for the way forests are managed. Recent research empirically comparing different types of forest ownership indicates that in communally owned forests, both carbon sequestration and livelihoods benefits can best be achieved by increasing the area of the individual forests under community control, giving greater autonomy to local communities in managing their forests, and compensating them to reduce forest use.[53] In privately owned forests, successful innovative approaches include a shift from regulation to economic instruments, such as transferable forest obligations in the Amazon in Brazil and payment for environmental services programs. As for nationally managed protected areas, they tend to be more effective if they have sufficient staff; guards are important for transforming "paper parks" into working parks and working with local residents.[54] But too often such protected areas are underfunded, with the result that deforestation continues unabated. On the flip side, stringent enforcement may have adverse social consequences on the forest communities if regulations prohibit the use of forest products. The economic and social costs of creating parks must be weighed against the economic opportunities presented by other types of management to improve both the social outcomes and the political feasibility of forest protection measures.

Policies and large investments outside the forest sector—energy and agricultural policy, road building, and other large infrastructure projects—have a very large impact on forest resources. By opening up new forest frontiers for agricultural and logging activities, roads are the single most important driver of deforestation. Agroecological zoning is one of the ways to mitigate the deforestation pressure created by road construction. The participatory agroecological zoning process involves identification of areas of high biodiversity value and prioritization of infrastructure and other development early on in the planning process, while taking into account the economic growth and conservation objectives.

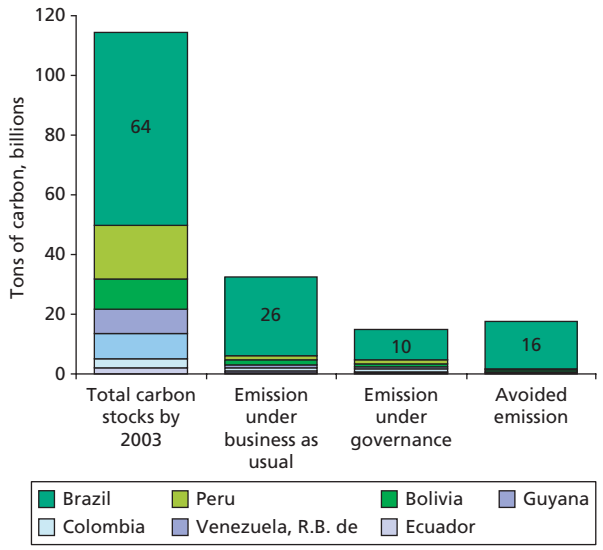
Modeling efforts point to a very large scope for reducing GHG emissions from land-use change in Brazil through a combination of domestic policies. Better road planning, agroecological zoning and the expansion, effective enforcement of conservation objectives in protected areas and—very important—also in private lands in Brazil alone can reduce future emissions from deforestation in Brazil by half.[55] Results of a combined agroecological and policy model of the Amazon show that deforestation rates in the Amazon vary significantly depending on a policy scenario and assumptions about the stringency of conservation efforts, including extension of the protected areas network, compliance with legislation requiring forest reserves on private land, and road construction and paving in the Amazon. Current trends in agricultural expansion may eliminate

a total of 40 percent of Amazon forests by 2050 in a business-as-usual scenario, releasing 32+/−8 Pg of carbon to the atmosphere, equivalent to four years of current annual carbon emissions worldwide.[56] In the "governance" scenario that assumes enforcement of mandatory forest reserves on private land, agroecological zoning of land use, and the expansion of the protected areas network, the deforestation rate initially rises due to road paving and declines over time. Under the governance scenario, 4.5 million km^2 of the forest would remain by 2050 compared to 3.2 million km^2—or 53 percent of the original area of the Amazon forest—under business as usual. In the governance scenario, emissions from deforestation are projected to fall to about 15+/−4 Pg of carbon (figure 6.16). None of these calculations take into account the possible dieback of the Amazon in the more extreme scenarios of the impact of climate change that would exacerbate the difference in the emission in the business-as-usual and governance scenarios.

Only a concerted, multisectoral approach can make forest conversion less attractive relative to other land-use options and reduce the pressures stemming from these sectors. But tailor-made policy solutions are needed to address particular drivers of deforestation while recognizing the specificities of each country's social and economic setting and its state of forest resources. In this regard, the LCR offers a very broad range of situations: from high deforestation (for example, in Nicaragua) to net reforestation (for example, in Costa Rica) to historically low deforestation (for example, in Guyana). Oftentimes agriculture is a key deforestation driver, sometimes as a result of policy incentives for extensive cattle farming or crop cultivation. Unclear land tenure is an outstanding feature of several of the region's countries that needs to be addressed. Of particular relevance to REDD, technical and human monitoring capacity, forest management know-how, and capability vary significantly among countries within the region. Hence, a mix of customized policies is needed to address the forest-climate nexus in each of the region's countries. Initiatives like the Forest Carbon Partnership Facility (FCPF) of the World Bank recognize the heterogeneity by country and seek to build capacity for custom-made solutions addressing REDD (box 6.9).

FIGURE 6.16

Falling Emissions Because of Strong Conservation in the Amazon



Sources: Soares-Filho et al. (2006); Nepstad et al. (2007).

Countries in the LCR are the world's leaders in implementing incentive-based payment schemes for forest conservation. In 1996, Costa Rica passed Forest Law 7575, which recognizes that forest ecosystems generate valuable ecosystem services and provides the legal basis for the owners of forest lands to sell these services. A large number of contracts were intermediated by the National Fund for Forest Financing as a result. Most of these payments to landowners have been for hydrological services and watershed protection—financed by such enterprises as hydropower generators and by municipalities—but availability of new financing through the CDM for afforestation and reforestation activities and payments for REDD are a promising source of revenue for Costa Rica in the future (Pagiola 2008). To a large extent, Costa Rica is now hailed as the global pioneer of payments for environmental services produced by forests. Mexico's experience with the ProÁrbol Program (box 6.10) illustrates that these programs have great potential to attract interest from land users. But they must be carefully designed and insulated from political pressures to be effective. A conservation banking scheme

BOX 6.9

Supporting Customized Solutions through the FCPF

The FCPF intends to build the capacity of developing countries, including at least 10 from the LCR (that is, Argentina, Bolivia, Colombia, Costa Rica, Guyana, Mexico, Nicaragua, Panama, Paraguay, and Peru), to benefit from future systems of positive incentives for REDD. As part of the capacity building, countries receive assistance to adopt or refine their national strategy for reducing emissions from deforestation and forest degradation.

The Readiness Plan Idea notes prepared by the LCR countries participating in the FCPF so far suggest that most of their programs and activities designed to reduce emissions from deforestation and degradation will fall in the following categories: (1) general economic policies and regulations; (2) forest policies and regulations; (3) economic mechanisms for forest conservation; (4) rural development programs; and (5) social programs.

Examples of **general economic policies and regulations** for REDD include Colombia's contemplation of eliminating perverse incentives from sectors causing deforestation, Guyana's willingness to promote less destructive practices in mining and road development, and Mexico's efforts to mainstream forest conservation in agriculture and transportation.

Forest policies and regulations are likely to form the bulk of LCR's REDD programs and activities. Argentina, Mexico, and Nicaragua are establishing alternative forest management practices to create alternative livelihood for forest-dependent communities. Bolivia and Mexico are promoting community forestry. Colombia and Guyana favor reduced impact logging. Costa Rica, Guyana, Mexico, Nicaragua, and Panama provide incentives for reforestation and plantations to relive pressure on natural forests. Costa Rica and Mexico see the need to reinforce the protection and management of their system of protected areas. Several countries emphasize the need for better forest law enforcement. Paraguay wishes to decentralize forest management to empower local governments in the conservation and sustainable use of forest resources. Guyana relies on log tagging and tracking to reduce illegal logging.

Several types of **economic mechanisms for forest conservation** are in use or in preparation in LCR countries. Costa Rica and Mexico will continue to rely on payments for environmental services for protection, reforestation, and forest regeneration, and Colombia may start doing so. Guyana has been using forest concessions. Panama may scale up its experience with debt-for-nature swaps. Bolivia is thinking about experimenting with tradable deforestation permits.

With respect to **rural development programs**, Bolivia recognizes the need for silvopastoral systems as a more efficient and less destructive alternative for cattle ranching, and for the development of income generation activities in the highlands so as to reduce migration to the lowlands of the Amazon region. Guyana proposes to reduce deforestation to foster ecotourism, handicraft using nontimber forest products, aquaculture, and rural electrification. Panama will improve its land administration and continue to promote investment projects at the subnational level, while Peru is launching a number of REDD pilot projects to identify the activities that are necessary to reduce poverty.

Finally, several LCR countries are proposing a range of **social programs** expected to generate direct or indirect benefits in terms of REDD. Argentina proposes to confer ownership rights over forest land to indigenous and rural communities and halt the internal displacement of indigenous peoples. Bolivia wants to promote the sustainable use of nontimber forest resources, wildlife, and environment services by peasant communities and indigenous populations, according to their knowledge, uses, and customs. Guyana will engage with Amerindian communities to use their titled lands in sustainable ways. Panama will rely on the ongoing Sustainable Rural Development program of the Ngöbe Buglé Region.

in Guyana (box 6.11) is another remarkable example of the emerging innovations in the region which—if they prove successful—can be replicated in other parts of the world.

The scope to achieve GHG reductions through domestic policies depends on the technical potential and biophysical characteristics of forests and soils, and on the economic factors. The cost of implementing forest

BOX 6.10

Paying to Protect Forests through ProÁrbol in Mexico

In 2003, Mexico instituted a program of payments for hydrological environmental services. This evolved into a broader program of payments for environmental services of forests, which, in turn, is part of a program of support to forests, ProÁrbol; 1.4 million ha were under conservation contracts in early 2008; the 2008 contracts should bring this total to more than 2 million ha. The program pays landowners to conserve existing forests, mainly for the services they provide in managing water resources. Payments are made ex post, after the conservation has been verified. Conservation contracts are for five years, and are conditionally renewable. Payments are uniform countrywide. They are stated in multiples of the minimum wage, and amount to about US$40 per hectare per year for cloud forest and US$30 per hectare per year for other forests. Despite a relatively careful preparation, the good intentions of the program designers have often been overwhelmed by intense political pressures. For example, when it became clear that the original intention to focus payments on areas where aquifers are most overexploited would concentrate payments in only a few states, criteria were changed to spread payments more broadly across the country, irrespective of relative importance for water services. The program has also been used as a vehicle to address unfunded mandates, such as a commitment that Mexico made at the Bishkek Mountain Summit to increase spending on conservation in mountain areas. The result was poor targeting, at least initially (Muñoz et al. 2008). From 2003 to 2005, as much as 90 percent of forest area under contract were in areas with aquifers in equilibrium or underexploited aquifers, and as much as 72 percent were in areas of low or very low risk of deforestation. More recent assessments are not available, but it is thought that efficiency has increased somewhat (for example, location in an area of high deforestation risk is now a prioritization criterion). A politically driven requirement for uniform payments also means that payment levels are often ill-suited to local conditions—paying much more than opportunity costs in some areas (resulting in much higher levels of demand for participation than funding allows) and much less than opportunity costs in other areas (resulting in limited participation in areas that could provide very high levels of environmental services).

BOX 6.11

Conservation Banking to Reduce Deforestation and Protect Biodiversity

Another innovation in the region to reduce deforestation is Guyana's President, Bharrat Jagdeo's offer to cede the management of his country's entire rain forest (more than 18 million hectares, covering more than 80 percent of Guyana's land mass) to the British government in return for economic assistance. While the offer is still on the table, the government and the 371,000-hectare Iwokrama Forest Reserve have recently negotiated a more limited deal with Canopy Capital, an investment group. Exact details have not been released, but basically in exchange for funding a "significant" part of Iwokrama's US$1.2 million annual research and conservation program for five years, Canopy Capital will receive partial "ownership" of the forest's ecosystems services. It will have the right to 16 percent of the proceeds generated from future environmental services payments, while 80 percent would go to local communities and 4 percent to the Global Canopy Program, an alliance of 29 scientific institutions in 19 countries. Similar deals in other developing countries include a US$9 million investment by Merrill Lynch in Sumatra in the expectation of eventual profits from sale of carbon credits, and a "wildlife conservation banking scheme" in Malaysia established by New Forests (a Sydney-based investment firm), which expects to receive a return of 15 to 25 percent by selling "biodiversity credits." This underscores the potential for forests to generate financial resources even outside of the formal carbon market.

conservation measures and achieving GHG reductions in this sector can be approximated using the opportunity costs associated with keeping land under forest rather than converting forest to alternative uses. Despite a large range of uncertainty in the current estimates of the opportunity costs of alternative land use, and high spatial heterogeneity of those estimates, even rough estimates provide a useful guide to policy makers regarding the likely costs of forest conservation.

Potential for mitigation through afforestation and reforestation

The efforts to harness the climate change mitigation potential of land-use change at the global level are focused on reducing emissions from deforestation and forest degradation and, to a lesser extent, around afforestation and reforestation activities. Assessing the mitigation potential of these types of activities requires estimating land availability and the potential carbon sequestration or retention potential of the available land. The latter depends mostly on biophysical considerations (soil type, precipitation, altitude, and so on) and the type of vegetation. Based on a literature review of regional bottom-up models, the IPCC estimates that the economic potential of forestry activities (A/R and reduced deforestation) in Latin America and the Caribbean Region by 2040 ranges from 500 to 1,750 $MtCO_2$ per year assuming a price of US\$20/tCO_2. In particular, land available for A/R activities in the LCR is estimated at 3.4 million square kilometers, most of it in Brazil. Other countries—especially Uruguay and some Caribbean countries—also offer a significant potential, at least in terms of the share of their corresponding territory (figure 6.17).[57]

Cost of avoided deforestation and mitigation potential of REDD

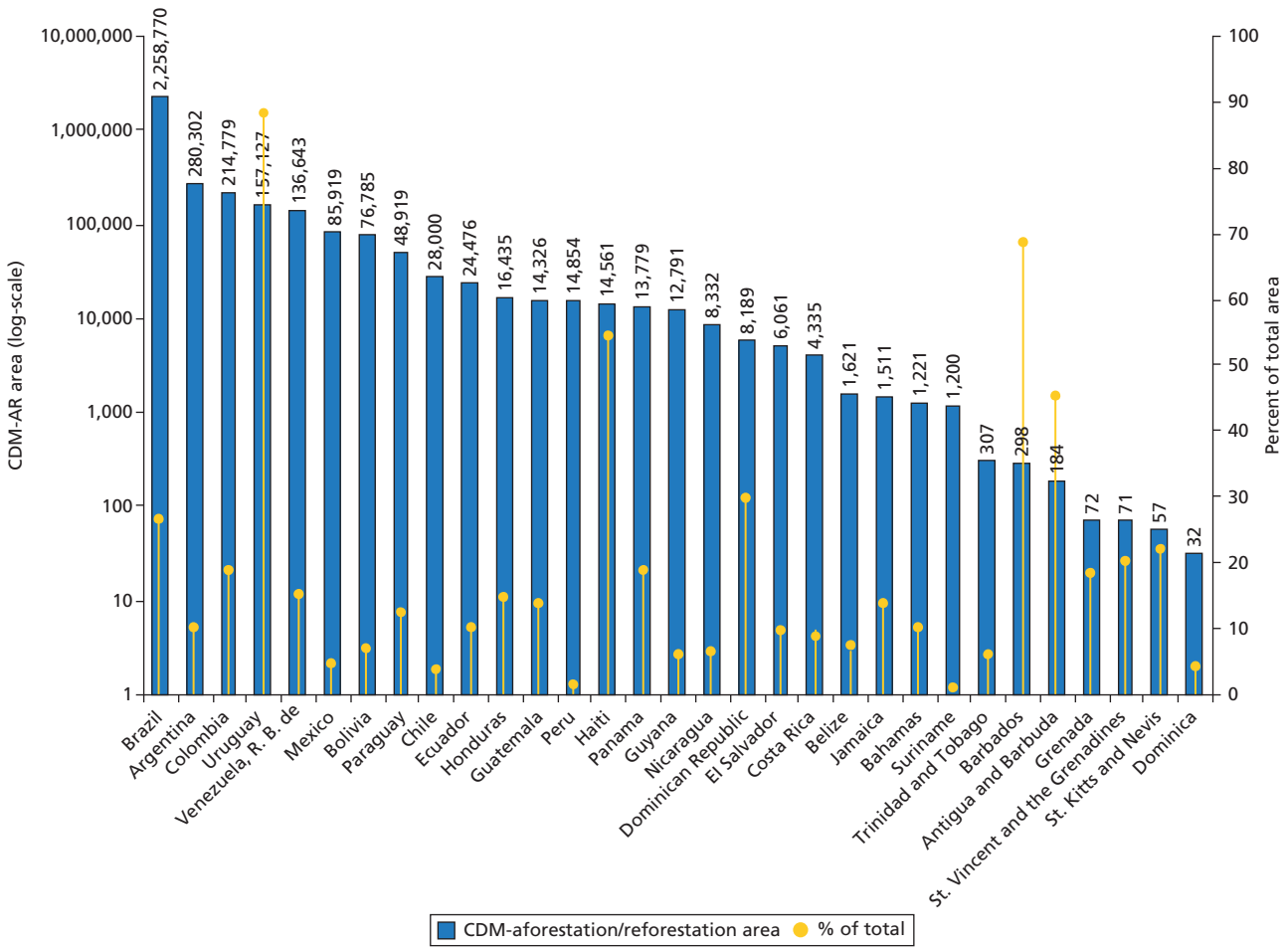
Empirical assessments of mitigation potential through REDD have focused on calculating the opportunity cost of avoided deforestation. To that end three different approaches have been used: local/regional empirical studies; global empirical area models like the Stern Review; and global simulation models of the forest and other sectors (for example, agriculture and in some cases energy also) from which to derive supply curves (Boucher and Reddy 2007). The results of 23 different local models suggest a cost of avoided emissions from deforestation ranging from US\$0 to US\$14 dollar per tCO_2, with a mean value of 2.51 US\$/tCO_2. The Stern Review estimated that deforestation could be reduced by 46 percent (in area terms) for a cost of US\$1.74 to US\$5.22 per tCO_2 with a midpoint that is 38 percent higher than the mean value of the estimates of local studies. Global models result in the highest cost per ton of avoided emissions, with values in a range of US\$6 to US\$18/tCO_2 for reducing deforestation by 46 percent also.

The large differences across different models are driven by the selection of baselines (rate of deforestation based on past or expected deforestation rates), the assumptions about the carbon content of the forest, and the dynamics of the different variables and sectors considered (from static to global equilibrium models). Expected deforestation rates, in particular, are based on multiple variables including current deforestation trends, drivers of land-use change (for example, roads and population growth), and land-use alternatives among others; while carbon content is determined by a series of assumptions about vegetation type and carbon pools. Other relevant factors that will have an impact on the cost of REDD include the existence of other types of costs (for example, transaction and stabilization costs to prevent leakage); asymmetries of information (knowledge about the location of potential deforesters) that determine the possibility to pay based on price discrimination instead of marginal costs; and consideration of the benefits of the foregone activity (for example, taxes paid by logger companies to the government, loss of income due to unemployment, and so on).

Even if available studies differ substantially in the assumptions made of key parameters used to estimate mitigation potential, such as carbon accounting, costs, baseline, and the inclusion or not of the mitigation potential of other sectors in the analysis, future deforestation rates are in general estimated to remain high in the tropic areas, particularly in Africa and South America. Therefore reducing deforestation is

FIGURE 6.17

Potential Area (in hectares) for CDM-A/R by Country (Without Considering Protected Areas)



Source: ENCOFOR CDM-AR online analysis tool. http://www.joanneum.at/encofor.
Note: The values presented for Argentina and the Dominican Republic reflect a closer estimate of the potential, because the online analysis tool did not allow applying their actual threshold values of 22.5 and 29, respectively.

a high-priority option for these regions. Table 6.8 summarizes the most recent estimates of the cost of REDD in LCR.

Synergies between global and local benefits from REDD and A/R

In addition to climate change mitigation, forests also play important roles in the adaptation to climate change. By mitigating climate change, REDD and A/R contribute to reducing the long-term vulnerability of natural ecosystems and socioeconomic systems and thus support long-term adaptation to climate change. REDD and A/R can also contribute to short-term adaptation to climate change and foster climate-resilient sustainable development, for example, by retaining moisture, regulating hydrological flows, stabilizing soils and protecting them against erosion, restoring soil fertility, protecting or increasing the supply of timber and nontimber wood products and fuelwood, and so forth. The opportunity to earn future carbon finance payments for A/R increases the value of formerly marginal lands. Higher land rents improve

TABLE 6.8

Economic Potential of Avoided Deforestation in Latin America and the Caribbean Region

Study	Region	Cost of avoided deforestation (US$/$tCO_2$)	Avoided emissions from deforestation
Sohngen and Sedjo, (2006)	South America	27.2	80,000 cumulative tCO_2 by 2050
	Central America	27.2	22,000 cumulative tCO_2 by 2050
IPCC AR4 (2007), Table 9.3[a]	Central and South America	100	1,845 tCO_2/year in 2030
	Central and South America	20	867 tCO_2/year in 2030
Strassburg et al. (2008)[b]	Brazil, Peru, Mexico, Colombia, Bolivia, Venezuela, R.B. de, and Argentina	5.63	97.5, 99.8, 93.4, 100, 86.7, 100, and 88.4%, respectively
Sathaye et al. (2008) (global model)	Central America (including Mexico)	34.6	CO_2 choke price to theoretically halt deforestation
	South America	40	
Swallow et al. (2007) (local model)[c]	Peru (Ucayali province)	5	90% of CO_2 emissions from deforestation have generated returns below this price
Obersteiner et al.	Central and South America	19.86 24.48 9.70	50% reduction in deforestation in 2030 using the GCOMAP, DIMA, and GTM models
Nepstad et al. (2007)	Brazilian Amazon	1.77	Average cost in 2007 of halting deforestation by 2017 (marginal cost is higher)

a. Reported numbers represent the average activity estimates reported for three global forest sector models including GTM (Sohngen and Sedjo 2006), GCOMAP (Sathaye et al. 2007), and IIASA-DIMA (Benitez-Ponce et al. 2007).
b. These results are for the scenario with an equivalent weight for both proposed incentives: emissions reductions by country compared to country specific past emissions and compared to the global baseline ($\alpha = 0.5$).
c. Examines associated gains to deforestation at the local level.

the economic position of landowners and enhance their adaptive capacity (Lal 2004). In addition, positive spillover effects for timber and nontimber forest products exist when sustainable forest exploitation is permitted on top of the delivery of the environmental service (Landell-Mills 2002).

REDD not only aims to avoid the emission of substantial amounts of GHGs but the conservation of forest ecosystems can also result in benefits for local climate, water resources, and most importantly biodiversity. The actual implications for biodiversity of REDD mitigation activities depend on the ecosystem concerned, the design and implementation of the activity, and particularly the site selection and management practices. In general, reducing deforestation and forest degradation involves both biodiversity preservation and climate benefits. The conservation of biodiversity enhances the adaptive capacity of ecosystems and, in turn, reduces their vulnerability to climate change.

This is not to say that trade-offs between mitigation and adaptation do not arise in REDD and A/R activities. With regard to water resources, the adaptation effects of A/R mitigation projects depend on the climatic characteristics of the region in which the projects are implemented as well as on the careful selection and composition of the tree species used. Findings of the U.K. Forestry Research Program show that A/R activities have numerous positive effects, such as soil conservation and flood control in regions with sufficient water resources. Furthermore, forests increase average water availability in regions with fewer water resources, intense rainfalls, and long spells of dry weather. There are, for example, documented cases of competition between tree plantation and agriculture in terms of the land and water that are needed. In arid and semiarid regions, A/R activities can reduce water yields. This is an important finding in the effort to align positive mitigation and adaptation effects that has to be

considered when planning A/R activities (UK FRP 2005). Another example of trade-off to be avoided is that REDD could lead to the exclusion of vulnerable communities from capacity building and carbon finance flows if their rights to the land are not recognized by the public and private sectors. However, positive synergies are clearly possible.

At present only a few studies exist that systematically analyze the interaction between mitigation, adaptation, and sustainable development. The experience of the World Bank's BioCarbon Fund shows that the quantification of these synergies is crucial from a development perspective and to convince potential investors. The Fourth Assessment Report concludes that guidelines to promote synergies between mitigation and adaptation programs and projects would be desirable for the existing Kyoto Protocol flexible mechanisms as well as emerging mechanisms (Klein et al. 2007). A systematic integration of adaptation practices in mitigation activities and vice versa would maximize the utility of the associated investment.

Other potential benefits of GHG mitigation

One of the key conclusions for the LCR is that there are numerous nonclimate related benefits for the most promising GHG mitigation policies examined in this chapter. While this is likely to be true for many other regions, it is particularly true for the LCR given the synergies and developmental benefits of the largest and fastest-growing emissions, such as from forestry, energy, and transport. Many of the mitigation options are often the least-cost option in financial terms—such as hydropower or energy efficiency—but are hampered by regulatory, legal, or other nonfinancial barriers. Among the nonclimate change motivations for pursuing GHG mitigation in the LCR are energy security, avoiding lock-in of high-carbon technologies, and other co-benefits.

Energy security

High and volatile oil and gas prices have underscored the potential for economic disruption that results from heavy reliance on these fuels for energy. The LCR has a number of energy-importing countries that have been negatively impacted by increasing energy prices or decreasing fuel supplies. In South America, Chile and Uruguay are net energy importers, thus vulnerable to volatility in energy prices and supplies. However, the dependence on imported hydrocarbons is most acute among Central American and Caribbean countries, including Barbados (86%), the Dominican Republic (78%), Jamaica (86%), and Panama (72%).[58] The exposure to volatile oil prices has prompted Latin American countries to take measures to diversify their energy matrixes and to reduce the need for energy imports through increasing renewable energy generation and improving energy efficiency. For instance, high oil prices have made hydroelectric, windpower and coal power generation competitive, especially in countries without access to low priced natural gas.

The development of the large potential of low-cost medium and large hydroelectric projects in South America and some Central American countries is not realistic without government support in most countries that have adopted a competitive electricity market with private participation. Private investors have difficulties and are unwilling to manage the high project risks of hydro plants: high capital cost, need of expensive and time-consuming feasibility studies, higher construction risks, long execution and amortization periods, and protracted and politically sensitive processes to obtain environmental licenses. Brazil is trying to overcome these difficulties by relying on competitive bids for awarding long-term concession contracts to new hydroelectric projects with environmental licenses. This scheme helps mitigate market and project risks for developers and has been effective in the development of hydroelectric projects thanks to strong participation of state-owned generators and local construction companies.

Avoiding high carbon technology lock-in

Investments in long-lived capital assets and their corresponding greenhouse gas emissions can last 40 to 50 years. The region is projecting a 4.8 percent annual rate of growth in electricity demand over the next 10 years, corresponding to a net increase of 100,000 MW in generation capacity, of which 60,000 MW is not under construction and has not been contracted (ESMAP 2007). The carbon intensity of this new generation capacity will be decided over the next few years as investment decisions are made. Policies and incentives

that would steer investment toward a low-carbon path can avoid lock-in of carbon-intensive technologies for the lifetime of the corresponding projects.

These policies would help the region avoid installing technologies that in an increasingly carbon-constrained world will soon become obsolete, and make the region lose competitiveness. In fact, in the context of the post-2012 climate regime, the European Union is already considering imposing an import tax on goods supplied by countries that have no emission policies and measures in order to protect the competitiveness of the European industry, which is under increasing emission controls.[59] The proposal has the support of major industries, and represents a potential trade barrier of concern to developing countries. The introduction of low-carbon technologies in the next few years may avoid much costlier mitigation costs in the future, when regulations become more stringent in terms of carbon intensity.

Other ancillary development benefits

The economic, environmental, and social co-benefits of climate change mitigation are considerable. From the perspective of the environment and human health, these benefits include higher agricultural productivity, reduced stress on natural ecosystems, lower air pollution, and better health conditions. The human health benefits from improved transportation systems may offset a substantial fraction of mitigation costs since they range between 30 and 50 percent of estimated mitigation costs (Burtaw et al. 2003; Proost and Van Regemorter 2003). Others estimate that these benefits are three to four times greater than mitigation costs (Aunana, et al. 2004; McKinley et al. 2005), depending on the stringency of the mitigation level, the source sector, and the measure and the monetary value attributed to mortality risks. Studies have calculated that for Asian and Latin American countries, several tens of thousands of premature deaths could be avoided annually from moderate CO_2 mitigation strategies (Aunana, et al. 2004; McKinley et al. 2005).[60] These deaths are avoided due to a reduction in air pollution, including emissions of SO_2, NOx, and particulate matter from vehicles and heat and power sources.

Climate mitigation also has ancillary energy-related sustainable development benefits: systemic urban transport efficiency improvements can provide better transport service, and methane capture projects can improve solid waste treatment and generate an additional source of energy. Decentralized electrification with renewable energy can provide substantial social and economic benefits to underserved populations who are dependent on traditional sources, such as biomass, kerosene, diesel generators, and car batteries. Compared to costly grid extensions, off-grid renewable electricity typically is the most cost-effective way to provide power to isolated rural populations, with an estimated 50–65 million people living without electricity in Latin America, particularly in Bolivia, Honduras, and Nicaragua where electrification rates of rural areas are below 30 percent (ESMAP 2007).

Summary and Conclusions

Priorities for the LCR

Among the mitigation options with the greatest potential in the LCR are avoided deforestation, expansion of hydropower and energy efficiency, sustainable urban transport, and solid waste management.

- **Avoided Deforestation.** The largest swings in emissions in the LCR are likely to come from deforestation and other land-use emissions, because these emissions are large and are likely to remain so in the future. Policies to reduce deforestation have been put in place in a number of countries, however, economic forces, such as an increase in soybean or beef prices, can overwhelm forestry conservation policies. Domestic and international policies to avoid deforestation and land degradation can reduce future GHG emissions from the LCR and should be among the highest priority policies for climate change mitigation for the region.
- **Hydropower.** There is considerable low-cost and relatively low-impact hydropower potential in the LCR that can help meet the growing demand for power. In some countries—Brazil, Colombia, Peru—hydro is already the least-cost alternative compared to coal but faces social and

environmental hurdles as well as potential risks from climate change itself. Reversing the decline in hydro development in the LCR will require establishing social and environmental frameworks and pursuing lower-impact hydro projects.

- **Energy Efficiency.** By any measure, there is substantial potential in the LCR for improving the efficiency of energy use, and in the process, generating significant financial savings and local environmental benefits. The potential lies not only in the dissemination of energy-efficient appliances and lighting in the residential, commercial, and buildings sectors, but in efficiency improvements in the industrial, transportation, and public sectors as well as the energy industry itself.
- **Sustainable Urban Transport.** The movement of people, goods, and services is among the largest energy-consuming activity in Latin America and has been expanding due to economic growth and motorization rates that are among the highest in the world. The LCR is a world leader in "sustainable transport," represented by the pro-public transit policies demonstrated by Curitiba, expanded in Bogota, and now under way in dozens of cities in the region. The mitigation options involve institutional and behavioral changes and must be part of an overall strategy instead of the current project-by-project approach. These strategies need to foster the use of more efficient modes of transport and modal integration, reduce travel demand, improve accessibility though better land-use planning, and reduce private vehicle use in congested areas.
- **Solid Waste Management**. The overall potential for GHG mitigation through improved solid waste management practices is relatively low compared to other sectors, but many mitigation options are of a no-regrets nature. Proper collection and disposal of solid waste has very significant health and public safety benefits. There is a growing demand for improved solid waste management in the region and therefore an opportunity to promote sustainable development and reduce GHG emissions. Solid waste management is high on the political agenda of local governments, and mitigation measures that also have large local co-benefits can be implemented at a modest incremental cost. Examples of successful implementation of waste management strategies in Brazil, Colombia, and Mexico highlight the need for integrated approaches that combine technical assistance with public education measures, and mechanisms for public participation to help overcome the collective action problems and cross municipality boundaries.

Financial analyses show that the net cost per ton of reducing GHG emissions through many of these mitigation options is low or negative (table 6.9). Aside from the financial benefits, most all have substantial nonmonetary co-benefits that contribute to their being regarded as no-regrets options. However, it is well known that there are sizeable transaction cost hurdles for implementing these measures, such as aggregation problems for many small-scale renewable energy and energy efficiency interventions, environment licensing requirements for hydropower, regulatory and principal agent problems associated with energy efficiency, and social and legal barriers associated with avoided deforestation.

Using largely existing technology, there is huge potential for reducing energy demand through the dissemination and mass marketing of energy-efficient products, including refrigerators, light bulbs, air conditioners, cars and trucks, and solar water heaters. The life-cycle cost of many energy efficiency measures is usually superior to the cheaper and less-efficient alternative, but this is often insufficient to sway the market. Part of the problem is the lack of information; and programs, such as efficiency labeling for appliances and other equipment, are beneficial. However, given the high discount rates that many consumers receive for energy efficient purchases, mandatory efficiency standards and other carrot-and-stick measures are needed to cause a major shift in the efficiency of consumer products, and, to a lesser extent, widely used industrial equipment, such as boilers, motors, and pumps.

Another area where regulation is needed to better align incentives for energy efficiency is in the electricity distribution sector. Unless specifically integrated

TABLE 6.9

Mitigation Options in Latin America and the Caribbean Region: Potential, Costs, and Technological and Institutional Barriers

	Mitigation potential	Short-term (5 years)	Long-term (>10 years)	Mitigation cost ($/t$CO_2$ reduced)	Technology and commercial readiness	Non-monetary, non-CO_2 co-benefits
Renewable energy						
1. Large hydro	H	M	H	L	H	L/M
2. Small hydro	M	M	M	L/M	M/H	M
3. Wind	M/H	L	H	M	M	L
4. Solar PV	L	M	L	H	M	M/H
5. Solar concentrating power	M?	M	M	M/H	L	L
6. Solar thermal hot water	M		M	L	M/H	M
7. Modern biomass	M		H	L	M	M/H
8. Second generation biofuels	M?		M	M	L	M
Energy Efficiency						
1. Residential	H	H	M	L	H	L
2. Commercial/industrial	H	H	M	L	H	M
3. Public sector	M	M	M	L/M	H	M
Transport						
1. Public	H	M	H	L/M	H	M/H
2. Commercial	H	M	H	L/M	H	M
3. Private	H	M	H	M/H	L/M	L/M
Waste Management						
1. Landfill methane gas capture	M	M	M	L/M	H	H
2. Composting and recycling	M	M	M	M/H	M	M
Agriculture						
1. Conservation tillage	H	M	H	M/H	L	M
2. Livestock management	M/H	M	H	H	L/M	L/M
Forestry						
1. REDD	H	M	H	L/M	H	H
2. Agroforestry	M	M	M	M/H	H	L/M

Source: Authors.
Note: L = low, M = medium, and H = high emission reduction potential.

into electricity regulation, distribution companies do not have a natural incentive to promote end-use efficiency measures as this typically reduces sales and revenues. Instead, it is necessary to devise regulatory systems that reward energy conservation and efficiency on the part of utilities and their customers. Earmarking a percentage of distribution company revenues for energy efficiency has been an approach instituted in Brazil that has helped finance energy efficiency investments, while Mexico's FIDE program has successfully achieved energy savings through investments in end-use efficiency.

While competitive in certain parts of the LCR, new renewables—wind, geothermal, solar electric, and bioenergy—do not broadly compete on financial terms with other energy sources, most importantly, hydro, natural gas, and coal. Without valuing local environmental benefits, or without carbon revenues, many countries in the LCR will be pursuing large expansions in coal-fired generation for their power needs over the coming five years. Carbon payments could help countries "switch" from high-carbon fuels to lower-GHG technologies in the power sector, such as hydro, wind, and natural gas, and this would be especially important for such long-lived investments.

Even excluding land-use change and deforestation, agriculture is a large source of GHG emissions in the LCR. The growth in nitrogen fertilizer use and methane from livestock production will accompany the expansion of the agricultural sector as the region becomes a major supplier of food to the rest of the world. To the extent that emissions are credited to "consumers," such emissions will be increasingly global. While there are numerous options to reduce GHG emissions in the agricultural sector, such as improved livestock breeding and conservation tillage,

their effectiveness and cost vary significantly by climatic and socioeconomic conditions, and there are currently few incentives for reducing GHG emissions from the agricultural sector in the LCR or worldwide. Since the mitigation solutions are very context-specific in the agricultural sector, research efforts need to have a strong participatory dimension and respond to the needs of small farmers.

Interactions between sectors and policy instruments are another important consideration for countries in the region as they devise their climate change strategies. Many mitigation options—particularly those relating to agriculture, production of biofuels, forestry, and building dams and reservoirs for hydropower—induce a change in land use. Where these interactions are important, they need to be explicitly taken into account. Otherwise, incentives to specific mitigation options could inadvertently lead to perverse outcomes.

Notes

1. The latest energy outlooks by the IEA and OLADE are the only projections with reasonable details on a regional basis for the expansion of power generation in the LCR. These results were complemented with specific generation planning studies on Mexico and Brazil, the two largest emitters of CO_2 in the region (SENER 2007a; EPE 2007).

2. The levelized cost is calculated as the cost of the electricity-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, and cost of capital.

3. About 25 US$/MWh in Peru, 45 US$/MWh in Colombia, and 55 to 72 US$/MWH in Brazil (average annual values), according to the latest indicative generation plans: Peru—Plan Referencial de Electricidad 2006–15, Colombia—Plan de Expansion de Referencia Generación-Transmisión 2008–22, Brazil—Plano Decenal de Expansao de Energia 2007–16.

4. Carbon prices in the Chicago Climate Exchange from March–May 2008 have been in the range of 5 to 7.5 US$/ton CO_2. Using optimistic assumptions, high carbon prices, and displacement of coal-fired generation from the baseline (896 tons CO_2/GWh), the average revenue would be 6.7 US$/MWh or about 10 percent of levelized cost for wind power.

5. According to the available estimates, the contribution of biomass to global energy supplies ranges from below 100 EJ per year currently to above 400 EJ per year in 2050. Uncertainty about land availability and yield levels results in this broad range of estimates. Availability of biomass resources in the future depends on many factors, and no integrated assessment of GHG mitigation potential from energy crops and scenario analysis is available. The broad range of estimates of the total global biophysical potential fossil fuel offset from energy crops puts it at 3,000 to 12,000 Mt CO_2e per year by 2030. Adding mitigation potential from using agricultural wastes and residues, the total potential from agricultural bioenergy is estimated to be about 4,000 to 16,000 Mt CO_2e per year by 2030. The economic potential is estimated at between 4 and 14 percent of the maximum bio-physical potential that could be achieved at carbon prices of US$20 and US$50 per ton of CO_2e, respectively. Thus, the maximum global economic mitigation potential of biomass from agriculture is estimated at 640 (16,000 x 4 percent) to 2,240 (16,000 x 14 percent) metric tons of CO_2e per year, or between 30 and 100 percent of all other agricultural greenhouse gas mitigation measures combined. Smith et al. (2007).

6. Farrell et al. 2006; Hill et al. 2006; Kartha 2006; review of studies reported in Worldwatch Institute (2006) and Kojima et al. (2007).

7. Koplow (2006).

8. Kojima et al. (2007).

9. At US$40 a ton, a multiple of the current market price of carbon, the maximum carbon credit would be US$0.07 per liter of ethanol and US$0.11 per liter of biodiesel (Avato 2007).

10. Searchinger et al. (2008).

11. Gibbs et al. (2008).

12. De Gorter and Tsur (2008).

13. Gurgel et al. (2008).

14. Zah et al. (2007), Gibbs et al. (2008), Searchinger et al. (2008).

15. Turner et al. (2007).

16. Rosegrant et al. (2008).

17. Mitchell (2008).

18 Whiteman and Cushion (2008).

19. De Gorter et al. (2008).

20. A note on the Economic Analysis of Projects in a Greenhouse World, The World Bank, February 2007.

21. International Energy Agency Outlook (2006), the Fourth Assessment of the Intergovernmental Panel on Climate Change (2007), and the study on cost curves published by the McKinsey Quarterly (2007).

22. A recent study by the Inter-American Development Bank assessed the cost of reducing electricity use by 143,000 GWh in 2018 using widely available energy efficiency measures of US$16 billion compared to the costs of about US$53 billion to build the equivalent of 328 gas-powered open cycle generators (250 MW each) necessary to produce the same 143,000 GWh of power.

23. In LCR many private companies were successful in reducing electricity losses from levels in the range of 20 percent to 30 percent to levels of 10 percent, by improving their commercial

practices. A substantial portion of the losses corresponded to nontechnical losses (metering problems, fraud, and theft), which while not energy efficient, can reduce demand if consumers have to pay for their electricity. Many of the remaining opportunities to reduce losses in the region will require restructuring public utilities to improve their corporate governance.

24. Exceptions to this are when: (1) the utility can save money by reducing peak demand—such as by shifting consumption from high-cost peak hours to low-cost times of day using baseload plants—a process known as "load management"; (2) the utility is supply-constrained and the reduction of demand allows the utility to serve new customers; and (3) there are large commercial losses and the utility can reduce costs by reducing electricity consumption by non- or under-paying customers.

25. In Brazil, government spending was about 15 percent of GDP in 2005. In the EU, public procurement is in excess of 200 billion euros, or about 3 percent of total GDP. The public sector accounts for 10 percent of the purchase of energy-using products in the United States.

26. Non-revenue water is the difference between the volume of water that is put into a water distribution system and the volume that is charged to consumers. NRW comprises three components: physical or technical (real) losses, commercial (or apparent) losses, and unbilled but authorized water consumption, such as for social purposes (for example, firefighting, free water to low income consumers). Electricity savings from reducing NRW by half would be about 1.5 billion kWh/year, while those from improving energy efficiency by 25 percent would equal 1.8 billion kWh/year, for a total of 3.3 billion kWh/year, or 34 percent of total electricity used by the sector in 2006.

27. In some public institutions, staffing is often tied to operating budgets, meaning that reducing the budget for a school or hospital by cutting energy expenditures may result in reductions in employees which, in turn, can be related to management compensation.

28. MEDEC (2008).

29. International Road Federation (2006).

30. Timilsina and Shrestha (2008). The study uses IEA data on CO_2 emission from the transport sector for 20 LCR countries during the 1980–2005 period.

31. *The Economist,* (2007).

32. http://www.time.com/time/world/article/0,8599,1733872,00.html.

33. MEDEC (2008).

34. Intelligent Transport Systems group information and communication technologies to improve management of transport infrastructure and vehicles. Intelligent Transport Systems aim to manage factors that are typically at odds with each other, such as vehicles, loads, and routes to improve safety and reduce vehicle wear, transportation times, fuel consumption, and, therefore, air pollution and greenhouse gas emissions.

35. A series of studies in these countries has been carried out with the sponsorship of the Spanish energy utility company ENDESA (2008).

36. World Bank (2008).

37. Pan American Health Organization (2005).

38. Gutierrez-Avedoy (2006) and CONAMA (2007) as cited by World Bank (2008).

39. As a result of uncertainties about the time profile of emissions, these estimates of methane emissions by the U.S. EPA (2006) fall within the range of +/− 10 to 30 percent for countries with good data on waste and +/− 20 to 60 percent for countries without annual data.

40. Smith et al. (2008).

41. IPCC (2007).

42. Bolliger et al. (2006).

43. Smith et al. (2008).

44. Background report on land-use and bioenergy (LUBIO) for the MEDEC low-carbon study (World Bank 2009).

45. U.S. EPA (2006).

46. The following options stand out in terms of the mitigation potential and low cost: antimethanogenic vaccination of beef cattle in Argentina, Brazil, and some other countries in the region; vaccination and intensification of dairy cattle production systems in Brazil; and intensive grazing of beef cattle in Argentina, Brazil, Colombia and some other countries in the region. Improved manure management is another measure with sizable mitigation potential and low costs.

47. Application of nitrogen inhibitors is another fairly low cost option with significant mitigation potential in some cropping systems in the region.

48. High-cost options tend to be those that are either not very effective at reducing net greenhouse gases or that have adverse yield and productivity effects. Adoption barriers have not been explicitly addressed (all mitigation options considered technically feasible in a given region are assumed to be adopted in data year 2000).

49. Projections by Smith et al. (2007).

50. FAO (2005).

51. The latest data from Houghton (2008) show a higher average value of CO_2 emissions for Brazil for the period 2000–05 compared to the decreasing trends observed for the years 1995 and 2000 based on his previous data (Houghton 2003). Still, the value for 1990 was higher than the average for 2000–05 in Brazil. In addition, due to a slight change in the methodology used to estimate emissions from deforestation in the latest data (most of the change affected estimations for Asia and not the LCR), time series data for emissions by country using the same methodology are not available.

52. FAO (2005).

53. Agrawal (2008).

54. Chomitz et al. (2007).

55. Soares-Filho et al. (2006).

56. Soares-Filho et al. (2006).

57. Potential land availability and location for A/R projects by country within the LCR region were obtained by applying the ENCOFOR CDM-AR Online Analysis Tool (Zomer et al. 2008) to the crown cover threshold defined by each country under the Kyoto Protocol. This tool is available online at http://csi.cgiar.org/encofor/forest/.

58. ESMAP (2007).

59. European Commission, proposal for Phase III of European Trading Scheme.

60. IPCC (2007), Chapter 11.

Appendix: Authors of Background Papers

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Carlos E. Arce
The Weather Insurance Market and Its Role in the Natural Catastrophic Agenda in Latin America

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Climate Change, Agricultural Productivity and Poverty

Juliano J. Assunçao, PUC-Rio, and Flavia Fein Cheres, CEDEPLAR/UFMG
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Harry de Gorter, Cornell University, and Yacov Tsur, Hebrew University of Jerusalem
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Vladimir Gil, The Earth Institute, Columbia University
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- 1,570 lbs. of solid waste

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This book, the companion volume to *Low Carbon, High Growth: Latin American Responses to Climate Change,* examines some of the major threats posed by climate change to the region's economies, societies, and biodiversity. It describes the patterns of greenhouse gas emissions in the Latin America and Caribbean region and in specific countries, finding that the future trajectory could be increases in emissions relative to other regions. *Low-Carbon Development* explains why it is in the region's best interest to participate actively in global efforts to reduce emissions and what type of global climate change architecture could allow the countries to make their most effective contributions. Finally, the book lays out an agenda for domestic policies and investments to help the countries adapt to climate change while reducing their emissions profiles. It will be useful to policy makers, civil society organizations, and researchers working in climate change.

Clearly and compellingly written, *Low-Carbon Development: Latin American Responses to Climate Change* illuminates the special challenges the developing countries of Latin America and the Caribbean face both in adapting to and in helping mitigate human-caused climate change. Perhaps even more helpfully, the report makes clear the many tools this resourceful region can deploy in addressing climate change over the coming decades. All the regions of the world would benefit from geographically focused studies of responses to climate change comparable to the one presented here.

— **Robert Engelman**
Vice President for Programs, The Worldwatch Institute, Washington, DC

Climate change mitigation and adaptation are crucial for the region's diverse society and economy. *Low-Carbon Development* raises many issues, some of which are open to scientific and political discussion, and provides the baseline material for such a debate, during which each society needs to make its own choices within the framework of global cooperation to fight climate change.

The authors also highlight an often-forgotten issue, which is the interrelation between climate change and other relevant environmental issues, such as deforestation, water, and soil degradation and desertification. This is important since in recent years many mitigation proposals, if approved, could have led to even worse consequences through social and environmental impacts.

— **Dr. Pablo O. Canziani**
Director, Interdisciplinary Team for the Study of Atmospheric Processes in Global Change,
The Pontifical Catholic University of Argentina, Buenos Aires

Low-Carbon Development: Latin American Responses to Climate Change provides the first comprehensive analysis of the effects of climate change in Latin America and the Caribbean and sketches what could become the regional contribution to its solution. The report endorses the adoption of differential caps on emissions, underscoring the importance of adopting tougher standards on changes in land use. In terms of costs, mitigation initiatives require transfers from countries with higher incomes and emissions. The proposed actions are worth careful consideration by governments committed to the protection of the region's rich biodiversity, without compromising economic growth.

— **Mauricio Cardenas**
Senior Fellow and Director, Latin America Initiative, The Brookings Institution, Washington, DC

An excellent primer on the economics of climate change from a Latin American and Caribbean perspective—consequences, risks, costs, and policy options—with a welcome emphasis on win-win "no regrets" opportunities. A timely entry for anyone concerned with development priorities in a region that, with luck and good leadership, can capture big gains for its poor and middle-income majorities by finding and exploiting a low-carbon growth path.

— **Nancy Birdsall**
Founding President, The Center for Global Development, Washington, DC

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