Greenhouse Gas Emissions: Perspectives on the Top 20 Emitters and Developed Versus Developing Nations

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Summary

Using the World Resources Institute (WRI) database on greenhouse gas emissions and related data, this report examines two issues. The first issue is the separate treatment of developed and developing nations under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. This distinction has been a pivotal issue affecting U.S. climate change policy. The second issue is the difficulty of addressing climate change through limiting greenhouse gas emissions to a specified percentage of baseline emissions (typically 1990). The data permit examination of alternative approaches, such as focusing on per capita emissions or the greenhouse gas emission intensity (measured as emissions per unit of economic activity). Key findings include:

- A few countries account for most greenhouse gas emissions: in 2005, China led by emitting 19% of the world total, followed closely by the United States with 18%; no other country reached 6%; the top seven emitters accounted for 52% of the 185 nations' emissions.
- Land-use effects (e.g., deforestation) on emissions are negligible for most nations, but they cause emissions to rise sharply for certain developing nations, most notably Brazil and Indonesia.
- While oil- and gas-producing Gulf States have the highest per capita greenhouse gas emissions, in general developed nations rank high in per capita emissions (in 2005, Australia, the United States, and Canada ranked 5, 7, and 8, respectively, in the world), while developing nations tend to rank low (China, Brazil, and Indonesia, and India ranked 71, 73, 100, and 119, respectively).
- The greenhouse intensity of the economy—the metric by which the George W. Bush Administration addressed climate change—varies substantially among developed countries (in 2005, not accounting for land use, Ukraine emitted 503 tons/million international $GDP, while France emitted 81 tons/million $GDP, with the United States at 153 tons/million $GDP; developing nations range from the 140s (Mexico and South Korea) to 369 (China).
- The time frame adopted for defining the climate change issue and for taking actions to address greenhouse gas emissions has differential impacts on individual nations, as a result of individual resource endowments (e.g., coal versus natural gas and hydropower) and stage of economic development (e.g., conversion of forest land to agriculture occurring before or after the baseline).

Differentiating responsibilities between developed and developing nations—as the UNFCCC does—has failed to engage some of the largest emitters effectively. Moreover, many developed countries have not achieved stabilization of their emissions despite the UNFCCC. Given the wide range of situations illustrated by the data, a flexible strategy that allows each country to play to its strengths may be necessary if diverse countries like the United States and China are ever to reach agreement.

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Introduction

Climate change is a global issue;[1] however, greenhouse gas emissions data on a global basis are incomplete. Some developing countries have no institutions for monitoring greenhouse gas emissions and have never reported such emissions to the United Nations Framework Convention on Climate Change (UNFCCC).[2] In a similar vein, data on individual greenhouse gases, sources, and land-use patterns vary greatly in quality. Despite shortcomings in the data, the emerging picture of emissions has implications for considering alternative policies for controlling emissions. First, the picture outlines the estimated contributions of individual countries. Second, evaluating those emissions in terms of socio-economic characteristics (e.g., population and economic activity) provides insights on the potentially divergent interests of differing groups of nations—especially concerning developed nations versus developing ones.[3]

The World Resources Institute (WRI) has compiled greenhouse gas emissions and related data from a variety of sources into a database that is available for analysis.[4] Covering 185 nations (plus a separate entry combining the members of the European Union),[5] the database includes total emissions, per capita emissions, and greenhouse gas (or carbon) intensity,[6] selected socio-economic indicators, and other measures. Emissions data for all six greenhouse gases[7] identified by the UNFCCC are available for 1990, 1995, 2000, and 2005 for both developed and non-Annex I nations. Data for carbon dioxide (CO_2) are available back to 1850 and up to 2005 for both developed and non-Annex I nations. Data on the effects of land use change and forestry on CO_2 emissions are only available from 1975 to 2000.

This report uses the data compiled by WRI to examine a pivotal and long-running issue surrounding U.S. climate change policy: the appropriate roles of developed and developing countries in addressing climate change.

The UNFCCC states as its first principle in Article 3:

> The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but

[1] For background, see CRS Report RL34513, *Climate Change: Current Issues and Policy Tools*, by Jane A. Leggett.

[2] For the most recent developments on submissions to the UNFCCC by non-Annex 1 countries, see http://unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php.

[3] The UNFCCC divides nations into two groups, nations listed in Annex I (which under the Kyoto Protocol would have specified reduction targets), encompassing "developed" nations including Eastern Europe and the former Soviet Union; and non-Annex I nations (which do not have specified reduction targets), including the rest of the world.

[4] Called the Climate Analysis Indicators Tool (CAIT), the database uses a variety of data sources to provide information on greenhouse gas emissions, sinks, and other relevant indicators. Full documentation, along with caveats, is provided on the WRI website at http://cait.wri.org/.

[5] Both the individual countries of the European Union and the European Community as an entity are Parties to the Kyoto Protocol. Within the EU, the differing situations of each constituent nation have resulted in differing emissions targets and policies for each country. While this analysis focuses on the implications of individual nations' situations, fifteen member states of the EU are authorized to meet their goals collectively.

[6] Carbon intensity is the ratio of a country's emissions to its gross domestic product (GDP), measured in international dollars (purchasing power parity).

[7] Carbon dioxide, nitrous oxide, methane, perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride.

> differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.[8]

The United States has struggled with the "common but differentiated responsibilities" of developing countries and with the pledge for the developed countries to "take the lead in combating climate change.... " The resulting debate concerns what actions to address greenhouse emissions should be "common" responsibilities (i.e., undertaken by all nations) and what actions should be "differentiated" (i.e., undertaken only by developed ones). Under the UNFCCC and the subsequent Kyoto Protocol, common actions include the responsibility to monitor and report emissions; differentiated actions include the commitment to reduce emissions to a 1990 baseline for designated developed nations, listed on Annex I to the UNFCCC (and hence known as Annex I nations).

Thus the UNFCCC, the Kyoto Protocol, and much of the current debate about actions to control greenhouse gas emissions focus on individual nations' amounts of emissions. As a result, primary attention falls on current greenhouse gas emissions, past greenhouse gas emissions, and projected greenhouse gas emissions. In this context, addressing global climate change has in effect meant reducing greenhouse gas emissions—for Annex I countries. (A complicating factor is that land use activities can affect net emissions, and the Kyoto Protocol provides methods for taking land use effects into account.) For the UNFCCC, the differentiated control action was for Annex I countries to take voluntary actions to ensure that their greenhouse gas emissions in 2000 did not exceed 1990 levels.[9] For the Kyoto Protocol, the differentiated control action was for Annex I countries to control emissions to individually specified percentages of baseline emissions, averaged over the period 2008-2012.[10] Under both the UNFCCC and the Kyoto Protocol, non-Annex I nations would be exempt from these specified control requirements—although they could voluntarily join in. This split in responsibilities—with the consequent lack of greenhouse gas control requirements for major emitting non-Annex I countries—played a key role in the United States' refusal to agree to the Kyoto Protocol.

Justifications for the differential treatment of the developed, Annex I nations compared to the developing nations are both environmentally and economically based.

- Environmentally, the developed, Annex I nations have dominated emissions. Cumulatively, from 1850 to 2005, Annex I nations had emitted 73.4% of energy-related CO_2, while non-Annex I nations had contributed 23.4%.[11] In 1990, when the UNFCCC was being conceived, Annex I nations accounted for 58.6% of emissions of all six greenhouse gases, while the non-Annex I nations accounted for 38.1%. By 2005, however, that ratio had shifted: non-Annex I nations accounted for 47.4% while Annex I nations accounted for 46.9%. Thus, while Annex I nations still dominate cumulative emissions, the rising share contributed by non-Annex I nations confounds the assignment of future obligations.

[8] *United Nations Framework Convention on Climate Change*, Article 3.1.

[9] The United States and many other countries failed to meet this voluntary goal. It was this general failure that gave impetus to the Kyoto Protocol to mandate reductions.

[10] Generally the baseline was 1990; the individual Annex I commitments were negotiated, with the U. S. commitment—*if* the United States had agreed to the Kyoto Protocol—being a 7% reduction.

[11] Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2008).

- Economically, as the UNFCCC explicitly recognizes, the development being pursued by the non-Annex I nations depends importantly on expanded use of energy, including fossil fuels, which are the main source of carbon dioxide, the dominant greenhouse gas. From this perspective, a logic for the differing treatment of the two groups is that the developed, Annex I countries can afford to control emissions because they have achieved a relatively high standard of living, while the developing nations have the right and should have the opportunity to expand energy use as necessary for their economic development.

This distinguishing of the responsibilities of the Annex I and non-Annex I nations generates crucial and interrelated tensions:

- First, this approach means that Annex I nations pay an economic price for addressing global climate change;
- Second, non-Annex I nations retain the opportunity to develop their economies using least-cost energy regardless of greenhouse gas emissions; this in turn means that from the perspective of the Annex I nations, developing nations—which may be competing in certain economic sectors—appear to be getting a free ride;
- And third, despite investments in controls and resulting tensions between competing economies, actual global emissions will continue to rise if the increase in emissions from non-Annex I nations exceeds any decrease in emissions achieved by Annex I ones.

The intensity of these tensions that arise from focusing on emissions levels is clear when one examines emissions data (see **Appendix A**, **Appendix B**, and **Appendix C**). To frame this discussion, CRS focuses on the 20 individual nations that emitted the most greenhouse gases in 2005.[12] The top 20 represent about 73% of global greenhouse gas emissions—an identical proportion for 1990 and for 2005 (latest available data from CAIT for all six greenhouse gases). In addition, data for the 27-member[13] European Union are included, as the Kyoto Protocol allows the EU to address its greenhouse gas emission obligations collectively. In 2005, the 27-nation EU was the third-largest emitter of greenhouse gases, after China and the United States.

A Look at the Historic Data

Most Recent (2005) and Baseline (1990) Emissions Data

A compelling fact to emerge from the database is that a few countries account for most of the emissions. **Appendix A**, **Appendix B**, and **Appendix C** present data concerning the top 20 greenhouse gas-emitting nations in 2005. They accounted for 73.5% of global emissions. Excluding land use data, by CAIT's accounting, China led in emitting greenhouse gases (1,970

[12] For a more general discussion of the top 25 emitters in the year 2000, see Kevin Baumert and Jonathan Pershing, *Climate Data: Insights and Observations* (Pew Center on Climate Change, December 2004).

[13] CAIT's EU-27 includes the EU-15 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom), plus Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia.

million metric tons of carbon equivalent, MMTCE)[14] at 18.6% of the total, followed by the United States (1,901 MMTCE) at 18.0%.[15] No other country reached 6% of total emissions (although the collective 27-member EU accounted for 13%); overall, only seven countries emitted 2% or more. These top seven emitters accounted for 55% of global emissions and the next 13 top emitters accounted for another 18% of emissions.

Thus one implication of these data is that greenhouse gas control in the short term depends mainly on the actions of a relatively few nations; if the top 20 emitters[16] (or even the top 10) all acted effectively, the actions of the remaining 160-plus nations would be of relatively little import, at least for years.

A second compelling fact about those top emitters is that they represent very different types and situations.[17] The top 20 nations include:

- Developed (Annex I) nations whose emissions *grew* between 1990 and 2005: the United States, Japan, Canada, Italy, France, Australia, Spain, and Turkey (ranked 2, 5, 8, 13, 14, 16, 18, and 20, respectively). These eight nations accounted for 29.8% of global greenhouse gas emissions in 2005.
- Developed (Annex I) nations whose emissions *declined* between 1990 and 2005, largely as a result of the collapse of the Eastern European and USSR socialist economies during the 1990s: Russian Federation, Germany,[18] and Ukraine, (ranked 3, 7, and 17, respectively). These three nations accounted for 8.8% of global greenhouse gas emissions in 2005.[19]
- Developed (Annex I) nations with free-market economies whose emissions *declined* between 1990 and 2005, largely because of a combination of low population growth, modest economic growth, and the displacement of high-emitting fuels (coal) with alternatives: the United Kingdom (ranked 9), is the only member of this category.[20] It accounted for 1.6% of global greenhouse gas emissions in 2005.
- Developing (non-Annex I) nations, all of whose emissions rose during the period: China, India, Brazil, Mexico, Indonesia, Iran, South Korea, and South Africa (ranked 1, 4, 6, 10, 11, 12, 15, and 19, respectively). These nine nations accounted for 33.2% of global greenhouse gas emissions in 2000.

[14] The UNFCCC provides a methodology for calculating the greenhouse gas contributions of nations and converting them to equivalent units—Million Metric Tons of Carbon Equivalents (MMTCE).

[15] However, for CO_2 only, the United States remained the leading emitter in 2005.

[16] Of the top 20 in1990, 18 are still in the top 20 15 years later, albeit with some shifting in order (most notably, China edging ahead of the United States in total greenhouse gas emissions). Kazakhstan dropped out of the top 20 early in the 1990s, and was replaced by Iran. Between 2000 and 2005, the only change in the top 20 was Turkey slipping ahead of Poland for the 20th spot.

[17] For a discussion of these situations, see CRS Report RL33970, *Greenhouse Gas Emission Drivers: Population, Economic Development and Growth, and Energy Use*, by John Blodgett and Larry Parker.

[18] Germany falls into this category as a result of its incorporation of East Germany. The pre-merger West Germany was of course not a centrally planned economy.

[19] Kazakhstan and Poland, which were in the top 20 in 1990, also fall into the Annex I nations with declining emissions; with the decline of their coal based economies, they have dropped out of the top 20, ranking 32 and 21 in 2005. Together they accounted for about 1.5% of 2005 emissions.

[20] France's emissions declined between 1990 and 2000.

For the year 2005, then, 12 of the top 20 countries were Annex I countries, including 6 of the top 10 emitters. In 2005, the top 20 Annex I countries accounted for about 55% of the top 20 group's greenhouse emissions, compared with 45% for the developing, non-Annex I countries; in 1990, the relative shares were 69% and 31%, respectively, so the developing countries have been proportionately increasing their share.

Highlighting the tension between Annex I and non-Annex I perspectives, the number-one emitters of each group were the top two emitters overall: At the top were the leading developing, non-Annex I country, China; and the leading developed, free-market economy, the United States. Combined, these two countries alone accounted for 36.6% of total global emissions.

Longer-Term Historical Data (1850-2005)

The impact of emissions on climate change is believed to be cumulative over decades and even centuries. Thus a longer-term examination of data provides an important perspective, and is one reason for the differing treatments of the Annex I and non-Annex I nations. Available data give emissions estimates of energy-related CO_2 emissions back from1850 to 2005 (with land use changes and forestry, from 1950 to 2000) (see **Appendix A** and **Appendix C**).

This longer-term view of emissions underscores the contribution of the Annex I nations:

- For all nations, excluding land use changes and forestry practices, Annex I countries' share of energy-related CO_2 emissions over the period 1850-2005 is 73%; non-Annex I countries' share is 23%. The ratio is similar for 1950-2000, 71 % to 26% (see also **Table 1**).
- The relative rankings of several developing countries, including Brazil, South Korea, Indonesia, and Iran, drop substantially using a longer historical baseline for emissions: from the 2005 rank to the 1850-2005 cumulative rank for CO_2, from 6^{th} to 21^{st}, 15^{th} to 20^{th}, 11^{th} to 25^{th}, and 12^{th} to 23^{rd}, respectively.

Greenhouse gas emissions, particularly energy-related emissions, are closely tied to industrialization. As "developed" is considered by many to be synonymous with "industrialized," it is not surprising that the developed countries dominate cumulative emissions, while developing ones are increasing their current annual share.

Impact of Land Use

Changes in land use can significantly affect net levels of emissions.[21] In general, deforestation increases CO_2 emissions and afforestation decreases them. Certain agricultural practices can increase emissions of methane or nitrous oxide. However, data on the effects on emissions of land use changes and forestry practices, and their conversion into equivalent units of greenhouse gas emissions, are both less available and less robust than data on emissions. Therefore, this discussion (see **Appendix A** and **Appendix C**) is at best illustrative.

Including land use in the calculations focuses discussion on certain developing countries.

[21] See CRS Report RS22964, *Measuring and Monitoring Carbon in the Agricultural and Forestry Sectors*, by Ross W. Gorte and Renée Johnson.

- Land use changes and forestry practices in certain developing countries, notably Brazil and Indonesia, are having the effect of substantially upping their relative emissions ranks. Counting land use, Brazil's emissions in 2000 rise from 257 MMTCE to 632 MMTCE (+146%), and Indonesia's rise from 137 to 837 (+511%). This ups their rankings of total emissions in 2000 from 8th to 4th, and 16th to 3rd, respectively.
- Compared to Brazil and Indonesia, the impact of accounting for land use on other top 20 emitters is much less. The next biggest adjustment is for Mexico, whose emissions rise 17% when land use is accounted for. For the United States, net emissions drop by 110 MMTCE (nearly 6%); its relative rank (as number 1 in 2000) does not change when land use is taken into account.
- Including land use changes and forestry practices in cumulative energy-related CO_2 emissions substantially increases the non-Annex I nations' share of global emissions: between 1950 and 2000, excluding land use, cumulative emissions were 71% for Annex I nations and 26% for non-Annex I nations; accounting for land use and forestry, the proportions are 51% to 46%.

What the land use changes and forestry practices data reflect are the relatively stable land use patterns of countries where most land-clearing and agricultural development occurred before 1950. The Western developed nations and China and India, for example, have long-established agricultural practices; in contrast, Brazil and Indonesia have over the past few decades been clearing large regions of forest and jungle for timber and/or conversion to agriculture, releasing greenhouse gases (or removing sinks). In terms of the UNFCCC and the Kyoto Protocol, including land use in the equation for controlling emissions disadvantages certain countries whose exploitation of resources and development of agriculture are occurring at a particular moment in history.

Implications of Focusing on Emissions Levels for International Actions

The data on greenhouse gas emissions highlight issues of both effectiveness and fairness in the effort to address global climate change. Differentiating responsibilities between Annex I and non-Annex I nations, as the UNFCCC has, does not focus efforts on all of the largest emitters. As **Table 1** shows, the emissions dominance of Annex I nations that existed in 1990 has ended: in 2005 global greenhouse gas emissions are closely split between Annex I and non-Annex I nations—in fact, non-Annex I emissions now surpass those of Annex I nations.

Moreover, contradictory issues of fairness arise. For Annex I countries, the present scheme of controlling greenhouse gases requires them to bear essentially all the direct economic costs. For non-Annex I countries, to the extent that development is linked to increasing greenhouse gas emissions, imposing controls on them could slow their development and hold down their standards of living vis-a-vis the developed nations.

Finally, the focus on emissions levels at specific times (e.g., a baseline of 1990) has differential and arbitrary impacts on individual nations.

- Looking at the industrialization process, to the extent that fossil fuel use is a necessary ingredient of economic development, as acknowledged by the UNFCCC, the emergence of the global climate change issue at this time effectively determines the distinction between the developed, Annex I nations and the developing, non-Annex I nations. For Annex I nations, that energy exploitation has been incorporated into their economies and is part of their baseline for considering any controls on greenhouse gases. For developing, non-Annex I nations, however, economic development will require expanded energy use, of which fossil fuels can be the least costly. Thus imposing limits on fossil energy use at this time could result in developing countries being relegated to a lower standard of living than those nations that developed earlier.
- Similarly, certain land-use activities, such as clearing land for agriculture and exploiting timber, affect net greenhouse gas emissions. Nations that are currently exploiting their resource endowments, such as Brazil and Indonesia, could find themselves singled out as targets for controls. Yet developed nations, like the United States and most European countries, which exploited such resources in the past, have those greenhouse gas implications embedded in their baselines.
- Also, the focus on 1990 as a baseline means that the Eastern European and former Soviet Union nations have the advantage of reductions in emissions from their subsequent economic contractions, which will allow them room for growth. Likewise, the discovery and exploitation of North Sea gas has allowed Great Britain to back out coal and thereby reduce emissions since the baseline.

In all these cases, the time frame adopted for defining the climate change issue and for taking actions to address greenhouse gas emissions has differential impacts on individual nations, as a result of their individual resource endowments[22] and stage of economic development. The differential impacts give rise to perceived inequities. Thus the effort to find a metric for addressing greenhouse gas emissions baselines and targets that will be perceived as equitable is challenging.

Table 1. Shares of Global Emissions by the Industrialized (Annex I), Developing (non-Annex I), and Top 20 Countries

Indicator	Industrialized (Annex I) Countries n = 38[a]	Developing (non-Annex I) Countries n = 147	Top 20 Nations
1990 GHG Emissions (excl. land use)	58.6%	38.1%	73.5%
2005 GHG Emissions (excl. land use)	45.9%	47.4%	73.5%
2000 GHG Emissions (excl. land use)	50.8%	45.3%	73.2%
2000 GHG Emissions (with land use)	40.8%	56.0%	68.7%
Cumulative Energy-Related CO2 Emissions 1950-2000 (excl. land use)	71.1%	25.5%	83.0%

[22] E.g., the availability of natural gas and/or coal, and when each has been or is being exploited; or the extent of deforestation and/or afforestation, and when either has occurred.

Indicator	Industrialized (Annex I) Countries n = 38[a]	Developing (non-Annex I) Countries n = 147	Top 20 Nations
Cumulative Energy-Related CO2 Emissions 1950-2000 (with land use)	51.1%	46.1%	72.2%

Source: CRS calculations; Climate Analysis Indicators Tool (CAIT) Version 6.0 (Washington, DC: World Resources Institute, 2008).

a. Counting the European Union countries individually, excluding the EU as a collective member.

Alternative Perspectives

The problems raised above prompt the question: What alternatives to controls derived from historically based emissions levels are available? Alternative metrics for taking into account greenhouse gas emissions and economic development include per capita emissions and economic intensity of emissions.[23]

Per Capita Emissions

The socioeconomic differences between the developed, Annex I nations and the developing nations lead to considerations about emissions other than simply their absolute amounts. One alternative is to consider per capita emissions: All else equal, populous nations would emit more greenhouse gases than less populated ones. On this basis, the difference between developed, Annex I countries and non-Annex I ones is apparent.

Appendix A and **Appendix B** show that of the top 20 emitters in 2005, the highest ranked by per capita greenhouse gas emissions[24] are developed countries (Australia, United States, and Canada, ranked 5, 7, and 8, respectively). Their per capita emissions (7.3, 6.4, and 6.2 tons per person, respectively) are double the emissions of the highest-ranked developing country in the top 20 (South Korea, at 3.1), and over four times that of China (1.5). The rankings for the non-Annex I countries in the top 20 emitters range from 31 (South Korea) to 119 (India), with China ranked 71. In contrast, Annex I countries range from 5 (Australia) to 46 (France), with the United States at 7. Reasons the United States, Australia, and Canada are so high on this measure include their dependence on energy-intensive transport to move people and goods around countries of large size and relatively low population density, the use of coal for power generation, and the energy requirements for resource extraction industries.

Thus, if one were considering how to control greenhouse gas emissions, one way of trying to bridge the different interests of the developed, Annex I nations and the developing ones would be to focus on per capita emissions as a way of giving each nation an equitable share of energy use. For the United States compared to the developing world, this metric could imply constraints,

[23] For other analyses bearing on this question, see CRS Report RL32762, *Greenhouse Gases and Economic Development: An Empirical Approach to Defining Goals*, by John Blodgett and Larry Parker; and CRS Report RL33970, *Greenhouse Gas Emission Drivers: Population, Economic Development and Growth, and Energy Use*, by John Blodgett and Larry Parker.

[24] The top four by this measure are oil- and gas-producing Gulf States.

depending on the compliance time frame and future technological advancements. Likewise, this approach could permit most less-developed countries to increase their emissions to accommodate expanding economies.

Greenhouse Gas Intensity of Economy

Another alternative for evaluating a nation's contribution to greenhouse gas emissions is to consider how efficiently that nation uses energy (and conducts other greenhouse gas-emitting activities) in producing goods and services. This concept is captured by greenhouse gas intensity—or carbon intensity[25]—measured as the amount of greenhouse gases emitted per million dollars of gross domestic product, measured in international dollars (parity purchasing power) (see **Appendix A, Appendix B,** and **Appendix C**). Carbon intensity as a greenhouse gas indicator has received considerable attention since President Bush decided to use it as a benchmark for his voluntary climate change program. Also, the World Resources Institute has advocated its use as an appropriate index for developing, non-Annex I nations.[26]

A nation's greenhouse gas intensity reflects both its resource endowment and the energy-intensiveness of its economy. In terms of energy resources, countries with rich resources in coal would tend to be higher emitters, while countries with rich resources in hydropower or natural gas would tend to be lower emitters. In terms of economic activity, countries with major heavy industry, major extractive industries, and extensive transportation systems tend to be higher emitters, while countries without these and/or dominated by service industries would tend to be lower emitters. As noted in terms of emissions, taking into account land use sharply increases the greenhouse gas intensity of Brazil and Indonesia.

These variables do not differentiate nations simply; overall, the top 20 emitters in 2005 (see **Appendix A, Appendix B,** and **Appendix C**) range widely in greenhouse gas intensity: from 503 tons per million international $GDP (Ukraine, which relies heavily on coal) to 81 tons/million international $GDP (France, which relies heavily on nuclear power for generating electricity). These are both Annex I nations; non-Annex I nations have a narrower range, from the 146 tons/million international $GDP (Mexico and South Korea) to 290 tons/million international $GDP (South Africa). Taking into account land use, however, would dramatically raise the intensity of Brazil and Indonesia: in 2000 it jumped Brazil by 145%, to 507 tons/million international $GDP and Indonesia by 510%, to 1,397 tons/million international $GDP; the next largest increase from land use change was Mexico at 17%.

As a metric for considering how to control greenhouse gas emissions, intensity focuses attention on the efficient use of energy and on the use of alternatives to fossil fuels. Thus, a greenhouse gas intensity metric would reward the use of renewables, hydropower, and nuclear power in place of fossil fuels; and among fossil fuels it would reward natural gas use and penalize coal use (with oil use falling in between).

[25] While the term "greenhouse gas intensity" encompasses all six greenhouse gases, the term "carbon intensity" is sometimes used identically and implicitly means "carbon equivalents intensity" and other times is used more narrowly to refer only to carbon emissions. The discussion in this analysis focuses on "greenhouse gas intensity," unless otherwise noted (e.g., in the discussion of cumulative emissions).

[26] See Kevin A. Baumert, Ruchi Bhandari, and Nancy Kete, *What Might A Developing Country Climate Commitment Look Like?* World Resources Institute Climate Notes, May 1999.

For greenhouse gas intensity, in 2005 the United States ranked number 72 in the world, making this a more favorable metric than absolute emissions (the United States ranked number 2 in the world) and per capita emissions (the United States ranked number 7). (The larger the intensity ranking number, the less GHGs emitted per dollar of GDP.) Of the indicators examined here, the United States gets the most favorable results from this one. Nevertheless, in absolute terms, the United States is relatively inefficient with respect to intensity compared with Western European countries (the EU-27 would have ranked 109 and Japan ranked 118. In addition, the United States is less efficient than non-Annex I emitters South Korea, and Mexico, but it is more efficient than China, India, Brazil, South Africa, Indonesia, and Iran.

Discussion

As stated above, the data on greenhouse gas emissions highlight issues of both effectiveness and fairness with respect to current efforts to address global climate change. Differentiating responsibilities between Annex I and non-Annex I countries fails to focus efforts on all the largest emitters. In addition, contradictory issues of fairness arise, as Annex I countries bear essentially all the direct economic costs of reducing emissions, and non-Annex I countries are granted the right to increase emissions to meet developmental needs. Finally, the focus on historical emissions as a baseline for regulation has differential and arbitrary impacts on individual nations.

The result of the UNFCCC and Kyoto Protocol's setting emissions targets for only developed nations and focusing on returning their emissions to a specific baseline is twofold: (1) the current regime has had little effect on global emissions, and will have little effect in the near future; and (2) the largest emitters, the United States and China, have not found it in their interests to join in the international effort to a significant degree. Indeed, the United States has pulled completely out of the Kyoto process. Proponents of the Kyoto Protocol assert that although it is only a first step, it is one that must be taken.

This history of the UNFCCC and the Kyoto Protocol raises serious questions about how to develop greenhouse gas targets, time frames, and implementation strategies. With respect to targets, the UNFCCC recognized the right of developing countries to develop and the responsibility of all countries to protect the global climate. These goals of the UNFCCC suggest that if there is to be any permanent response to climate change that involves controlling greenhouse gases, then a regime that combines some measure reflecting the right of developing countries to develop, such as per capita emissions, and some measure reflecting the need to be efficient, such as carbon intensity, may be necessary to move the world toward a workable and effective climate change framework.

As shown above a global target focused on per capita emissions generally rewards developing nations,[27] providing them room for economic growth; the target's balance between limiting emissions and permitting growth determines the individual winners and losers. For example, based on **Appendix B**, a target of 3 tons carbon per person would allow all the developing nations in the top 20 emitters except South Korea growth room (South Korea is at 3.1 tons per capita), while five developed nations (United States, Russian Federation, Germany, Canada, and Australia) would have to make cuts. In contrast, a target focused on greenhouse gas intensity would have more diverse implications for developing nations. Several major developing nations

[27] An exception is several Gulf States that are high emitters due to exploitation of their oil reserves.

produce considerably higher greenhouse gas emissions per million dollars of GDP than some developed nations. For example, in 2005 China's carbon intensity was over 3.8 times that of Japan's and Italy's (369 tons/million international $GDP versus 95). Thus a greenhouse gas intensity goal could be a counterforce to the economic development process for some countries, meaning that the winners and losers of a regime combining per capita and carbon intensity measures could be highly dynamic and contentious. Adding land-use implications would further complicate the regime, and selectively affect certain nations, especially those just now at the point of exploiting forests (notably Indonesia and Brazil).

For the United States, a regime containing some mix of per capita and greenhouse gas intensity measures[28] would likely imply a need to constrain emissions over some time frame. The U.S. greenhouse gas intensity is declining, as is the case with most nations, but the decrease currently does not completely offset increased emissions resulting from the growth of population and of the economy. The extent to which targets could translate into economic costs would depend on the other two features of the regulatory scheme: (1) time frame (specifically, whether it would accommodate technological advances in less-carbon-intensive technology or accelerated commercialization of existing low-carbon technologies such as nuclear power); (2) implementation strategy (specifically, whether it encourages least-cost solutions and development of advanced technologies).

With respect to time frame, the data indicate two things: (1) most countries that achieved a significant reduction during the 1990s did so as a result of either an economic downturn or a substantial realignment in energy policy; (2) many countries have not been able to stabilize their emissions despite the UNFCCC's voluntary goal, much less reduce them. That failure was the impetus for the Kyoto Agreement's prescribed reductions. Using economic contraction as an emission reduction strategy can scarcely be considered an option. Instead, the substantial development and/or deployment of less-carbon-intensive technology, improved land-management strategies, and other actions would be necessary to achieve stabilized emissions. As noted above, greenhouse gas emissions are closely tied to industrialization—a synonym for "developed." With few exceptions, improvement in efficiency has been gradual. A permanent transformation of the global economy necessary to ensure a long-term stabilization of greenhouse gas emissions may involve a multi-stage, long-term time frame.

The difficulty in implementing the UNFCCC suggests implementation and compliance are still an open issue. The United States submitted climate action plans during the 1990s indicating it would achieve the UNFCCC goal of returning emissions to 1990 levels. It did not. There were no sanctions. Likewise, some Kyoto signatories may not achieve their reduction targets in 2008-2012. The sanctions are unclear. Given the wide range of situations illustrated by the data, a flexible strategy that permits each country to play to its strengths may make it easier for diverse countries like the United States and China to reach some acceptable agreement.

The extent of flexibility would depend on the balance between emission reductions and economic cost designed into the targets, time frame, and implementation strategy. Market-based mechanisms to reduce emissions focus on specifying either the acceptable emissions level (quantity), or compliance costs (price), and allowing the marketplace to determine the economically efficient solution for the other variable. For example, a tradeable permit program

[28] See CRS Report RL33970, *Greenhouse Gas Emission Drivers: Population, Economic Development and Growth, and Energy Use*, by John Blodgett and Larry Parker.

sets the amount of emissions allowable under the program (i.e., the number of permits available caps allowable emissions), while permitting the marketplace to determine what each permit will be worth. Conversely, a carbon tax sets the maximum unit (per ton of CO2) cost that one should pay for reducing emissions, while the marketplace determines how much actually gets reduced.

Hence, a major implementation question is whether one is more concerned about the possible economic cost of the program and therefore willing to accept some uncertainty about the amount of reduction received (i.e., carbon taxes), or one is more concerned about achieving a specific emission reduction level with costs handled efficiently, but not capped (i.e., tradeable permits). Of course, combinations of these approaches are possible, depending on the flexibility desired.[29] The data presented here portray a very wide range of situations and conditions among the 20 top countries that represent over 70% of total emissions. Significant flexibility may not only be desirable but necessary for them to reach any significant agreement.

[29] See CRS Report RL33799, *Climate Change: Design Approaches for a Greenhouse Gas Reduction Program*, by Larry Parker; CRS Report RL30024, *U.S. Global Climate Change Policy: Evolving Views on Cost, Competitiveness, and Comprehensiveness*, by Larry Parker and John Blodgett; and CRS Report RS21067, *Global Climate Change: Controlling CO2 Emissions—Cost-Limiting Safety Valves*, by Larry Parker.

Appendix A. Relative Ranking of 20 Top Emitters (Plus EU-27) of Greenhouse Gases Based on 2005 Greenhouse Gas Emissions

Table A-1.

Country	Annex I	2005 GHG Emissions (without land use)	1990 GHG Emissions (without land use)	2005 Per Capita GHG Emissions (without land use)	2005 GHG Intensity (without land use)	2000 GHG Emissions (with land use)	1850-2005 Cumulative Energy CO_2 Emissions (without land use)	1950-2000 Cumulative Energy CO_2 Emissions (with land use)
China	No	1	2	71	17	2	2	2
United States	Yes	2	1	7	72	1	1	1
European Union-27	*Yes*[a]	*[3]*[b]	*[2]*	*[39]*	*[109]*	*[2]*	*[2]*	*[2]*
Russian Federation	Yes	3	3	18	23	5	3	3
India	No	4	6	119	49	6	8	13
Japan	Yes	5	5	37	118	7	6	7
Brazil	No	6	9	73	63	4	21	5
Germany	Yes	7	4	25	106	8	4	6
Canada	Yes	8	10	8	61	10	9	9
United Kingdom	Yes	9	8	36	120	12	5	8
Mexico	No	10	13	64	74	11	15	16
Indonesia	No	11	17	100	38	3	25	4
Iran	No	12	22	53	34	20	23	32
Italy	Yes	13	12	44	116	14	12	15
France	Yes	14	11	46	132	13	7	12
Korea (South)	No	15	19	31	75	16	20	24
Australia	Yes	16	15	5	37	17	14	18
Ukraine[c]	Yes	17	7	39	8	18	11	11
Spain	Yes	18	20	40	109	26	18	25

South Africa	No	19	16	47	26	22	14	20
Turkey	Yes	20	21	72	77	24	29	35

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0. (Washington, DC: World Resources Institute, 2008).

a. European Union members, listed in Annex I, signed the Kyoto Protocol individually and, collectively, as the EU. The Protocol gave explicit authority to the original 15 member European Union to meet its obligations collectively; the EU has coordinated the compliance strategies of the newer member states into its overall compliance scheme, but those countries retain their individual Kyoto reduction targets.

b. The bracketed numbers would be the ranking of the EU; if the EU ranking were counted, equal and lower rankings would increase by one (e.g., Turkey would rank 21st in 2005 emissions and 73rd in 2005 per capita emissions, but remain at 77th in 2005 GHG intensity).

c. Data from land use change and forestry not available.

Appendix B. Greenhouse Gas Emissions and Other Climate Change-Related Indicators for 2005 Top 20 Emitting Countries

Table B-1.

2005 Rank	Country	Annex I	2005 GHG Emissions MMTCE	2005 GHG missions % of World	1990 GHG Emissions MMTCE	1990-2005 Emissions Difference MMTCE	1990-2005 Increase or Decrease %	2005 Per Capita GHG Emissions (tons C/person)
1	China	No	1,970	18.6%	981	989	100.8%	1.5
2	United States	Yes	1,901	18.0%	1,631	270	16.6%	6.4
[3]	*European Union-27*	*Yes[a]*	*1,378*	*13.0%*	*1,472*	*-94*	*-6.4%*	*2.8*
3	Russian Federation	Yes	535	5.1%	803	-268	-33.4%	3.7
4	India	No	506	4.8%	301	205	68.1%	0.5
5	Japan	Yes	366	3.5%	322	44	13.7%	2.9
6	Brazil	No	277	2.6%	188	89	47.3%	1.5
7	Germany	Yes	267	2.5%	326	-59	-18.1%	3.2
8	Canada	Yes	200	1.9%	158	42	26.6%	6.2
9	United Kingdom	Yes	175	1.7%	195	-20	-10.3%	2.9
10	Mexico	No	172	1.6%	125	47	37.6%	1.7
11	Indonesia	No	162	1.5%	91	71	78.0%	0.7
12	Iran	No	155	1.5%	67	88	131.3%	2.2
13	Italy	Yes	154	1.5%	137	17	12.4%	2.6
14	France	Yes	150	1.4%	147	3	2.0%	2.5
15	Korea (South)	No	150	1.4%	84	66	78.6%	3.1
16	Australia	Yes	150	1.4%	110	40	36.4%	7.3
17	Ukraine	Yes	132	1.2%	255	-123	-48.2%	2.8

18	Spain	Yes	120	1.1%	77	43	55.8%	2.8
19	South Africa	No	115	1.1%	91	24	26.4%	2.5
20	Turkey	Yes	107	1.0%	72	35	48.6%	1.5
Total[b]			7,764	73.5%	6,161	1,603	26.0%	
	WORLD		10,569	100.0%	8,380	2,189	26.1%	1.6

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0. (Washington, DC: World Resources Institute, 2008).

a. The Kyoto Agreement gave explicit authority to the original 15 member European Union to meet its obligations collectively; the EU has in effect expanded that authority as it has incorporated new members. If the EU-27 were ranked in terms of its 2005 GHG emissions, it would place 3rd.

b. Totals are of the 20 individual nations; they do not include the European Union.

Appendix C. Additional Emissions and Other Climate Change-Related Indicators for 2005 Top 20 Emitters

Table C-1.

2000 Rank	Country	2000 GHG Emissions (without land use) (MMTCE)	2000 GHG Emissions (with land use) (MMTCE)	1950-2000 Cumulative Energy CO2 Emissions (without land use) (MMTCE)	1950-2000 Cumulative Energy CO2 Emissions (with land use) (MMTCE)	2005 GDP (millions of international $)	2005 GHG Intensity (without land use) (tons/million intl. $GDP)
1	China	1,315	1,302	18,888	29,508	$5,333,233	369
2	United States	1,868	1,758	57,594	50,444	$12,397,900	153
[3]	*European Union-27*[a]	*1,342*	*1,336*	*49,693*	*49,882*	*$13,031,057*	*106*
3	Russian Federation	520	535	20,805	24,582	$1,697,957	315
4	India	435	424	4,961	4,636	$2,440,832	207
5	Japan	358	360	9,998	11,355	$3,870,284	95
6	Brazil	257	632	1,933	18,567	$1,583,162	175
7	Germany	275	275	12,608	12,659	$2,510,750	106
8	Canada	191	210	4,762	6,180	$1,130,010	177
9	United Kingdom	173	173	7,965	7,960	$1,889,387	92
10	Mexico	157	183	2,424	3,598	$1,173,898	146
11	Indonesia	137	837	1,161	21,833	$707,874	229
12	Iran	116	118	1,512	1,666	$643,503	240
13	Italy	146	145	3,939	3,938	$1,626,330	95
14	France	148	146	5,068	5,082	$1,862,193	81
15	Korea (South)	139	140	1,844	2,080	$1,027,374	146
16	Australia	138	139	2,462	2,823	$645,777	232
17	Ukraine[b]	126	126	5,652	5,652	$263,007	503

2000 Rank	Country	2000 GHG Emissions (without land use) (MMTCE)	2000 GHG Emissions (with land use) (MMTCE)	1950-2000 Cumulative Energy CO2 Emissions (without land use) (MMTCE)	1950-2000 Cumulative Energy CO2 Emissions (with land use) (MMTCE)	2005 GDP (millions of international $)	2005 GHG Intensity (without land use) (tons/million intl. $GDP)
18	Spain	102	100	2,066	2,035	$1,179,577	102
19	South Africa	105	105	2,554	2,567	$397,537	290
20	Turkey	96	102	1,086	1,466	$747,327	144
Total[c]		6,802	7810	169,282	218,631	$43,127,912	
	WORLD	9,285	11,868	216,905	302,910	$56,175,865	188

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0. (Washington, DC: World Resources Institute, 2008).

Note: Due to rounding, independent calculations may give slightly different results.

a. The Kyoto Agreement gave explicit authority to the original 15 member European Union to meet its obligations collectively; the EU has coordinated the compliance strategies of the newer member states into its overall compliance scheme, but those countries retain their individual Kyoto reduction targets. If the EU-27 were ranked in terms of its 2000 GHG emissions, it would place 3rd.

b. Data from land use change and forestry not available.

c. Total is of the 20 individual nations; it does not include the European Union.

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