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), the Kyoto Protocol, and the Copenhagen Accord. 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 eight emitters (those emitting 2% or more of total emissions) accounted for 58% 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 countries whose economies are dominated by oil and gas production 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 6, 9, and 10, respectively, in the world), while developing nations tend to rank low (China, Brazil, Indonesia, and India ranked 81, 84, 117, and 148, respectively).
- The greenhouse intensity of the economy—the metric by which the George W. Bush Administration addressed climate change, and by which China has proposed to set its objectives under the Copenhagen Accord—varies substantially among developed countries (in 2005, not accounting for land use, Ukraine emitted 512 tons/million international $GDP, while France emitted 80 tons/million $GDP, with the United States at 153 tons/million $GDP; developing nations range from the 136 (Mexico) to 372 (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. The difficulty in finding a common strategy was evidenced by the outcome of the Copenhagen meeting, which set a climate change objective of holding global warming to less than 2 degrees C but then left up to each country the choice of how to address emissions.

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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 2006 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 1990 to 2005, and only for a subset of nations.

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 (name redacted).

[2] For the most recent developments on submissions to the UNFCCC by non-Annex 1 countries, see http://unfccc.int/national_reports/annex_i_ghg_inventories/inventory_review_reports/items/4715.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]

U.S. policymakers have struggled with the "common but differentiated responsibilities" of all nations and with the pledge for the developed countries to "take the lead in combating climate change." 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 for designated developed nations (including the United States), listed on Annex I to the UNFCCC (and hence known as Annex I nations).

The original UNFCC commitment was voluntary, and many Annex I nations, notably including the United States, failed to meet the objective of reducing 2000 emissions to a 1990 baseline.[9] Thus the Kyoto Protocol made mandatory individual Annex I nations' commitments of percentage reductions for 2008-2012, but meeting them has proved difficult—and the United States refused to join the commitment.[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.

Two key issues emerged from the UNFCC and Kyoto commitments to reduce emissions by developed nations: first, meeting the commitments is proving to be both technically and politically difficult; and second, it has become increasing evident that any reductions achieved by Annex I nations could be nullified by increases in emissions from non-Annex I nations like China and India that have been undergoing rapid economic growth and emitting increasingly large amounts of greenhouse gases—such that by 2005 China passed the United States to become the number one emitter of greenhouse gases in the world.

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 2006, Annex I nations had emitted approximately 74% of energy-related CO_2, while non-Annex I nations had contributed 24%.[11] In 1990, when the UNFCCC was being conceived, Annex I nations accounted for 60% of emissions of all six greenhouse gases, while the non-Annex I nations accounted for 40%. By 2005, however, non-Annex I nations dominated, accounting for 51% of total emissions, while Annex I nations accounting for approximately 47%. Thus, while Annex I nations still dominate cumulative emissions, the fact that non-Annex I nations are now contributing more than half the emissions 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] ClimateAnalysis Indicators Tool (CAIT) Version 7.0 (Washington, DC: World Resources Institute, 2009).

- Economically, as the UNFCCC explicitly recognizes, the economic 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 bear the preponderance of the direct economic costs 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, at least some 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 crux of the Copenhagen Conference, to plot a post-Kyoto course for addressing climate change, was how to engage the two largest emitters, the United States and China—the former having rejected Kyoto in part because developing nations were not obligated to curtail emissions; and the latter having become the world's largest emitter of greenhouse gases. Politically, while George W. Bush administration had been a reluctant partner in the UNFCC process, including early negotiations pointing toward Copenhagen, President Obama has been a vigorous proponent of engagement. At the Copenhagen Conference, he met twice with Chinese Premier Wen Jiabao in an effort to move the negotiations forward.

The Copenhagen outcome showed both some progress in bridging the gap between the developed and developing nations, and continuing difficulties in finding common ground on how to reduce greenhouse gas emissions. The accord[12] did not mandate specific reductions, but set a goal of reducing global emissions "so as to hold the increase in global temperature below 2 degrees C, and take action to meet this objective consistent with science and on the basis of equity." Annex I nations commit to implement "quantified economy-wide emissions targets for 2020" and non-Annex I nations commit to implement "mitigation actions." Both sets of nations commit to reporting and verification procedures "in accordance with guidelines adopted by the Conference of the Parties." (Monitoring, reporting, and verification were a key demand of the United States of developing nations.) Also, the accord contained the promise of $100 billion a year by 2020 "to address the needs of developing countries."

To clarify how nations' emissions levels intersect with social and economic contexts, this paper focuses on the 20 individual nations that emitted the most greenhouse gases in 2005 (see

[12] http://en.cop15.dk/files/pdf/copenhagen_accord.pdf

Appendix A, **Appendix B**, and **Appendix C**). [13] In 2005, not taking into account emissions implications of land use and forestry, the top 20 represented about 75% of global greenhouse gas emissions—up slightly from about 73% in 1990 (latest available data from CAIT for all six greenhouse gases). In addition, data for the 27-member[14] 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

2005 and 1990 Emissions Data (without accounting for land use and forestry emission effects)

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 75.3% of global emissions. Excluding land use data, by CAIT's accounting, China led in emitting greenhouse gases (1,974 million metric tons of carbon equivalent, MMTCE)[15] at 19.1% of the total, followed by the United States (1,892 MMTCE) at 18.3%.[16] No other country reached 6% of total emissions (although the collective 27-member EU accounted for 13.4%); overall, only eight countries emitted 2% or more. These top eight emitters accounted for 58.3% of global emissions and the next 13 top emitters accounted for another 17% 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[17] (or even the top eight) 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 are highly diverse and represent very different situations.[18] The top 20 nations include:

- Developed (Annex I) nations whose emissions *grew* between 1990 and 2005: the United States, Japan, Canada, Italy, Australia, France, Spain, and Turkey (ranked

[13] 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).

[14] 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.

[15] 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).

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

[17] 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.

[18] For a discussion of these situations, see CRS Report RL33970, *Greenhouse Gas Emission Drivers: Population, Economic Development and Growth, and Energy Use*, by (name redacted) and (name redacted).

2, 5, 8, 13, 14, 16, 18, and 20, respectively). These eight nations accounted for 30.5% 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,[19] and Ukraine, (ranked 3, 7, and 17, respectively). These three nations accounted for 9.0% of global greenhouse gas emissions in 2005.[20]
- 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.[21] It accounted for 1.7% 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, South Korea, Iran, and South Africa (ranked 1, 4, 6, 10, 11, 12, 15, and 19, respectively). These eight nations accounted for 34.1% of global greenhouse gas emissions in 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 37.4% 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 2006 (see **Appendix A** and **Appendix C**).

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

[19] 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.

[20] 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 dropped out of the top 20, ranking 32 and 22 respectively, in 2005. Together they accounted for about 1.5% of 2005 emissions.

[21] France's emissions declined between 1990 and 2000, and between 1990 and 2005 increased only 2.0%.

- For all nations, excluding land use changes and forestry practices, Annex I countries' share of energy-related CO_2 emissions[22] over the period 1850-2005 is 74%; non-Annex I countries' share is 24% (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 6th to 21st, 15th to 20th, 11th to 25th, and 12th to 23rd, 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.[23] In general, deforestation increases CO_2 emissions and afforestation decreases them. Certain agricultural practices can increase emissions of methane or nitrous oxide; other agricultural processes can sequester carbon. 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 is at best illustrative (see **Appendix A** and **Appendix C**; note that numerous countries lack data on land use and forestry).

Including land use in the calculations for 2005 focuses discussion on certain developing countries.

- 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 2005 rise from 276 MMTCE to 776 MMTCE (+181%), and Indonesia's rise from 159 to 557 (+250%). This ups their rankings of total emissions in 2005 from 6th to 3rd, and 11th to 4th, 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 6% when land use is accounted for. For the United States, net emissions drop by 32 MMTCE (-1.7%); its relative rank (as number 2 in 2005) does not change when land use is taken into account.

Historic land use and forestry data are not available. Evaluating the impact of land use and forestry at any one time directs attention to those few countries undergoing particular points in the development cycle. For many countries, land-clearing and agricultural development occurred long ago: 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

[22] Note that the cumulative data includes only energy-related CO_2.

[23] See CRS Report RS22964, *Measuring and Monitoring Carbon in the Agricultural and Forestry Sectors*, by (name re dacted) and (name redacted).

greenhouse gases (or removing sinks). In terms of the UNFCCC and the Kyoto Protocol, and potentially the Copenhagen Accord, 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, while for other countries the effects of past changes in land use and forestry practices are embedded in their baseline emissions.

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 non-Annex I nations' global greenhouse gas emissions definitively surpass those of Annex I nations, by a margin of 15% when taking land use and forestry into account. On the other hand, on the basis of energy-related CO_2 emissions, cumulative from 1850-2006, Annex I nations still dominate by margin of 3 to 1.

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[24] 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 in 2005
1990 GHG Emissions (excl. land use)	59.9%	39.8%	75.2%
2005 GHG Emissions (excl. land use)	47.0%	51.5%	75.3%
1990 GHG Emissions (with land use)	50.1%	47.8%	72.6%
2005 GHG Emissions (with land use)	41.2%	56.6%	73.6%
Cumulative Energy-Related CO2 Emissions 1850-2006 (excl. land use)	74.4%	24.5%	83.0%

Source: CRS calculations; Climate Analysis Indicators Tool (CAIT) Version 7.0 (Washington, DC: World Resources Institute, 2009).

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.[25]

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

[24] 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.

[25] For other analyses bearing on this question, see CRS Report RL32762, *Greenhouse Gases and Economic Development: An Empirical Approach to Defining Goals*, by (name redacted) and (name redacted); and CRS Report RL33970, *Greenhouse Gas Emission Drivers: Population, Economic Development and Growth, and Energy Use*, by (name redacted) and (name redacted).

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[26] are developed countries (Australia, United States, and Canada, ranked 6, 9, and 10, respectively). Their per capita emissions (7.5, 6.4, and 6.2 tons per person, respectively) are nearly double the emissions of the highest-ranked developing country in the top 20 (South Korea, at 3.2), and over four times that of China (1.5). The rankings for the non-Annex I countries in the top 20 emitters range from 29 (South Korea) to 148 (India), with China ranked 81. In contrast, Annex I countries range from 6 (Australia) to 51 (France), with the United States at 9. 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, 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[27]—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** 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.[28]

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

[26] The top five by this measure are countries whose economies are dominated by oil and gas production.

[27] 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).

[28] 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.

lower emitters. As noted in terms of emissions, taking into account land use sharply increases the greenhouse gas intensity of Brazil and Indonesia.

The top 20 emitters in 2005 (see **Appendix A** and **Appendix C**) range widely in greenhouse gas intensity: from 512 tons per million international $GDP (Ukraine, which relies heavily on coal) to 80 tons/million international $GDP (France, which relies heavily on nuclear power for generating electricity). (The larger the intensity number, the more GHGs emitted per dollar of GDP: from a climate change perspective, the lower the intensity the better.) These are both Annex I nations; non-Annex I nations have a narrower range, from the 136 tons/million international $GDP (Mexico) to 372 tons/million international $GDP (China). Taking into account land use, however, would dramatically raise the intensity of Brazil and Indonesia: in 2005 it jumped Brazil by 182%, to 490 tons/million international $GDP and Indonesia by 250%, to 790 tons/million international $GDP; the next largest increase from land use change was Mexico at 6%.

As a metric for considering how to control greenhouse gas emissions, intensity has an inherent political appeal: for most nations, intensity is declining. For the world, greenhouse gas intensity declined at a rate of -1.6% annually from 1990 to 2005. Causes of this decline in intensity are cost efficiencies that focus attention on the efficient use of energy, policies promoting the use of alternatives to fossil fuels generally and to coal in particular, and substitutions for perfluoro- and hydrofluorocarbons. A consequence of focusing on intensity, however, is that even with declining intensity, actual emissions can rise as a result of population growth and economic growth.[29]

For greenhouse gas intensity, in 2005 the United States ranked number 122 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 9). 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 less efficient with respect to intensity compared with Western European countries (the EU-27 would have ranked 154) and Japan ranked 166. 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.

In its positioning for the Copenhagen meeting, China pledged that it would cut its carbon intensity 40-45% by 2020 from a 2005 baseline.[30] China's greenhouse gas intensity in 2005 ranked 34, indicating that its economy was comparatively GHG-inefficient, and suggesting that intensity reductions should be relatively easy to achieve. But in fact, based on CAIT data, this commitment simply reflects China's historical trend for intensity: for the 15-year period 1990 to 2005, China's carbon intensity, based on CO_2 emissions only, declined by 43% (its carbon-equivalent intensity, based on all six greenhouse gases, declined by 53%).[31]

[29] See CRS Report RL33970, *Greenhouse Gas Emission Drivers: Population, Economic Development and Growth, and Energy Use*, by (name redacted) and (name redacted).

[30] http://en.rian.ru/world/20091126/156994803.html; http://www.guardian.co.uk/environment/2009/nov/26/china-targets-cut-carbon-footprint

[31] China's commitment on intensity has parallels with George W. Bush's 2002 call for reducing intensity 18% by 2012—a reduction that was only slightly more aggressive than the business-as-usual trend.

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 pulled completely out of the Kyoto process under the George W. Bush administration. This process has continued to be difficult, as the recent Copenhagen meetings illustrate.

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,[32] 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 produce considerably higher greenhouse gas emissions per million dollars of GDP than some developed nations. For example, in 2005 China's carbon intensity (372 tons/million international $GDP) was about four times that of the United Kingdom's (91) and Italy's (93). 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).

[32] An exception is several oil-producing States, mainly in the Gulf, that are high emitters due to exploitation of their oil reserves.

For the United States, a regime containing some mix of per capita and greenhouse gas intensity measures[33] 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 and of the Copenhagen meeting. 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. Now, for the Copenhagen Accord, nations are asked to voluntarily commit to reductions. 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 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 CO_2) 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

[33] See CRS Report RL33970, *Greenhouse Gas Emission Drivers: Population, Economic Development and Growth, and Energy Use*, by (name redacted) and (name redacted).

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.[34] 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.

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

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)	2005 GHG Emissions (with land use)	1850-2006 Cumulative Energy CO_2 Emissions (without land use)
China	No	1	2	81	34	1	2
United States	Yes	2	1	9	122	2	1
European Union-27[a]	*Yes*[b]	*[3]*[c]	*[2]*	*[43]*	*[154]*	*[3]*	*[2]*
Russian Federation	Yes	3	3	22	45	5	3
India[a]	No	4	6	148	88	6	8
Japan[a]	Yes	5	5	39	166	7	6
Brazil	No	6	9	84	107	3	21
Germany[a]	Yes	7	4	28	157	8	4
Canada	Yes	8	10	10	103	9	9
United Kingdom[a]	Yes	9	8	38	170	11	5
Mexico	No	10	13	72	134	10	15
Indonesia	No	11	17	117	77	4	25
Korea (South)[a]	No	15	19	29	128	12	20
Italy[a]	Yes	13	12	48	167	13	12
Australia[a]	Yes	16	15	6	71	14	14
Iran[a]	No	12	22	59	72	15	23
France[a]	Yes	14	11	51	179	16	7
Ukraine[a]	Yes	17	7	40	18	17	10
Spain[a]	Yes	18	20	44	159	20	17

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)	2005 GHG Emissions (with land use)	1850-2006 Cumulative Energy CO_2 Emissions (without land use)
South Africa[a]	No	19	16	50	53	22	13
Turkey	Yes	20	21	83	133	21	29

Source: Climate Analysis Indicators Tool (CAIT) Version 7.0. (Washington, DC: World Resources Institute, 2009).

a. Data from Land Use Change & Forestry not available.

b. 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.

c. 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 84th in 2005 per capita emissions).

Appendix B. Greenhouse Gas Emissions and Other Climate Change-Related Indicators for 2005 Top 20 Emitting Countries (Excludes Land Use Change & Forestry)

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	1,974	19.1%	981	993	101.2%	1.5
2	United States	Yes	1,892	18.3%	1,634	258	15.8%	6.4
[3]	*European Union-27*	*Yes*[a]	*1,378*	*13.4%*	*1,467*	*-89*	*-6.1%*	*2.8*
3	Russian Federation	Yes	532	5.2%	800	-268	-33.5%	3.7
4	India	No	509	4.9%	302	207	68.5%	0.5
5	Japan	Yes	370	3.6%	326	44	13.5%	2.9
6	Brazil	No	276	2.7%	188	88	46.8%	1.5
7	Germany	Yes	266	2.6%	326	-60	-18.4%	3.2
8	Canada	Yes	202	2.0%	159	43	27.0%	6.2
9	United Kingdom	Yes	176	1.7%	194	-18	-9.3%	2.9
10	Mexico	No	176	1.7%	125	51	40.8%	1.7
11	Indonesia	No	159	1.5%	90	69	76.7%	0.7
12	Korea (South)	No	155	1.5%	84	71	84.5%	3.2
13	Italy	Yes	154	1.5%	137	17	12.4%	2.6
14	Australia	Yes	153	1.5%	110	43	39.1%	7.5
15	Iran	No	152	1.5%	67	85	126.9%	2.2
16	France	Yes	150	1.4%	147	3	2.0%	2.5
17	Ukraine	Yes	135	1.3%	257	-122	-47.5%	2.9

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)
18	Spain	Yes	119	1.2%	76	43	56.6%	2.7
19	South Africa	No	115	1.1%	91	24	26.4%	2.5
20	Turkey	Yes	107	1.0%	71	36	50.7%	1.5
Total[b]			7,772	75.3%	6,165	1,607	26.1%	
	WORLD		10,320	100.0%	8,380	2,189	26.1%	1.6`

Source: Climate Analysis Indicators Tool (CAIT) Version 7.0. (Washington, DC: World Resources Institute, 2009).

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	2005 GHG Emissions (without land use) (MMTCE)	2005 GHG Emissions (with land use) (MMTCE)	1950-2000 Cumulative Energy CO2 Emissions (without land use) (MMTCE)	2005 Per Capita GDP (millions of international $)	2005 GDP (millions of international $)	2005 GHG Intensity (without land use) (tons/million intl. $GDP)
1	China	1,974	1,962	27,075	$4,076	$5,314,365	372
2	United States	1,892	1,860	91,088	$41,873	$12,376,100	153
[3]	*European Union-27*[ab]	1,378	*1,378*	*83,447*	*$26,883*	*$13,175,925*	*105*
3	Russian Federation	532	547	25,404	$11,861	$1,697,957	313
4	India[a]	509	509	7,487	$2,234	$2,445,194	208
5	Japan[a]	370	370	12,155	$30,310	$3,872,843	96
6	Brazil	276	776	2,581	$8,505	$1,582,642	174
7	Germany[a]	266	266	21,937	$31,397	$2,589,299	103
8	Canada	202	219	6,860	$35,065	$1,133,018	178
9	United Kingdom[a]	176	176	18,623	$32,207	$1,939,686	91
10	Mexico	176	186	3,212	$12,563	$1,295,157	136
11	Indonesia	159	557	1,788	$3,197	$705,159	226
12	Korea (South)[a]	155	155	2,699	$22,783	$1,096,741	142
13	Italy[a]	154	154	5,132	$28,122	$1,648,164	93
14	Australia[a]	153	153	3,470	$31,702	$646,550	236
15	Iran[a]	152	152	2,211	$9,314	$643,503	236
16	France[a]	150	150	8,810	$30,710	$1,869,387	80
17	Ukraine[a]	135	137	6,856	$5,583	$263,007	512

2000 Rank	Country	2005 GHG Emissions (without land use) (MMTCE)	2005 GHG Emissions (with land use) (MMTCE)	1950-2000 Cumulative Energy CO2 Emissions (without land use) (MMTCE)	2005 Per Capita GDP (millions of international $)	2005 GDP (millions of international $)	2005 GHG Intensity (without land use) (tons/million intl. $GDP)
18	Spain[a]	119	119	2,915	$27,366	$1,187,655	100
19	South Africa[a]	115	115	3,492	$8,504	$398,757	289
20	Turkey	107	116	1,490	$10,977	$781,243	136
Total[c]		7,772	7810	255,285		$43,486,427	
	WORLD	10,320	11,868	314,056	$8,769	$56,601,925	182

Source: Climate Analysis Indicators Tool (CAIT) Version 7.0. (Washington, DC: World Resources Institute, 2009).

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

a. Data from Land Use Change and Forestry not available.

b. 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 2005 GHG emissions, it would place 3rd.

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

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