PART I. COUNTRY-BASED DATA AND INDICATORS

CHAPTER 2

GHG Emissions and Trends

In absolute terms, a relatively small number of countries produce a large majority of global GHG emissions. Together, the 25 countries with the largest GHG emissions account for approximately 83 percent of global emissions (see Figure 2.1). The largest emitter is the United States, with 21 percent of global emissions, followed by China (15 percent). If the European Union (EU) is treated as a single entity, it and the four other largest emitters—the United States, China, Russia, and India—contribute approximately 61 percent of global emissions. It follows that most of the remaining countries contribute little to the buildup of GHGs in the atmosphere; 140 countries contribute only 10 percent of annual emissions (Figures 2.2 and 2.3). This group includes the least developed countries and many small island states.

There is significant diversity among the 25 highest emitters. As a whole, the group transcends the conventional country groupings (Figure 2.4). It includes:

- 13 Annex I (developed) countries, 11 of which are OECD members
- 11 non-Annex I (developing) countries
- 1 regional Party and six of its member states (EU-25)
- 2 OECD countries not in Annex I (South Korea, Mexico)
- 3 economies in transition (Poland, Russia, Ukraine)
- 3 OPEC members (Indonesia, Iran, Saudi Arabia)
- 4 non-Parties to the Kyoto Protocol (United States, Australia, Turkey, Iran).

Most of the largest GHG emitters have large economies, large populations, or both (Figure 2.5, Table 1). All but eight of the top 25 emitters are also among the 25 most populous nations, with China the most populous and Australia the least (52nd globally). Collectively, the major emitters represent 70 percent of the global population. In other words, the sheer size of some countries mean that they are among the largest emitters, even though per capita emissions may be small (see Chapter 4).

With respect to GDP, all but three of the top 25 emitters are also among the 25 countries with the largest economies, ranging from the United States and the EU (each with over 20 percent of global GDP) to Ukraine (0.5 percent of global GDP)

(Figure 2.5). Together, the 25 top emitters generate 87 percent of global GDP. Some countries rank among the largest economies by virtue of their very large populations (China and India together comprise 38 percent of global population and 18 percent of global GDP); others by virtue of affluence (the United States and the EU together comprise only 12 percent of global population, and nearly 44 percent of global GDP) (Table 1).

Country rankings in GHG emissions vary depending on which gases are counted (Table 2).[10] The estimates described cover CO_2 from fossil fuels and cement,[11] plus emissions from methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). The inclusion of non-CO_2 gases generally increases the shares of emissions from developing countries (Figure 2.6). In agrarian economies with little heavy industry or energy production, CH_4 is often the largest single source of emissions. Similarly, land-use change also represents a larger share of CO_2 emissions in developing countries, where emissions largely arise from tropical deforestation.

The United States' share of world emissions is estimated at 24 percent when counting only CO_2 emissions from fossil fuel use, but drops to 21 percent when non-CO_2 gases are added, and to 16 percent for all gases and LUCF absorption (although the U.S. nevertheless ranks first in all three methods). Conversely, Indonesia, which ranks 21st in total emissions when only CO_2 from fossil fuels is considered,

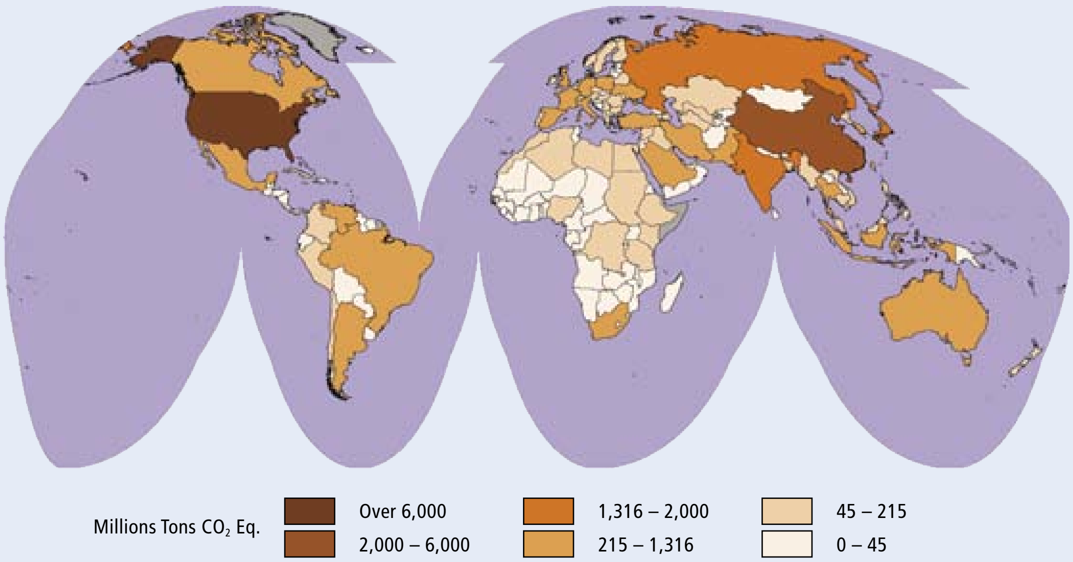
Figure 2.1. Top GHG Emitting Countries

CO_2, CH_4, N_2O, HFCs, PFCs, SF_6

Country	$MtCO_2$ equivalent	% of World GHGs
1. United States	6,928	20.6
2. China	4,938	14.7
3. EU-25	4,725	14.0
4. Russia	1,915	5.7
5. India	1,884	5.6
6. Japan	1,317	3.9
7. Germany	1,009	3.0
8. Brazil	851	2.5
9. Canada	680	2.0
10. United Kingdom	654	1.9
11. Italy	531	1.6
12. South Korea	521	1.5
13. France	513	1.5
14. Mexico	512	1.5
15. Indonesia	503	1.5
16. Australia	491	1.5
17. Ukraine	482	1.4
18. Iran	480	1.4
19. South Africa	417	1.2
20. Spain	381	1.1
21. Poland	381	1.1
22. Turkey	355	1.1
23. Saudi Arabia	341	1.0
24. Argentina	289	0.9
25. Pakistan	285	0.8
Top 25	**27,915**	**83**
Rest of World	**5,751**	**17**
Developed	**17,355**	**52**
Developing	**16,310**	**48**

Notes: Data is for 2000. Totals exclude emissions from international bunker fuels and land use change and forestry.

Figure 2.2. GHG Emission Levels by Country



Sources & Notes: WRI, CAIT. Data is in absolute totals of six GHGs for 2000. EU-25 is not shown collectively.

ranks 4th when land use and non-CO_2 gases are added. Results for all major emitters are shown in Table 2. Uncertainty levels, it should be noted, are very high for land-use change and forestry emissions (see Chapter 17).

Emissions Trends

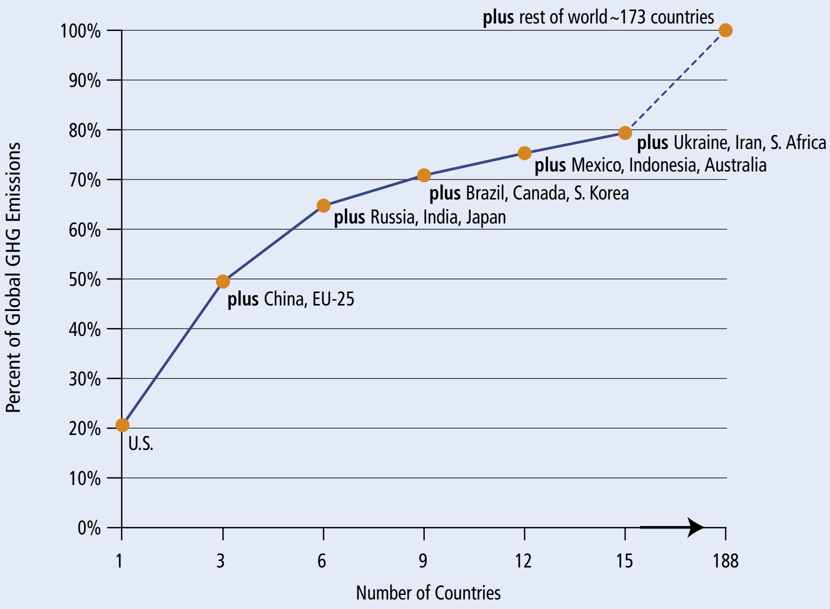
Emissions growth rates are highest among developing countries, where collectively CO_2 emissions increased by 47 percent over the 1990–2002 period. Among the major developing country emitters, growth was fastest in Indonesia (97 percent), South Korea (97 percent), Iran (93 percent), and Saudi Arabia (91 percent) during this period (Figure 2.7, 2.8). Emissions in China grew about 50 percent, although preliminary estimates for 2003 and 2004 suggest extraordinary growth in China, about 35 percent over this two-year period alone.[12] In absolute terms, this CO_2 growth in China accounts for more than half of the worldwide CO_2 increase during the 2003–04 period.[13]

Carbon dioxide emissions in the developed countries were unchanged over the 1990–2002 period, although this figure masks considerable national disparities. Emissions in the EU declined slightly over this period, led by significant GHG (six gas) reductions in the United Kingdom (-15 percent) and Germany (-19 percent). The only other countries with declining emissions are those transitioning from centrally planned economies, such as Russia and Ukraine, where emissions have declined precipitously due in part to economic transition. In contrast, GHG (six gases) growth was significant in the U.S. (13 percent), Canada (20 percent), and Australia (22 percent) over the 1990 to 2002 period (Figure 2.7).[14] These growth rates, while smaller than those of many developing countries, are nonetheless significant in terms of absolute contributions to the growing stock of GHGs in the atmosphere. Because of the sheer size of the U.S., for instance, its jump in CO_2 emissions added roughly the same amount of CO_2 to the atmosphere (863 $MtCO_2$) as the combined 64 percent emissions growth from India, Brazil, Mexico, and Indonesia (832 $MtCO_2$) (Figure 2.8).

Emissions Drivers

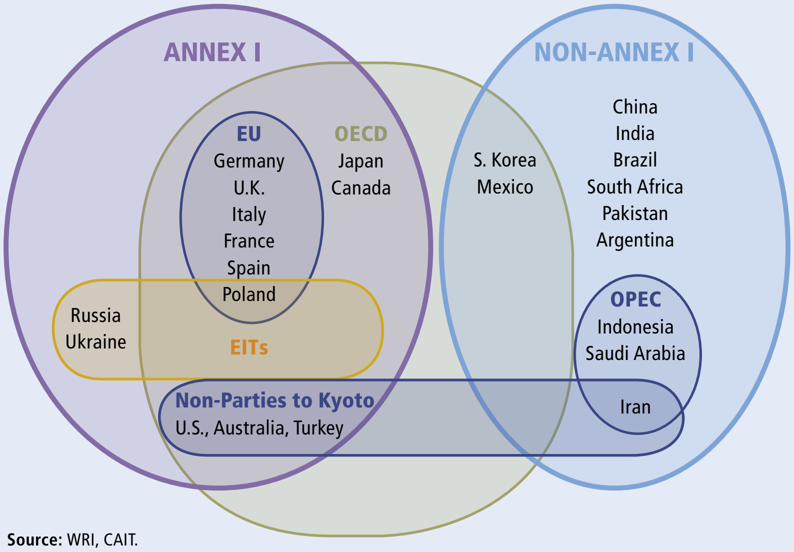
The strong correlation between emissions, population, and GDP rankings reflects the importance of population and economic growth as emissions drivers. Through a *decomposition analysis*, it is possible to derive the relative contribution of several factors to changes in a country's emissions level, including

Figure 2.3. Aggregate Contributions of Major GHG Emitting Countries



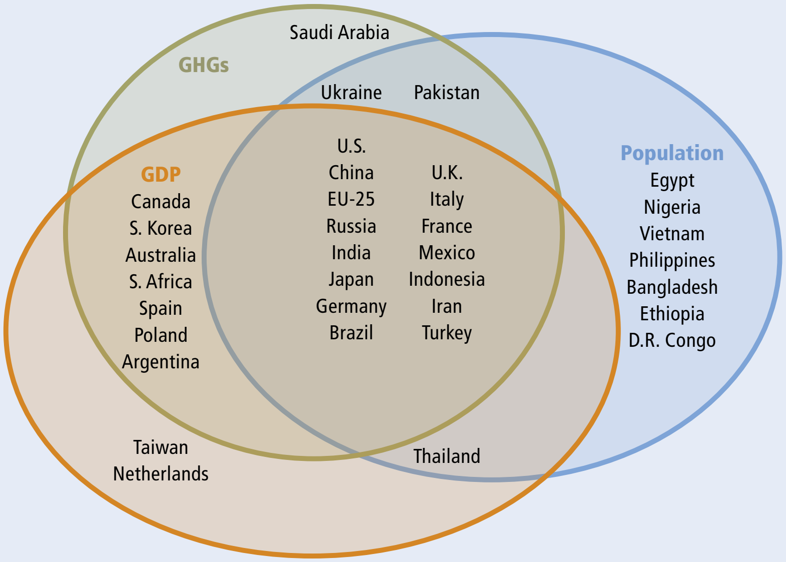
Sources & Notes: WRI, CAIT. Moving from left to right, countries are added in order of their absolute emissions, with the largest being added first. Figures exclude CO_2 from land-use change and forestry and emissions from international bunker fuels.

Figure 2.4. Top 25 GHG Emitters by Region and Organization



Source: WRI, CAIT.

Figure 2.5. Top 25: GHG Emissions, Population, and GDP



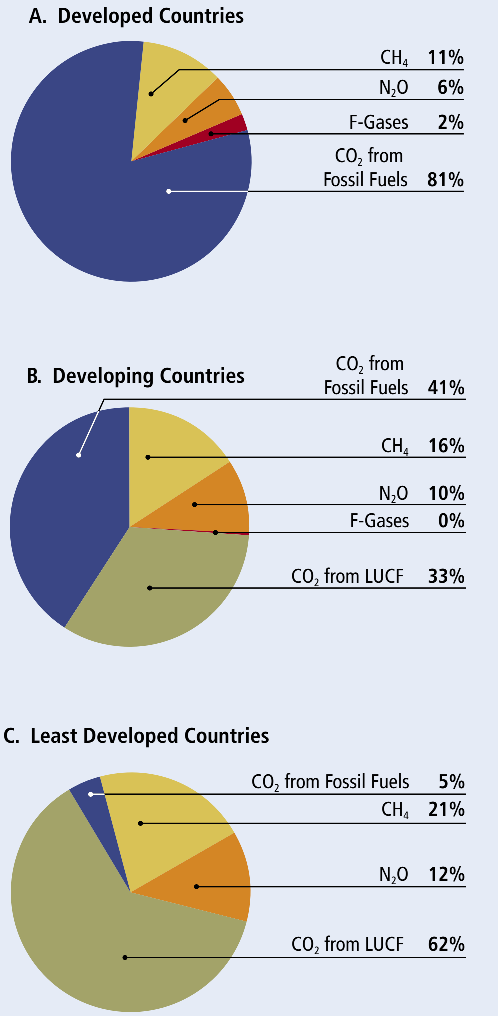
Source: WRI, CAIT.

changes in energy intensity and fuel mix. (See Box 2.1 for a more detailed description of decomposition analysis.) The results for the 25 top emitters, for the period 1990–2002, are presented in Figure 2.8. (For each country, the sum of the four factor contributions is equal to actual percent change in CO_2.)

In a majority of countries, economic growth (measured here as increases in GDP per capita) has the strongest influence on emissions levels, usually putting upward pressure on emissions. This is the case in countries as diverse as the United States, India, Indonesia, Australia, and Iran. In Russia and Ukraine, as noted above, economic contraction contributed to a decline in emissions. Surprisingly, however, economic decline was not the largest contributor to Russia's much-discussed emissions drop. Rather, structural changes in Russia's economy—as evidenced by the energy intensity decline—were a larger factor. Population decline and changes in fuel mix also contributed. In some countries, large movements in one factor were substantially counterbalanced by one or more other factors. China, for instance, experienced a very large decline in energy intensity, putting downward pressure on CO_2 emissions. However, this pressure was more than counterbalanced by astonishingly high GDP growth, leading to an overall increase in emissions over the 1990–2002 time period.

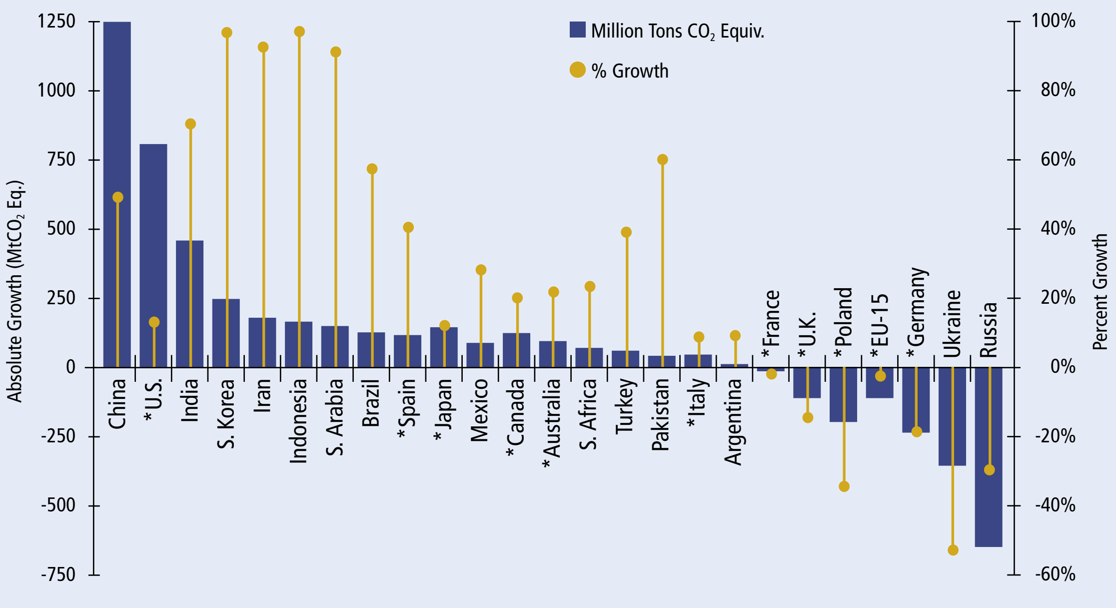
The decomposition analysis shows the importance of population, income, energy intensity, and fuel mix shifts in shaping energy-related emission trends. These factors are discussed in greater depth in Chapters 4 (population) and 5 (energy intensity, fuel mix). It is important to note, however, that the drivers of GHG emissions are more complex and multifaceted than suggested by the decomposition analysis. This report illustrates a range of additional factors that shape emission levels and trends, including natural resource

Figure 2.6. Emission Profiles by Gas and Source



Sources & Notes: WRI, CAIT. Data is from 2000. "LUCF" is land use change and forestry. LUCF is not shown in developed countries because this sector is believed to be a net absorber of CO_2. "Least developed countries" is a subset of "developing countries."

Figure 2.7. GHG Emissions Growth, 1990–2002



Sources & Notes: WRI, CAIT. Countries without asterisks are CO_2 only; countries with asterisks (*) include six GHGs (CAIT-UNFCCC, based on national inventories submitted by Parties to the UNFCCC).

Figure 2.8. Factors Contributing to CO_2 Emissions Growth, 1990–2002

	CO_2 Change 1990–2002		% Contributions to CO_2 Changes				
Country	$MtCO_2$	%	GDP per capita (GDP/Pop)	Population (Pop)	Energy Intensity (E/GDP)	Fuel Mix (CO_2/E)	Non-CO_2 % Changes (1990–2000)
China	1,247	49	122	15	-96	8	21
United States	863	18	23	16	-20	-1	4
India	457	70	55	28	-31	19	20
South Korea	246	97	84	15	12	-15	49
Iran	178	93	44	26	24	-1	46
Indonesia	164	97	44	25	2	26	13
Saudi Arabia	148	91	-7	46	52	0	50
Brazil	125	57	17	21	7	13	10
Spain	98	44	31	6	7	-1	21
Japan	96	9	12	3	0	-7	24
Mexico	87	28	17	22	-12	1	3
Canada	87	20	24	13	-18	0	15
Australia	73	28	31	16	-19	-1	11
South Africa	69	23	-2	28	-2	-1	11
Turkey	59	39	16	25	0	-2	9
Pakistan	40	60	18	38	-1	5	29
Italy	33	8	17	2	-6	-5	4
Argentina	10	9	17	13	-9	-11	9
France	2	0	17	5	-6	-15	-12
United Kingdom	-36	-6	24	3	-20	-13	-32
Poland	-60	-17	35	0	-46	-6	-24
EU-25	-70	-2	21	3	-14	-12	-18
Germany	-127	-13	15	4	-21	-10	-33
Ukraine	-291	-48	-32	-5	40	-51	-35
Russian Federation	-453	-23	-5	-3	-12	-3	-44

Notes: Methodology was adapted from Ang, 2001. See Box 2.1. CO_2 excludes land use change and forestry. For Russia and Ukraine, the time period evaluated is 1992 to 2002, due to lack of energy data in 1990.

Box 2.1. Factors Driving Energy-Related CO_2 Emissions

One approach to understanding energy-related CO_2 emissions is a simple model utilizing four factors: activity levels, structure, energy intensity, and fuel mix. Altering any of these factors—alone or in combination—can influence emissions. By way of illustration, the farther one drives a car (*activity*), the more CO_2 emissions will result. However, fewer emissions will also result if the car is more energy efficient (*energy intensity*), and emissions might be avoided entirely if the car is operating on a zero-carbon fuel (*fuel mix*).

Equation A

$$CO_2 = \overset{\text{Activity}}{\overset{\swarrow \qquad \searrow}{\frac{\text{GDP}}{\text{Person}} \times \text{Population}}} \times \overset{\text{Energy Intensity}}{\overset{\downarrow}{\frac{\text{Energy}}{\text{GDP}}}} \times \overset{\text{Fuel Mix}}{\overset{\downarrow}{\frac{CO_2}{\text{Energy}}}}$$

Equation A represents these dynamics at the economy-wide level. An additional factor not represented directly is *structure*. For example, a structural change away from heavy industry (high energy inputs) toward commercial activities (e.g., financial or insurance, with low energy inputs) will reduce emissions, even if all other factors remain unchanged over time. Similarly, a shift from domestic production to imports of energy-intensive goods represents structural change. There are no specific national-level indicators to denote structure. Rather, structural changes are part of the energy intensity factor (which decreases when there is structural change away from industry and toward services, for instance).

Isolating the degree to which the discrete variables in Equation A are driving energy-related CO_2 emissions is done through a technique called decomposition analysis.* Decomposition analysis identifies and quantifies the contribution of each factor toward changes in the aggregate indicator over a specific time period (CO_2 changes from 1990 to 2002, in this case). Factors can have compounding or offsetting effects on changes in emissions. Relatively small changes in factors can result in a large change in emissions when all the factors change in the same direction. On the other hand, large changes in one factor can be offset by opposing changes in other factors, resulting in only a small change in emissions.

This decomposition model only accounts for energy-related CO_2 emission changes. In some cases, overall GHG changes are significantly influenced by increases or decreases in non-CO_2 gases. For that reason, the final column in Figure 2.8 shows changes in non-CO_2 emissions. Finally, *percentage* changes such as those shown in the table should be evaluated in the context of absolute shifts. This effect can be seen in the second column of Figure 2.8.

* The approach to decomposition analysis employed in this paper follows the methodology of Ang (2001).

endowments (Chapter 8), climatic conditions (Chapter 8), and trade (Chapter 9). A further set of factors influence most of the non-CO_2 emissions, including developments in the agriculture (Chapter 15), waste (Chapter 16), and forestry (Chapter 17) sectors.

Implications for International Climate Cooperation

Focus on the largest countries, developed and developing. Because global emissions are concentrated among a small number of political entities, these entities are by definition crucial to achieving the environmental objective of the Climate Convention. A regime that does not establish adequate GHG mitigation incentives and/or obligations within these political entities—through domestic initiatives, international agreements, or both—will fail environmentally. Given the diversity of large emitting countries, it is simply not possible to adequately address the climate change problem without engaging both developed and developing countries. However, the specific incentives and obligations within an agreement are likely to differ by country due to a variety of factors, such as economic structure and development level.

Along these lines, it is often said that successful climate agreements must be "global." This is only true insofar as this term is shorthand for engaging the largest emitters. Successful mitigation agreements need not be global, in the sense of engaging all countries. The least developed countries and small island developing states, most of which have negligible emissions, are not critical to GHG mitigation efforts.

The strong concentration of emissions among a relatively small number of countries might suggest possible changes in the structure of international climate negotiations with respect to mitigation actions. Alternative institutional models might be explored that engage the major emitting countries as a group, either within or outside the U.N. Climate Convention.