



Introduction

Obtaining relevant and reliable data is the first step in addressing any environmental problem; global climate change is no exception. In considering next steps in the international effort against climate change, policy-makers and stakeholders are confronted by a wealth of data on everything from century-old emission trends to likely economic growth decades into the future. Turning these data into useful input for decision-making is an enormous challenge.

This report seeks to convey the wide range of greenhouse gas (GHG) emissions data in digestible form, with the hope of increasing knowledge and awareness within the climate change policy community. In addition, the report offers a set of policy-relevant insights and observations that flow from the data. In some cases, an understanding of GHG emissions and related trends can help illuminate particular national circumstances faced by countries and inform the international community's policy responses. Data in this report are drawn primarily, though not exclusively, from the Climate Analysis Indicators Tool (CAIT) developed by the World Resources Institute (WRI) (Appendix 1). Using CAIT and other databases, WRI has organized data relevant to climate change policy and extracted some of the most relevant

details and findings. The hope is that sound information will contribute to a better-informed debate among stakeholders and, ultimately, to improved decision-making.

While GHG emissions and other data can lend important insight into the international climate policy challenge, they must also be treated with some caution. As will be seen, some of the data are more reliable than others. In some cases, the aura of precision projected by a table of figures masks considerable uncertainty in the underlying data. As with any complex issue, a given trend or relationship can be viewed through any number of lenses, with the potential for differing conclusions.

The remainder of this introduction briefly outlines the challenge of climate change and the major policy responses taken by the international community to date. This includes the adoption of the 1992 Climate Convention and the 1997 Kyoto Protocol. Looking ahead, much of the international community is turning its attention to a successor agreement that builds on—or replaces—Kyoto. A more complete understanding of GHG emissions should inform future

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decisions. The introduction also includes an overview of global GHG emissions—by sector, activity, and gas—to provide the context for the remainder of the report. It concludes with some explanations and cave-

ats that should be kept in mind throughout the report.

The global picture of GHG emissions data is complex, and may be examined using a variety of perspectives. This report adopts two principal approaches to examining the data. First, Part I of this report employs a country-level perspective on emissions data and a range of related indicators. A country-level perspective is useful primarily because governments tend to be the primary actors and subjects of international efforts to mitigate GHG emissions. Chapters 2–6 examine national emissions from several angles—historical, current, projected, per capita, and intensity. Because climate change issues cannot be fully appreciated from emissions

data alone, Chapters 7–9 of Part I examine country-level socioeconomic indicators, energy data, and international trade issues. Our hope is that these chapters will enhance the understanding of cross-country differences by highlighting the national contexts within which emissions arise.

Part II employs a different perspective: emissions at the sectoral level. This perspective is useful because it helps illuminate which activities are contributing most to the buildup of GHGs in the atmosphere and, accordingly, where policy-makers and investors need to focus the most attention. Equally important, an examination of individual sectors—in terms of production processes, product mixes, corporate presence, trade, and other factors—can also yield insights into which sectors might be attractive candidates for cooperation on climate change. Chapter 10 discusses the sectoral perspective, its rationale, and describes an analytical approach for comparing and evaluating sec-

tors. Chapter 10 also summarizes the findings of the remainder of Part II. Chapters 11–17 examine specific sectors and subsectors using available data and the methodology described in Chapter 10.

Taken together, Parts I and II provide a data-intensive analysis with important implications for international climate change cooperation from two different but complementary perspectives.

Introduction to Global Climate Change

Addressing global climate change is a paramount challenge of the 21st Century. Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide (CO₂), the chief heat-trapping greenhouse gas, have risen 35 percent, from about 280 to 377 parts per million (ppm) (Figure 1.1). This increase is primarily from the burning of fossil fuels and from deforestation. Atmospheric concentrations of methane (CH₄), the second leading GHG, have more than doubled over the past two centuries. These and other GHG increases have led to a 0.6° C (1.1° F) increase in the global average surface temperature since 1900. If current emissions trends are not altered, global temperatures are expected to rise a further 1.4 to 5.8° C (2.5 to 10.4° F) by 2100, according to the Intergovernmental Panel on Climate Change (IPCC). The effects of such temperature changes on agricultural production, water supply, forests, and overall human development are uncertain, but are likely to be detrimental to a large portion of the world's population, particularly in developing countries.

To keep the global average temperature from rising more than 2° C (3.6° F) above pre-industrial levels, worldwide emissions would need to peak around 2015 and subsequently decline by 40 to 45 percent by 2050 compared to 1990 levels.² Yet, over this century, the global population is expected to increase by 40 to 100 percent and economic growth is projected to climb 10- to 20-fold. Reducing emissions to levels that avoid dangerous human interference with the climate system, in the face of economic and population growth, will require substantial changes in energy use, including technological innovation plus advances in efficiency, conservation, and alternative energy sources.

The characteristics of climate change create unique policy challenges, and provide the foundation for appropriate policy responses. At the most basic level, climate change is a global problem, necessitating a coordinated international response. But countries do not have equal interests in reducing emissions, nor are they all equally significant. The problem is also long

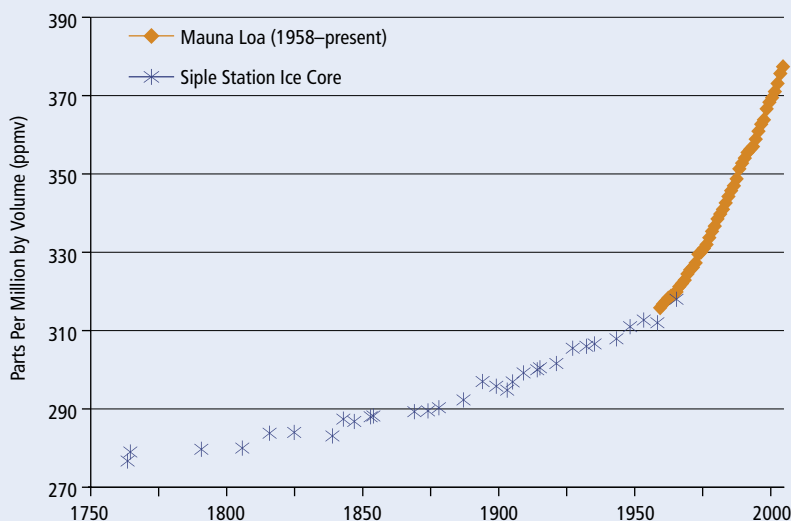
term, since CO₂ emissions, on average, remain in the atmosphere for about 100 years (some other gases persist for thousands of years). Left unchecked, some consequences of climate change, such as sea level rise, can be irreversible. Finally, responding to climate change implicates essential interests such as economic development and national security. As will be illustrated in this report, nearly the full range of human activities is associated with GHG emissions, including transport, industrial activities, and electric power usage. Collectively, these features create considerable challenges facing the development of a consensus-based international legal process.

Because of the nature and scale of the climate change problem, it is not surprising that the global agreements needed to adequately address climate change are only partially formed (Box 1.1). Governments adopted the UN Framework Convention on Climate Change (UNFCCC, or “Climate Convention”) in 1992. This agreement has nearly universal membership—including the United States and all major GHG emitting countries—and establishes the basic principles and preliminary steps for addressing climate change at a global level. Most importantly, the Climate Convention establishes an ultimate objective of stabilizing atmospheric concentrations of greenhouse gases at a level that avoids dangerous human interference with the climate system. Yet, the Convention established little in the area of firm governmental commitments. Recognizing this shortcoming, and responding to firmer scientific findings, governments agreed in 1997 to the Kyoto Protocol.

Under the Kyoto Protocol, industrialized and transition economies assumed legally binding emission caps to be achieved during the five-year period from 2008 to 2012. Targets ranged from a decrease of 8 percent relative to 1990 (European Union and others), to an increase of 10 percent (Iceland). However, developing countries, including major emitters such as China and India, have no emission limits under Kyoto. Furthermore, two industrialized countries—the United States and Australia—have not acceded to the Kyoto Protocol, and are therefore not bound by its emission controls.

Since the Protocol entered into force in February 2005, much of the international community has turned its attention to a successor agreement that builds on—or replaces—Kyoto by incorporating new features that attract the interest of the United States, Australia, and key developing countries. It is within this context that a more complete understanding of GHG emissions—at the global, national, and sectoral levels—should inform future decision-making.

Figure 1.1. Atmospheric Carbon Dioxide (CO₂) Concentrations, 1750–2004



Source: WRI, based on A. Neftel et al., 1994; C.D. Keeling and Whorf, 2005.

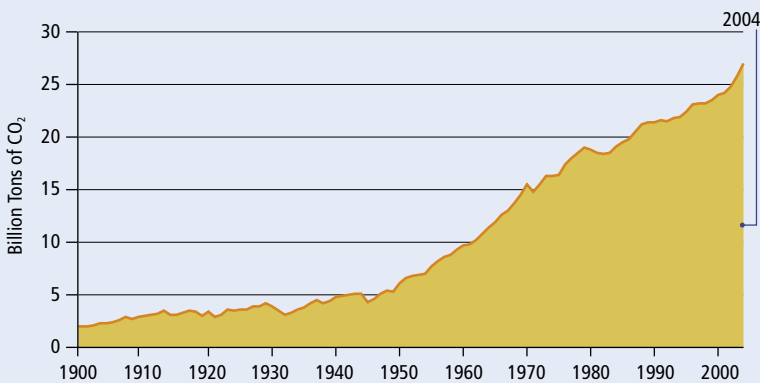
Box 1.1. Major Milestones in the International Climate Change Regime

1988	UNEP and WMO establish the Intergovernmental Panel on Climate Change (IPCC), which produces regular scientific and technical assessments on climate change
1992	The U.N. Framework Convention on Climate Change is agreed to at the Earth Summit in Rio de Janeiro, Brazil. The Convention enters into force in 1994.
1995	The IPCC Second Assessment Report concludes that the balance of evidence suggests a discernible human influence on the global climate
1997	Adoption of the Kyoto Protocol to the UN Climate Convention
2001	The IPCC Third Assessment Report finds stronger connections between human activities and the global climate system The United States announces that it will not become a Party to the Kyoto Protocol Other signatories adopt the “Marrakesh Accords,” a set of detailed rules for the implementation of the Kyoto Protocol.
2004	Russian Federation ratifies the Kyoto Protocol, triggering its entry into force in February 2005
2005	First meeting of the Parties of the Kyoto Protocol takes place in Montreal, Canada

Overview of Global Greenhouse Gas Emissions

Worldwide emissions of GHGs have risen steeply since the start of the industrial revolution, with the largest increases coming after 1945 (Figure 1.2). In the past 200 years, more than 2.3 trillion tons of CO₂ have been released into the atmosphere due to human activities relating to fossil fuel consumption and land-use changes.³ Fifty percent of these emissions have been released in the 30-year period from 1974 to 2004.⁴ The largest absolute increase in CO₂

Figure 1.2. Global Emissions of CO₂ from Fossil Fuels, 1900–2004

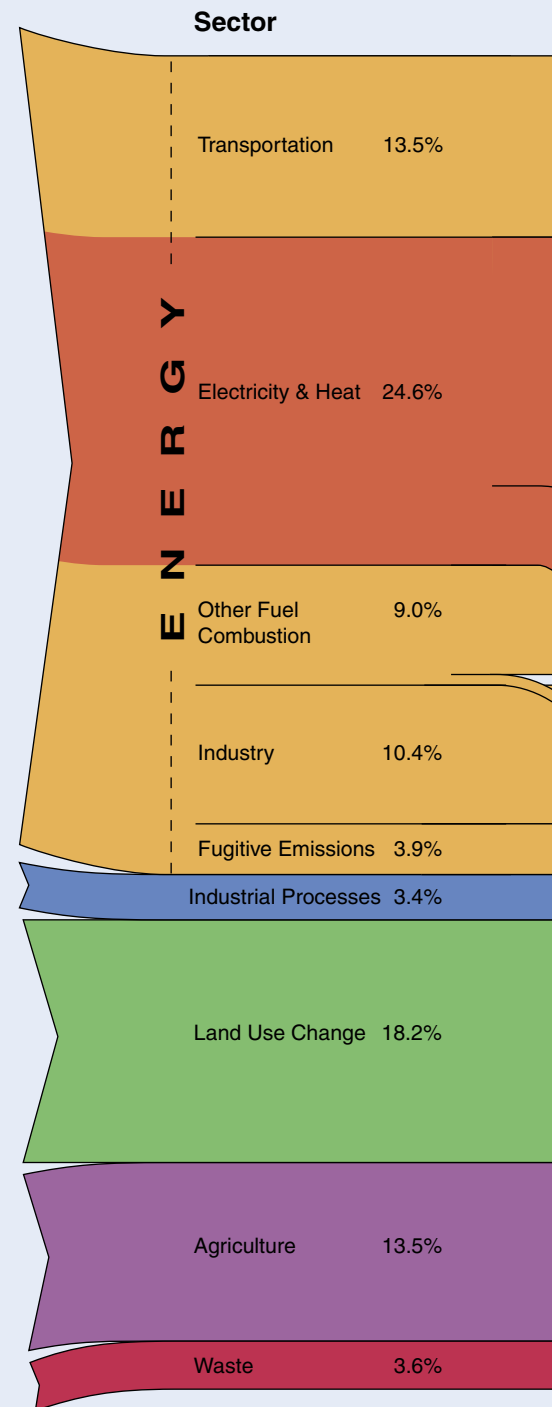


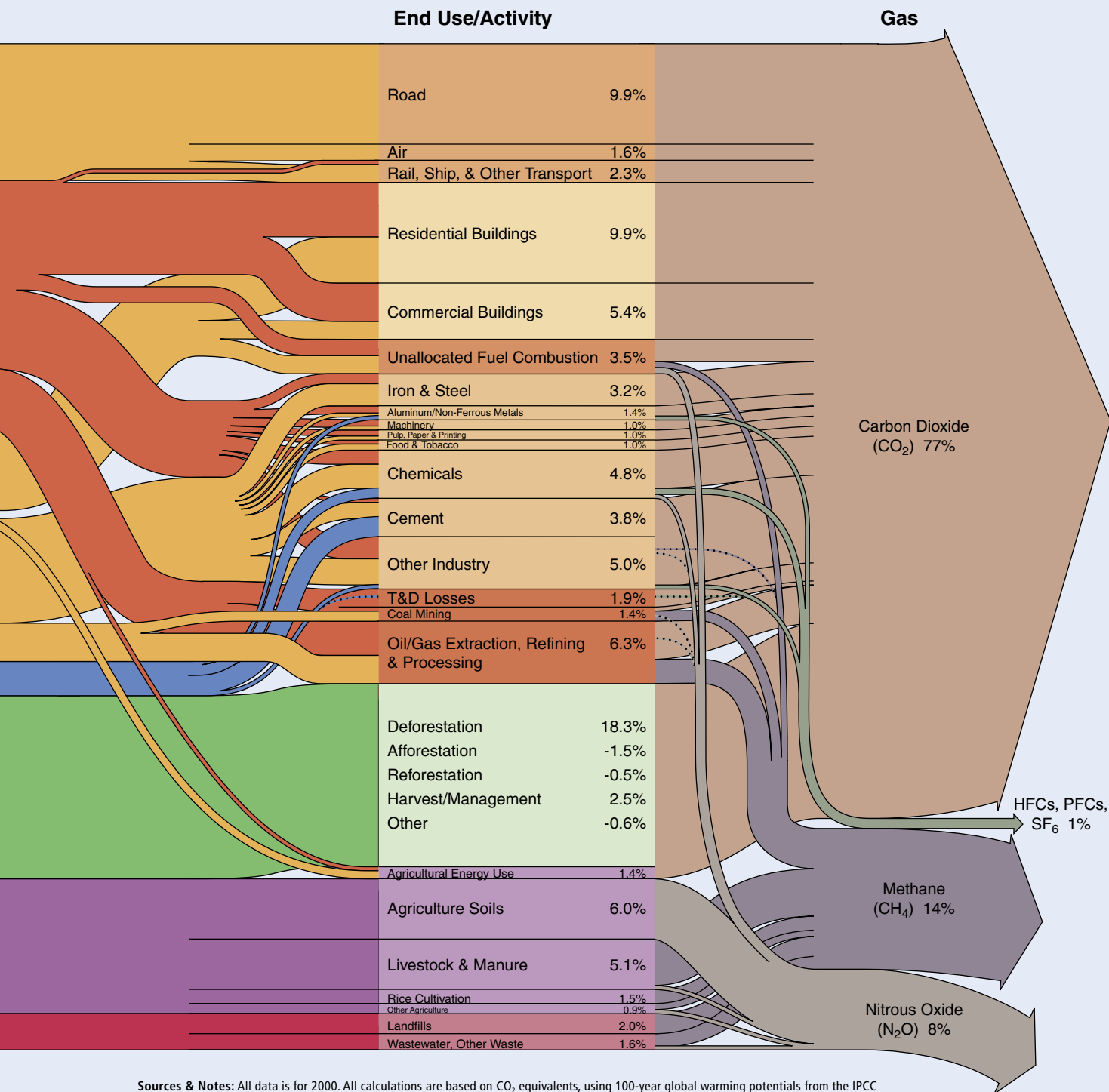
Sources & Notes: WRI estimates based on IEA, 2004; EIA, 2004; Marland et al., 2005; and BP, 2005. Emissions include fossil fuel combustion, cement manufacture, and gas flaring.

emissions occurred in 2004, when more than 28 billion tons of CO₂ were added to the atmosphere from fossil fuel combustion alone.⁵ The year 2004 also represented the largest percentage increase in emissions since 1976.⁶

One of the great challenges of climate change is that GHG emissions result from almost every major societal function, spanning transportation, agriculture, space heating, and many more activities. Using data from a wide range of sources, the GHG Flow Diagram (Figure 1.3) shows a complete picture of global GHG emissions. The left side of the figure shows that energy-related emissions account for about 60 percent of the world total. (Energy-related emissions come from the production and combustion of coal, oil, and natural gas, and are discussed in more detail in Chapter 8 and throughout Part II.)

Figure 1.3. GHG Flow Diagram, Global Greenhouse Gas Emissions





Sources & Notes: All data is for 2000. All calculations are based on CO₂ equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41,755 MtCO₂ equivalent. Land use change includes both emissions and absorptions; see Chapter 17. See Appendix 2 for detailed description of sector and end use/activity definitions, as well as data sources. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

At the sector level, the largest contributors to global emissions are electricity and heat (collectively 24.6 percent), land-use change and forestry (18.2 percent), transport (13.5 percent), and agriculture (13.5 percent). Figure 1.3 also shows emissions by “activity” or end-use (middle column). Here, the largest emissions come from road transport (9.9 percent), residential buildings (9.9 percent), oil and gas production (6.3 percent), agricultural soils (6.0 percent), commercial buildings (5.4 percent), and chemicals and petrochemicals (4.8 percent).⁷ Many of these sources include direct emissions (such as fossil fuel combustion, industrial process emissions) as well as indirect emissions (such as electricity consumption). Collectively, the industry-related subsectors shown in the middle column of Figure 1.3 (spanning “iron & steel” down to “other industry”) comprise about 21 percent of global emissions. Sectors and subsectors are discussed in greater detail in Part II and Appendix 2 of this report.

The data in Figure 1.3 includes the six major GHGs. Carbon dioxide (CO₂) contributes the largest share of the global total (77 percent, using global warming potentials⁸), followed by methane (CH₄, 14 percent) and nitrous oxide (N₂O, 8 percent). Most of the energy and land-use activities result in CO₂ emissions, although there are also significant CH₄ emissions from mining, processing, and refining of fossil fuels. Emissions from agriculture and waste, on the other hand, are largely comprised of CH₄ and N₂O. About 1 percent of global emissions (by global warming potentials) are from fluorinated gases (SF₆, HFCs, PFCs). Further details on non-CO₂ gases are described in Figure 1.4.

Guide to This Report

The following conventions and caveats apply to the data and analysis presented in this report:

- Data Sources.** Most information presented in this report is drawn from CAIT version 3.0 (see Appendix 1). Where no data source is provided, it can be presumed that CAIT is the source. This report—and CAIT—use data from a wide variety of sources, including the Carbon Dioxide Information Analysis Center (Marland et al., 2005); Houghton (2003a); the Intergovernmental Panel on Climate Change (IPCC, 2000a); International Energy Agency (IEA, 2004a); U.S. Environmental Protection Agency (EPA, 2004); U.S. Energy Information Administration (EIA, 2003, 2004); RIVM/TNO (2003); and the UN Framework Convention on Climate Change (UNFCCC, 2005).⁹ For more information, see Appendices 1 and 2 and the CAIT website (<http://cait.wri.org>).
- Definition of Sectors.** When examining GHG emissions, this report follows the sector and sub-sector definitions adopted by the IPCC (1997). However, there are many exceptions that are explained in Appendix 2, endnotes, and supporting documentation to CAIT (WRI, 2005a; WRI, 2005b). In some cases, the report deviates from IPCC guidelines because the underlying GHG data sources do not match IPCC definitions. In other cases, definitions are refined to enable a more comprehensive accounting of a particular end-use activity (for example, combining energy-related emissions with industrial process-related emissions for cement).

Figure 1.4. Selected Sources of Non-CO₂ Greenhouse Gases

Methane (CH ₄)	Nitrous Oxide (N ₂ O)	High GWP Gases (HFCs, PFCs, SF ₆)
Landfills	Agricultural Soils	Substitutes for ozone-depleting substances (HFCs, PFCs)
Coal mining	Adipic and nitric acid production	Industrial activities, including:
Natural gas & oil systems	Fossil fuel combustion	semiconductor manufacturing (PFCs, SF ₆ , HFCs)
Livestock (enteric fermentation)	Livestock manure management	electrical transmission & distribution (SF ₆)
Livestock manure management	Human sewage	aluminum production (PFCs)
Wastewater treatment		magnesium production (SF ₆)
Rice cultivation		
Biomass combustion		
Fossil fuel combustion		

- **Treatment of Different Gases and Sources.** When examining GHG emissions, this report's default approach is to include six greenhouse gases: CO₂, CH₄, N₂O, sulfur hexafluoride (SF₆), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). Unless noted otherwise, CO₂ emissions from land-use change and forestry are generally not included in national totals due to large data uncertainties. In addition, data on emissions of non-CO₂ gases is generally unavailable after 2000. All emissions figures in this report are expressed in CO₂ equivalents, using 100-year global warming potentials from the IPCC (1996).
- **Data Uncertainties.** In many cases, there is significant uncertainty with respect to emission estimates. This is true even for CO₂ from fossil fuels, although uncertainties tend to be smaller in OECD countries (Andres et al., 2000). The largest uncertainties are for CO₂ from land-use change and forestry (LUCF). Chapter 17 discusses global and national-level uncertainties for this sector, and caution is urged when analyzing LUCF data. For non-CO₂ data, the largest uncertainties tend to be for N₂O, followed by CH₄ (WRI, 2005a). For more detailed information about uncertainty, readers should also refer to documentation from individual data sources.
- **The European Union.** The European Union (EU) is in most cases treated as a separate entity. This is because the European Community has acceded to the UNFCCC as a regional economic integration organization, with "Party" status. The EU is typically considered here as a 25-member state body ("EU-25"), rather than the 15-member state body that existed when the EU ratified the Kyoto Protocol. Member states of the EU are also listed in many tables and figures. Where data are summed—for example, emissions of the "top 25 countries"—the EU figure is included in this total, but individual member states are not (to avoid double counting).
- **"Developed" and "Developing" Countries.** References to "developed" and "developing" countries correspond to the distinction under the UNFCCC between "Annex I" and "non-Annex I" countries (with non-Parties placed accordingly). Annex I includes several economies in transition. See Glossary and Abbreviations.
- **Top 25 GHG Emitting Countries.** This report frequently selects for analysis the 25 countries with the largest absolute emissions of GHGs.



This is done even for most of the indicators analyzed in this report, including gross domestic product, income, population, and others. The report focuses on these countries more than others for reasons of environmental importance and convenience. The intent is not to suggest that these are the only countries of importance for greenhouse gas mitigation; only that they are the most important.

- **GDP.** In this report, except where noted, gross domestic product (GDP) is measured in units of purchasing power parity. These units, while the subject of some controversy, are believed to be more appropriate than market exchange rates for making international comparisons, especially between developed and developing countries.
- **Figures and Tables.** Charts, graphs, and tables that appear *within* the body of this report are referred to as "figures." Because this report contains a great deal of data, however, supplementary Data Tables are included at the end of the report. Where the text refers to "tables," readers are directed to those tables. Tables typically provide more quantitative detail than the figures in the body of the report.

