Articles

The Scientific and International Context for Climate Change Initiatives

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Introduction

THE GLOBAL CLIMATE CHANGE PROBLEM is enormous and complex. To solve the problem, it is important that we have a good grasp of the whole climate system—not only the atmosphere and the oceans, not only the flora and the fauna, but also the human activities that are causing the problem and the human institutions that are attempting to solve the problem.

As one human institution—the United States legal system—faces the climate problem, it must grapple with ongoing challenges in environmental law.[1] How do judges without scientific backgrounds make rulings in cases of complex environmental questions? How do the courts make decisions in cases of uncertainty and risk? How do the courts recognize causal connections or suggest remedies in cases of large-scale, long-term environmental problems?

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1. In addition to examination of themes of judicial competence, judicial authority, and standing throughout this issue of the *U.S.F. Law Review*, a helpful summary is provided by JUSTIN PIDOT, GEORGETOWN ENVTL. LAW & POLICY INST., GLOBAL WARMING IN THE COURTS: AN OVERVIEW OF CURRENT LITIGATION AND COMMON LEGAL ISSUES (2006), *available at* http://www.law.georgetown.edu/gelpi/current_research/documents/GWL_Report.pdf.

As environmental challenges from air toxics to acid rain have emerged, the courts have pushed the relevant agencies to address this.[2] When the courts have faced complex environmental questions, they have tended to defer to the technical competence of experts.[3] When faced with uncertainty and potentially large risks to human and ecosystem health, the courts have exercised different degrees of precaution.[4] And to effectively resolve large-scale, long-term environmental problems, the stepping stones of initial legal remedies have led to more comprehensive policy.[5]

This Article provides context for the examination of United States climate policy and litigation initiatives covered by other articles in this issue of the *University of San Francisco Law Review*. Part I of this Article highlights the current scientific understanding of global climate change and offers a framework to connect the many scientific findings with the human influence on this phenomenon. Part II of this Article then provides a synthesis of international climate initiatives, from international legal agreements under the United Nations ("UN"), to policies and programs outside the UN framework. Finally, Part III of this Article presents possible solutions and emphasizes the urgent need for action.

I. Scientific Context

A. Scientific Certainty of Climate Change

Scientific certainty about climate change is not new. Since the 1800s, scientists such as France's Fourier and Sweden's Arrhenius explained the Earth's greenhouse effect and the role that some atmospheric gases—especially carbon dioxide ("CO_2") and methane

2. *See, e.g.*, ROSEMARY O'LEARY, *Environmental Policy in the Courts*, *in* ENVIRONMENTAL POLICY: NEW DIRECTIONS FOR THE TWENTY-FIRST CENTURY 151–74 (Norman Vig & Michael Kraft eds., 5th ed. 2003).

3. *See, e.g.*, P.F. Ricci & L.S. Molton, *Risk and Benefit in Environmental Law*, 214 SCIENCE 1096–1100 (1981).

4. For an excellent comparative analysis of risk and the precautionary principle in environmental law, see David Vogel, *Comparing Environmental Governance: Risk Regulation in the EU and the U.S.* (Ctr. for Responsible Bus., Univ. of Cal., Berkeley, Working Paper No. 2, 2003).

5. For example, litigation over local cancer clusters has led to larger policies (such as the Toxic Substances Control Act of 1976) on carcinogens, persistent organic pollutants, and hazardous waste. For more on the role of the courts in environmental policy, see O'LEARY, *supra* note 2.

("CH_4")—play in warming our planet.[6] Back in the 1890s, Arrhenius, as well as the American scientist Chamberlain, realized that the burning of fossil fuels could lead to global warming.[7] Since the 1900s, systematic measurements of global surface temperatures and atmospheric CO_2 concentrations have identified a remarkable increasing trend, most notably in the "Keeling curve."[8] Investigation of temperatures in the more distant past, through measurement of gases trapped in ice cores and carbon dating of corals, as tracked in Mann's famous "hockey stick" graph, show an abnormal increase in temperatures over the past fifty years that is beyond the natural variation found in more than 1,000 years.[9]

What is new about scientific certainty on climate change is increasing evidence to support past scientific findings. For nearly two decades, the Intergovernmental Panel on Climate Change ("IPCC")—composed of experts from around the world—has been assessing the understanding of the climate change problem.[10] Through a formal process of review involving national governments as well as climate experts, the IPCC has issued four assessment reports. In 1995, the Second Assessment Report carefully worded its conclusion: "The balance of evidence suggests a discernible human influence on global climate."[11] Even this cautious statement evoked sharp reactions from those reluctant to acknowledge the climate change problem. In the Third Assessment Report of 2001, the IPCC strengthened its language and made it more specific: "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to

6. For further information on the history of climate change science, see INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE ("IPCC"), CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS (forthcoming Oct. 2007) (on file with the author).

7. *Id.*

8. The "Keeling curve" refers to high-precision measurements of atmospheric CO_2 concentrations taken by Dr. David Keeling, of Scripps Institute of Oceanography, from an observatory atop Mauna Loa on the island of Hawaii. *See* Welcome to Scripps CO_2, http://scrippsco2.ucsd.edu/ (last visited Aug. 11, 2007).

9. Numerous studies have supported the findings of Mann's temperature record. For an authoritative discussion by actual climate scientists, see Realclimate.org, Myth vs. Fact Regarding the "Hockey Stick" (Dec. 4, 2004), http://www.realclimate.org/index.php?p=11.

10. For more information on the founding of IPCC, see IPCC, About IPCC, http://www.ipcc.ch/about/about.htm (last visited Aug. 10, 2007).

11. IPCC, WORKING GROUP I, CLIMATE CHANGE 1995: THE SCIENCE OF CLIMATE CHANGE (1995) [hereinafter IPCC WG1, CLIMATE CHANGE 1995].

human activities."[12] By 2007, the Fourth Assessment Report left no doubt and stated: "warming of the climate system is unequivocal."[13]

In the 2007 Fourth Assessment Report, the IPCC made considerable effort to provide decision makers with further information about the strength of their findings.[14] To do this, the IPCC sought to quantify the degree of certainty on expert findings, by calculating confidence intervals and by using consistent language to describe the level of confidence. For example, the IPCC used the language "very high confidence" or "very likely" to express a level of certainty of ninety percent or greater.[15] IPCC used the language "very likely" to convey that climate experts around the world are more than ninety percent certain that human emissions of greenhouse gases are the cause of observed global warming.[16]

By better quantifying and communicating scientific certainty, the IPCC clarified misconceptions or misrepresentations about agreement among the majority of climate experts. Misrepresentation has been especially problematic in the United States. Lack of media coverage on climate change has left the public unaware of the extent of the problem.[17] False journalistic balance—where the media presents unsupported conjectures of individuals on the same footing as the rigorous findings of hundreds of experts based on years of research—has confused both the public and policy makers.[18] Perhaps most blatant

12. IPCC, WORKING GROUP I, CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS (2001), *available at* http://www.grida.no/climate/ipcc_tar/wg1/index.htm.

13. IPCC, WORKING GROUP I, CLIMATE CHANGE 2007: THE PHYSICAL SCIENTIFIC BASIS – SUMMARY FOR POLICYMAKERS (S. Solomon et al. eds., 2007) [hereinafter IPCC WG1, SUMMARY FOR POLICYMAKERS], *available at* http://ipcc-wg1.ucar.edu/wg1/wg1-report.html (follow "Summary for Policymakers" hyperlink).

14. The Fourth Assessment Report incorporated four "cross-cutting themes," one of which was better quantification and communication of risk and uncertainty. *See* Martin Manning & Michel Petit, *A Concept Paper for the AR4 Cross Cutting Theme: Uncertainties and Risk*, IPCC (2003), *available at* http://www.ipcc.ch/activity/cct1.pdf.

15. In the 2007 Fourth Assessment Report, each Summary for Policymakers ("SPM") from the three Working Groups of the IPCC provides definitions of levels of confidence and highlights the language used to describe scientific certainty.

16. IPCC WG1, SUMMARY FOR POLICYMAKERS, *supra* note 13.

17. For example, European media coverage of the 2003 heat wave in Europe emphasized the connection between the heat wave and human-induced climate change. In contrast, mainstream news media in the United States hesitated to mention any connection between climate change and severe weather events, notably the hurricane season of 2005.

18. A remarkable example of this was the invitation of novelist Michael Crichton (author of the fictional novel, *A State of Fear*) to give congressional testimony rather than climate experts. *The Role of Science in Environmental Policy-Making: Hearing Before the Committee on Environment and Public Works*, 109th Cong. (2005) (testimony of Michael Crichton, author), *available at* http://epw.senate.gov/public/hearing_statements.cfm?id=246766.

and disturbing has been political tampering with scientific findings, including White House staff deleting text and re-writing scientific reports, or attempts to gag scientists at government agencies when they communicate their findings in presentations or written reports.[19] In contrast, the IPCC Fourth Assessment Report presents the conclusions of more than 2500 scientific expert reviewers, over 800 contributing authors, and 450 lead authors from more than 130 countries around the world, after six years of current work.[20]

Four main conclusions were conveyed in the authoritative IPCC Fourth Assessment Report: (1) the climate system is warming, (2) climate change is human-induced, (3) climate change impacts are happening now, and (4) climate change solutions are available and needed now.[21]

1. The Climate System Is Warming

Based on direct and indirect measurements of temperature around the globe, scientists have found that the warming of the Earth's climate is "unequivocal."[22] Observations of temperatures on the land surface, on the ocean surface and below, and at different heights in the atmosphere show that the average global temperature is increasing.[23] Greater trapping of incoming solar radiation by higher levels of greenhouse gases in the upper atmosphere is causing the

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19. *See* UNION OF CONCERNED SCIENTISTS, SCIENTIFIC INTEGRITY IN POLICYMAKING: INVESTIGATION OF BUSH ADMINISTRATION'S ABUSE OF SCIENCE (2004), *available at* http://www.ucsusa.org/scientific_integrity/interference/scientific-integrity-in-policy-making-204.html (follow "Read the full report" hyperlink) (documenting abuses of science under the current Bush administration); *see also* Union of Concerned Scientists, The A to Z Guide of Political Interference in Science, http://www.ucsusa.org/scientific_integrity/interference/a-to-z-guide-to-political.html (last visited Aug. 11, 2007).

20. IPCC WG1, SUMMARY FOR POLICYMAKERS, *supra* note 13.

21. These four main conclusions of the IPCC 2007 Fourth Assessment Report are the author's synthesis, based on the Summary for Policymakers from the three Working Groups of the IPCC. *See* IPCC WG1, SUMMARY FOR POLICYMAKERS, *supra* note 13; IPCC, WORKING GROUP II, CLIMATE CHANGE 2007: IMPACTS, ADAPTATION, AND VULNERABILITY – SUMMARY FOR POLICYMAKERS (2007) [hereinafter IPCC WG2, SUMMARY FOR POLICYMAKERS], *available at* http://www.ipcc.ch/SPM13apr07.pdf; IPCC, WORKING GROUP III, CLIMATE CHANGE 2007: MITIGATION OF CLIMATE CHANGE – SUMMARY FOR POLICYMAKERS (2007) [hereinafter IPCC WG3, SUMMARY FOR POLICYMAKERS], *available at* http://www.ipcc.ch/SPM040507.pdf.

22. IPCC WG1, SUMMARY FOR POLICYMAKERS, *supra* note 13.

23. Incorrect analysis of satellite data and weather balloon data led some climate scientists to say that the lower atmosphere was cooling, not warming. However, this assertion was not supported by any physical explanation and was inconsistent with other observations and models. Subsequent analysis of the satellite data by other research groups showed that so-called cooling was spurious and that drifting of satellite orbits accounted for the erroneous assertion. *See, e.g.*, Benjamin D. Santer et al., *Amplification of Surface Tem-*

land surface to heat up.[24] The ocean layers are also showing warming, with surface heat slowly penetrating into deeper levels, weakening some ocean currents and conveying more heat in cyclical phenomena like El Niño events.[25] Higher temperatures at the Earth's surface are causing changes in the height of atmospheric layers, like some giant café latte; the height of the lowest layer (the stratosphere) has risen, while the layer above (the stratosphere) has cooled. Further investigation into climatic change is now showing changes in circulation patterns and hurricane intensity due to global warming, as well as changes in the water vapor content of the atmosphere.[26]

2. Climate Change Is Human-Induced

Even if we recognize that the globe is warming, how do we know that humans are causing the phenomenon? Through a combination of measurements and models, we can discern the human "fingerprint" on the climate system in a number of ways.[27] First, the observed warming goes well beyond natural variation. Paleoclimatology—the sleuthing for indicators of past temperatures in ice cores and coral reefs—indicates that current levels of CO_2 in the atmosphere far exceed the natural range of the last 650,000 years.[28] We know that atmospheric concentrations of CO_2 and temperature are strongly correlated, explaining why temperature levels are higher than ever before.[29] Second, the rapid increase in levels of CO_2 in the atmosphere coincides with the onslaught of the industrial revolution and the release of CO_2 from fossil fuels, along with dramatic changes in land use by humans.[30] Third, models of the climate system with and without human emissions show that natural variation alone cannot explain ob-

perature Trends and Variability in the Tropical Atmosphere, 309 SCIENCE 1551–56 (2005); *see also Et Tu LT?*, REALCLIMATE, Aug. 11 2005, http://www.realclimate.org/index.php?p=170.

24. IPCC WG1, SUMMARY FOR POLICYMAKERS, *supra* note 13.

25. T.P. Barnett et al., *Penetration of Human-Induced Warming into the World's Oceans*, 309 SCIENCE 284–87 (2005).

26. *See, e.g.*, News Release, Univ. Corp. for Atmospheric Research, Human Activities Are Boosting Ocean Temperatures in Areas Where Hurricanes Form, New Study Finds (Sept. 11, 2006), http://www.ucar.edu/news/releases/2006/oceantemps.shtml.

27. *See* Union of Concerned Scientists, Global Warming 101: Human Fingerprints, http://www.ucsusa.org/global_warming/science/Fingerprints.html (last visited Aug. 10, 2007) [hereinafter Union of Concerned Scientists, Global Warming 101] (summarizing the human "fingerprint" on different aspects of the climate system).

28. IPCC WG1, SUMMARY FOR POLICYMAKERS, *supra* note 13.

29. Eric Steig, *The Lag Between Temperature and CO2 (Gore's Got It Right)*, REALCLIMATE, Apr. 27, 2007, http://www.realclimate.org/index.php/archives/2007/04/the-lag-between-temp-and-co2/.

30. *See id.*

served changes.[31] Natural fluctuations in the Earth's orbit, natural variation in solar activity, and other non-human phenomena cannot account for the rapid rise in atmospheric greenhouse gases and average temperature over the past century. Human activity does explain the observed changes.

3. Climate Impacts Are Happening Now

Another way we know that climate change is real is that harmful impacts are already happening and increasing. While it is still difficult to predict in great detail precisely where and when impacts will occur, these observed impacts are consistent with our physical, chemical, and ecological understanding of the climate system. Perhaps the climate change impact most familiar to the general public is the melting of glaciers and polar ice—dramatic pictures of huge Antarctic ice sheets breaking off into the ocean, and polar bears stranded and drowning for lack of Arctic sea ice. Deadly heat waves and hurricanes, intensified by climate change, have also made the news.[32] Many other impacts are occurring as well across the globe.[33] Global warming is causing more rapid melting of snow packs, resulting in both flooding and freshwater shortages.[34] Drought and desertification is intensifying in many regions—from the usually lush Amazon Basin to chronically dry regions of India and Africa.[35] This drying is adversely affecting human food supply (both crops and livestock), as well as interrupting other food chains.[36] The combination of increased ocean temperatures and acidity has already led to the death of one-third of the word's coral reefs.[37]

The above-mentioned impacts are already happening, and predictions show impacts increasing in more regions and intensifying.[38] Because our main greenhouse gas of concern, CO_2, can linger in the atmosphere for hundreds of years after being emitted,[39] our past

31. Union of Concerned Scientists, Global Warming 101, *supra* note 27.

32. *See id.*

33. IPCC WG2, SUMMARY FOR POLICYMAKERS, *supra* note 21.

34. *See id.*

35. *See id.*

36. *See id.*

37. Seaworld, Coral Reefs, http://www.seaworld.org/animal-info/Animal-Bytes/animalia/eumetazoa/radiata/cnidaria/coral-reefs.htm (last visited Sept. 11, 2007).

38. Andrew C. Revkin, *U.N. Study Shows Likely Impact of Global Warming*, N. Y. TIMES, Apr. 4, 2007, http://www.nytimes.com/2007/04/04/science/earth/04cnd-climate.html?ex=1333339200&en=5a60838ec16b03f6&ei=5088&partner=rssnyt&emc=rss.

39. Unlike atmospheric pollutants that may be "washed out" from the atmosphere within days or months, CO_2 is removed slowly as part of the Earth's carbon cycle. Biological

emissions have already locked in some climate impacts. But just as we have caused the problem, we can also solve it—by reducing emissions and preventing further impacts of human-induced climate change.

4. Climate Change Solutions Are Available and Needed Now

Another key message of the IPCC Fourth Assessment Report is the urgency of taking action now.[40] The sooner we begin significant reductions in greenhouse gas emissions, the less we will suffer from adverse impacts. Means of taking action are available now, in the form of more efficient electrical appliances, more efficient industrial processes, greater use of public transportation, vehicles with better fuel economy, and zero-carbon energy sources like wind and solar power. To achieve even more significant emission reductions, we must strengthen research and development of new energy technologies. But new technology alone cannot avert devastating climate change. We also need changes in our economic system: phase out of fossil fuel subsidies, economic incentives for low- and no-carbon products and activities, and economic penalties for those activities that harm the long-term well-being of the planet's hospitable climate. At the same time, we must also face the damage already done and adapt to climate impacts already occurring.

B. A Framework for Understanding Human Influence on the Climate System

To make sense of the many pieces of information—from greenhouse gas emissions to rising temperatures to melting polar ice—Figure 1 offers a simple flow diagram of the climate system, including the human component. More commonly, we are shown schematics of the Earth's carbon cycle,[41] or we are shown images of the greenhouse ef-

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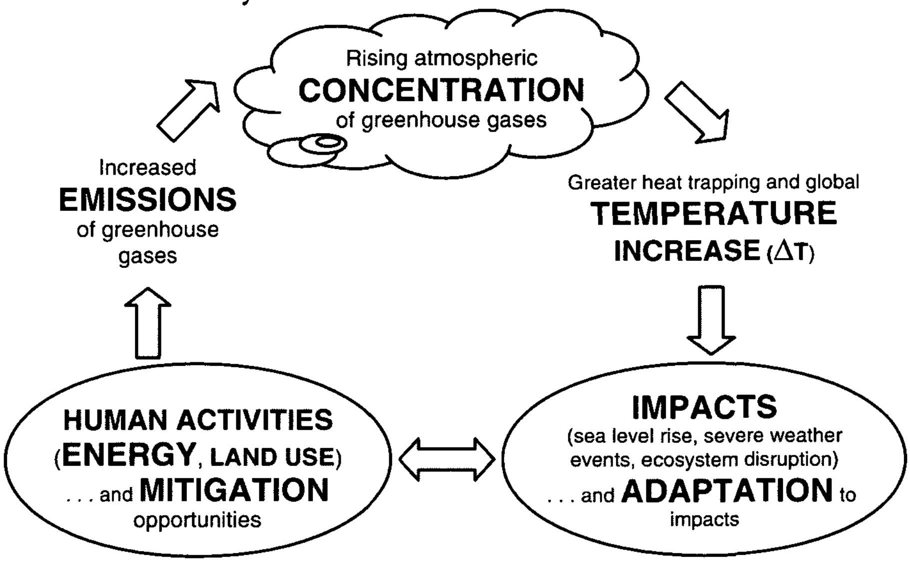
and chemical processes on land and in the oceans can take hundreds of years to remove some CO_2 from the atmosphere. More CO_2 can be removed by geologic processes that take hundreds of thousands of years. One of the first models on the fate of CO_2 from fossil fuels came from T.M.L. Wigley, *Balancing the Carbon Budget: Implications for Projections of Future Carbon Dioxide Concentration Changes*, 45 TELLUS 409–25 (1993). A summary of this and more recent studies, and a helpful graphical portrayal of CO_2 residence time in this atmosphere, can be found at GlobalWarmingArt.com, http://www.globalwarmingart.com/wiki/Image:Carbon_Dioxide_Residence_Time_png (last visited Aug. 10, 2007).

40. IPCC WG3, SUMMARY FOR POLICYMAKERS, *supra* note 21.

41. *See, e.g.*, NASA Earth Observatory, The Carbon Cycle, http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle4.html (last visited Aug. 10, 2007) (showing a flow diagram of the Earth's carbon cycle).

fect and the Earth's heat balance.[42] The flow diagram in Figure 1 seeks to connect the science (physical, chemical, and ecological) of the climate system with the human causes of the problem and the human responses. From a legal perspective, Figure 1 may be a useful reference of causal chains. From a policy perspective, it illuminates the points in the system where policies can intervene to lessen or prevent harmful impacts.

Figure 1. A Framework for Understanding Human Influence on the Climate System



Source: Author

In essence, we can follow the human influence on the climate system through the following main components: (1) human activities involving energy and land use, (2) increased emissions of greenhouse gases from human activities, (3) rising concentration of greenhouse gases in the atmosphere, (4) greater heat trapping (radiative forcing) and rising average global temperature, (5) impacts on humans and ecosystems, (6) adaptation to impacts, and (7) mitigation opportunities to reduce emissions and prevent impacts.

In the following section, this Article will illustrate the connections among these interdependent components. Taking a solutions-oriented view, we begin with observations of the problem and work back

42. IPCC WG1, CLIMATE CHANGE 1995, *supra* note 11 (depicting the Earth's heat balance and the greenhouse effect).

(counter-clockwise in Figure 1) to the sources and solutions to the problem. This solutions-oriented presentation follows the organization in the *Stern Review on the Economics of Climate Change* ("*Stern Review*").[43]

1. Climate Impacts and Global Temperature Change

A temperature rise of a few degrees does not seem that worrisome; we experience larger fluctuations in a single day in a single location. But a few degrees increase in the global average temperature is troubling, resulting in: higher high temperatures, nights that do not cool off, hotter summers, and winters that are not cold enough to generate much snow or to keep glaciers intact. Compared to pre-industrial times, before humans rapidly extracted large amounts of carbon from the bowels of the Earth and released them into the atmosphere, the planet has experienced a global average temperature increase of roughly 1°C.[44] We are already experiencing the impacts of that warming.

As climate models predict, impacts will increase as global temperature increases. For example, we know that species have already shifted their ranges toward the poles and higher up into hills and mountains over the past several decades.[45] If the increase in global average temperature exceeds 1.5 to 2.5°C (~3 to ~5° F) relative to the recent average temperature, up to thirty percent of plant and animal species are projected to face extinction.[46] A similar increase in temperature would also lead to freshwater shortages for billions of people, as well as decline in food production in lower latitudes.[47] A slightly higher temperature increase of just 2 to 3°C (from present levels) would lead to expanded wildfires and the widespread death of coral reef systems around the world's oceans.[48]

Scientists' ability to make better predictions at smaller scales—for example, at the scale of a region or an individual state—has been im-

43. Sir Nicholas Stern, Stern Review: The Economics of Climate Change (2006), *available at* http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm (including full report, summaries, commentary, presentation files, and post-release analysis).

44. To be precise, global average temperature has risen 0.8°C since the time period 1850–1899 (the onset of the industrial revolution). *See* IPCC WG2, Summary for Policymakers, *supra* note 21; *see also* Union of Concerned Scientists, Global Warming 101, *supra* note 27.

45. IPCC WG2, Summary for Policymakers, *supra* note 21.

46. *See id.*

47. *See id.*

48. *See id.*

proving. This ability to model at smaller scales is powerful, as it makes the issue more compelling to local decision makers and communities. Whereas discussion of global averages often elicits little response from local politicians or bureaucrats, models showing severe water shortages in California[49] lead local water agencies to put climate change planning on their agenda.

2. Global Temperature Change and Greenhouse Gas Concentrations

How much CO_2 (or other greenhouse gas) in the atmosphere will lead to the global temperature increases and impacts noted above? The relationship between greenhouse gas concentrations and global temperature changes is referred to as the *sensitivity* of the climate system.[50] Rough estimates of climate sensitivity made by Arrhenius over a century ago have largely held true; the increase in atmospheric concentrations of greenhouse gases matches the observed temperature increases.[51]

The carbon cycle is complex, however, and different processes that take up and release carbon work at different rates. As an added twist, the rates of those processes—like the speed with which the ocean absorbs CO_2, or the growth rate of terrestrial plants that take in CO_2—are affected by temperature.[52] So as scientists make projections based on concentration levels until now unknown on the planet, the possibility of dramatic departures from past behavior increases. For that reason, scientists present projections of changes in temperature (and in other variables, like water vapor) as likely ranges of values, rather than a single estimate.

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49. Two key reports have analyzed potential climate impacts in California: (1) CAL. CLIMATE CHANGE CTR., OUR CHANGING CLIMATE: ASSESSING THE RISKS TO CALIFORNIA (2006), *available at* http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF; and (2) Katharine Hayhoe et al., *Emissions Pathways, Climate Change, and Impacts on California*, 101 PNAS 12,422–12,427 (2004), *available at* http://www.pnas.org/cgi/reprint/101/34/12422.

50. An oft-cited measure of climate sensitivity is the change in global mean surface temperature resulting from a doubling of the atmospheric concentration of CO_2 (including the CO_2 equivalents of other greenhouse gases). The IPCC Fourth Assessment Report estimates this value to be in the range of 2 to 4.5°C, with a best estimate of about 3°C. IPCC WG1, SUMMARY FOR POLICYMAKERS, *supra* note 13, at 12.

51. Arrhenius estimated a 2°C average temperature increase for a doubling of atmospheric CO_2. For a summary of Arrhenius's prediction and current estimates of warming related to CO_2 doubling, see Univ. of Cal., S.D., Earth Guide, Global Warming: The Rise of CO_2 & Warming, http://earthguide.ucsd.edu/globalchange/global_warming/03.html (last visited Aug. 11, 2007).

52. *See* IPCC WG2, SUMMARY FOR POLICYMAKERS, *supra* note 21.

Considering the dangers of global warming noted above, many climate policy analysts advocate for limiting the average temperature increase to 2 °C.[53] This temperature increase roughly corresponds to stabilizing atmospheric concentrations of CO_2 at 450 parts per million ("ppm").[54] For example, a highly recommended climate stabilization scenario from the IPCC uses a 450 ppm target, as does the 2006 Sanders-Boxer-Waxman bill in the United States Senate.[55]

3. Atmospheric Concentrations and Emissions of Greenhouse Gases

Working our way further around Figure 1, to the source of the climate change problem, we can determine a level of greenhouse gas emissions that would limit atmospheric CO_2 concentration to 450 ppm. At this point, we face a sobering realization: to avoid dangerous climate impacts, we need to dramatically reduce emissions as much as sixty to eighty percent from current levels.[56] In order to reach a 450 ppm target, emissions must first slow their pace of increase and peak, then decline and level off. For example, both IPCC and the *Stern Review* analyze an emission pathway to climate stabilization at 450 ppm, from the year 2000 to the year 2100. From an initial level of forty-two Gt CO_2 equivalent per year ("Gt CO_{2eq}/yr"), emissions peak at forty-five Gt CO_{2eq}/yr shortly after 2010.[57] Emissions then decline steeply

53. The increase is 2°C relative to pre-industrial times. Presentation materials from the *Stern Review* illustrate the relationship between atmospheric CO_2 concentration and temperature rise. STERN, *supra* note 43.

54. *See* IPCC WG1, Summary for Policymakers, *supra* note 13.

55. *See* Manik Roy, Dir. of Cong. Affairs, Pew Ctr. on Global Climate Change, U.S. Climate Policy: Where to from here?, Presentation at the University of California, Berkeley Conference on Cap and Trade: Design and Implementation (Feb. 22, 2007), *available at* http://www.law.berkeley.edu/centers/envirolaw/capandtrade/speakers/PDFs/Roy%20presentation.pdf (summarizing CO_2 stabilization targets proposed in United States federal policy); *see also* IPCC, SPECIAL REPORT ON EMISSIONS SCENARIOS (2000), *available at* http://www.grida.no/climate/ipcc/emission/ (providing information on IPCC scenarios).

56. STERN, *supra* note 43, at vii, *available at* http://www.hm-treasury.gov.uk/media/3/2/Summary_of_Conclusions.pdf.

57. The term "CO_2 equivalent" refers to the fact that different greenhouse gases take up different amounts of heat (infrared radiation), based on their molecular structure. For example, methane causes twenty-one times more warming than CO_2, so one metric ton of methane equals twenty-one metric tons of CO_2 equivalents. The IPCC Second Assessment Report is the primary reference on global warming potential and CO_2 equivalents. For the full report, see IPCC, SECOND ASSESSMENT, CLIMATE CHANGE 1995 (1995), *available at* http://www.ipcc.ch/pub/sa(E).pdf. *See also* U.S. Envtl. Prot. Agency Non-CO_2 Gases and Carbon Sequestration—Conversion Units, http://www.epa.gov/nonco2/units.html (last visited Aug. 10, 2007) (summarizing conversion factors among greenhouse gases and between CO_2 equivalents and carbon equivalents).

over the next twenty-five years to approximately twenty-five Gt CO_{2eq}/yr by 2025, and then slowly approach nine Gt CO_{2eq}/yr by the year 2100.

There are numerous estimates of emission pathways to climate stabilization; IPCC presents pathways for six scenarios, most of which show higher emissions levels yielding an atmospheric CO_2 concentration higher than 450 ppm. While some may argue that an eighty percent reduction in emissions is difficult to achieve, the alternative is even less appealing. Stabilizing at a CO_2 concentration above 450 ppm means that the global average temperature would increase more than 2°C, which in turn would result in rather severe impacts: several meters of sea level rise, millions of people flooded out of coastal areas while inland areas suffer drought and wildfires, and cholera outbreaks due to warmer water temperatures. While different analysts have quibbled about the timing of the peak, the urgency of beginning the downturn in emissions is now widely recognized.

4. Greenhouse Gas Emissions from Human Activities: Energy and Land Use

Where do greenhouse gas emissions come from? Worldwide, the majority (sixty-five percent) of greenhouse gases generated by human activities are energy-related: electric power, transportation, industry, buildings, and other energy-related emissions. Table 1 summarizes emission shares, based on metric tons of CO_2 equivalent.[58] CO_2 is the main energy-related greenhouse gas, resulting from combustion of fossil fuels: coal, oil, and natural gas.[59] Energy-related processes also emit methane; two examples are leaks in gas pipelines and releases from coalmines where pockets of gas (coal-bed methane) are disturbed during mining.[60] Because methane has a global warming potential twenty-one times that of CO_2, activities emitting methane garner a proportionally larger share than those emitting CO_2.[61]

The remainder of emissions (thirty-five percent) come from human land use, land use changes, and forestry, as well as from industrial and municipal waste. Land use and land use changes include urbanization, related expansion of transportation corridors,

58. *See* Table 1, *infra* Part I.B.4.

59. *See* Energy Info. Admin. ("EIA"), Greenhouse Gases, Climate Change, and Energy, http://www.eia.doe.gov/oiaf/1605/ggccebro/chapter1.html (last visited Aug. 11, 2007).

60. *See* U.S. Envtl. Prot. Agency, Methane: Sources and Emissions, http://www.epa.gov/methane/sources.html (last visited Aug. 10, 2007) [hereinafter EPA, Methane].

61. *See* Table 1 *infra* Part I.B.4.

deforestation, agriculture, and the raising of livestock.[62] Some of these activities release CO_2, such as burning to clear agricultural land and other deforestation. Other activities release methane; collectively, "bovine burps," from ruminant herds raised for human consumption of meat, release significant amounts of methane.[63] Industrial and municipal waste releases methane and other greenhouse gases; methane from biological processes in wastewater treatment is one example.[64]

Table 1. Global Shares of Greenhouse Gas Emissions, by Sector[65]

Sector	Share (%)
energy emissions	***65%***
electric power	24%
Transportation	14%
Industry	14%
Buildings	8%
other energy	5%
non-energy emissions	***35%***
land use	18%
Agriculture	14%
Waste	3%

Source: *Stern Review*, based on data from WRI and IEA

5. Preventing and Responding to Climate Change: Mitigation and Adaptation

One significant characteristic of the sectoral emissions data in Table 1 is that sources of greenhouse gas emissions are widespread, encompassing multiple sectors of human activity. While targeting the electric-power sector can effectively address some environmental

62. *See* EPA, Methane, *supra* note 60.

63. *Id.*

64. *Id.*

65. Global sectoral shares of greenhouse gas emissions in Table 1 are from the *Stern Review*. STERN, *supra* note 43, at 171, *available at* http://www.hm-treasury.gov.uk/media/3/2/Chapter_7_Projecting_the_Growth_of_Greenhouse-Gas_Emissions.pdf. Note that Table 1 gives data on multiple greenhouse gases, whereas other references may present sectoral shares of CO_2 emissions only, resulting in different numbers. Also note that the *Stern Review* offers but one view of attributing emission sources. Others attribute more energy use to buildings (from heating, cooling, lighting, appliances, etc.). *See, e.g.*, Edward Mazria, *It's the Architecture, Stupid! Who Really Holds the Key to the Global Thermostat?*, SOLAR TODAY, May–June 2003, at 48–51.

problems, such as acid rain, attempting to address climate change requires more. All of the sectors generating greenhouse gas emissions must undertake reductions to bring emissions to a sustainable level. Individual sectors that are significant contributors to the problem can contribute significantly towards remedying the problem.

Thus we come full circle in Figure 1. As with the old adage "what goes round, comes round," the human activities that generate climate-warming gases are impacted by that same warming. Energy-intensive air conditioners must work harder to cool hotter air, using more energy and exacerbating the warming in the process.[66] However, what goes round does not necessarily come round just to the people who caused the problem. Those who have not caused the problem—the world's poorest people, living on marginal land—may be the hardest hit by climate impacts. The poorest will have to adapt to climate impacts: shifting to higher ground, rationing already limited water, facing the dwindling of meager food supplies, and suffering further from disease. The large emitters must curb their generation of greenhouse gases to mitigate further impacts and adapt to the impacts they have already caused.

The urgent need to both adapt and mitigate climate change challenges us to quickly move beyond discussions of the Earth's temperature record and the compelling evidence for human-induced climate change, and into a discussion on developing and implementing solutions.

II. International Context

While scientists have been concerned about climate change for more than a century, it was the first World Climate Conference in 1979 that gave significant international attention to the matter.[67] Since then, international efforts have developed under the auspices of the UN, and through other international channels outside the UN. Despite important contributions from its own climate experts, the United States as a nation has been slower than others in coming to

66. This type of reinforcement is an example of a problematic feedback loop. Technically speaking, this is termed "positive feedback," but in the case of adverse climate impacts "positive" does not mean "good." Rather, we would be fortunate to find opportunities for "negative feedback," meaning feedback that calms or dampens or corrects the adverse effects of climate change.

67. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, CARING FOR CLIMATE: A GUIDE TO THE CLIMATE CHANGE CONVENTION AND THE KYOTO PROTOCOL (rev. ed. 2005) [hereinafter UNFCCC, CARING FOR CLIMATE], *available at* http://unfccc.int/resource/docs/publications/caring2005_en.pdf.

grips with the climate change problem. As a result, other nations have taken the lead in forging international solutions. The discussion below highlights important features of international agreements on climate change, along with current developments, as context for the United States initiatives now underway.

A. International Climate Change Agreements Under the United Nations

1. United Nations Framework Convention on Climate Change

Recognizing the significance of current and projected climate change, most nations of the world became signatories to the United Nations Framework Convention on Climate Change ("UNFCCC" or "the Convention") in 1992.[68] The Convention signaled international recognition and attention to the climate change problem and established an institutional structure for working on the problem. The goals and desired actions of the Convention are summarized well in Article 3.1 of the UNFCCC:

> 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 differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.[69]

The Convention reflected the precautionary principle of protecting the climate in consideration of "present and future generations," in line with the ideas promulgated by the earlier Brundtland Commission.[70] The theme of "common but differentiated responsibilities" was a way to reconcile the many different interests of the world's nations. Recognizing that developed countries had emitted the bulk of global warming emissions past and present, and that those countries had the most resources to resolve the problem, the Convention called on developed countries to "take the lead."[71] The developed countries are noted in Annex I of the Convention.[72]

68. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, May 9, 1992, S. Treaty Doc. No. 102-38, 1771 U.N.T.S. 107 [hereinafter UNFCCC], *available at* http://unfccc.int/resource/docs/convkp/conveng.pdf.

69. *Id.* at 4.

70. *See* U.N. WORLD COMM'N ON ENVT. AND DEV., THE BRUNDTLAND REPORT ("OUR COMMON FUTURE") (1987).

71. UNFCCC, *supra* note 68, at 4.

72. "Developed countries" in Annex I of the Convention are mainly wealthy industrialized countries in the Organization for Economic Cooperation and Development, or OECD. Org. for Econ. Co-operation & Dev., Member Countries, http://www.oecd.org/

Signing of the Convention was just the first step in the process. Signatory nations had to then go back to their national governments to gain ratification before the Convention could enter into force. Even after signing the agreement, nations still needed to work out many details on how the Convention would function and how its goals were to be achieved. Since entering into force in 1994, the Convention annually convenes a meeting, or Conference of the Parties ("COP"), which provides a forum for further climate change negotiations. When nations later signed and ratified the Kyoto Protocol, they convened an annual Meeting of the Parties ("MOP") of the Kyoto Protocol. Table 2 highlights these and other developments in a timeline of events related to the UNFCCC. Significant United States involvement in the Convention initiatives are noted as well.

Table 2. A Timeline of Key Events in the International Response to Climate Change: UNFCCC Initiatives[73] and United States Involvement[74]

Year	*Event*
1988	• IPCC established by the World Meteorological Organization ("WMO")
1990	• Second World Climate Conference and IPCC calls for global treaty • Initial negotiations on a framework convention under the UN General Assembly
1992	• Earth Summit in Rio de Janeiro: over 180 nations of the world become signatories to the UNFCCC • United States among the signatories and subsequently ratifies the UNFCCC, with the support of President G. H. W. Bush
1994	• UNFCCC enters into force
1995	• COP1 Berlin Mandate: Specified the need for greenhouse gas reduction targets for Annex I countries and set a 1997 deadline for determining targets • Berlin Mandate supported by United States President Clinton • IPCC Second Assessment Report

countrieslist/0,3351,en_33873108_33844430_1_1_1_1_1,00.html (last visited Aug. 11, 2007).

73. *See* UNFCCC, CARING FOR CLIMATE, *supra* note 67; UNFCCC, HANDBOOK (2006), *available at* http://unfccc.int/resource/docs/publications/handbook.pdf; UNFCCC, COP 1-11 DECISIONS (2006).

74. Roy, *supra* note 55.

1997	• COP3 Kyoto Protocol: Set binding emission reduction targets for Annex I countries, including the United States • President Clinton supports Kyoto Protocol, but no legislation advances • United States Senate passes Byrd-Hagel Resolution[75] against the Berlin Mandate by a vote of 95–0
1998	• COP4 Buenos Aires Plan of Action: Established deadlines for finalizing work on the Kyoto Mechanisms (Joint Implementation, Emissions Trading, and the Clean Development Mechanism), compliance issues and policies and measures • United States Congress remains opposed to international climate agreements and to domestic action
2000	• COP6: Talks break down in The Hague, Netherlands
2001	• COP6 resumed; Bonn Agreements: Established less strict compliance standards for the Kyoto Protocol to encourage ratification • COP7 Marrakesh Accords: Detailed rules for implementation of the Kyoto Protocol • IPCC Third Assessment Report • Change in United States Administration; President G. W. Bush opposes the Kyoto Protocol, reneges on domestic pledge to cap electric power plant emissions
2002	• COP8 Delhi Declaration: Took out requirements for developing countries to cut greenhouse gas emissions due to opposition from countries like China and India
2004	• COP10 Buenos Aires Programme of Work on Adaptation and Response Measures: Produced a modest new program on adaptation and response measures to climate change
2005	• Kyoto Protocol enters into force, following ratification by Russia • United States and Australia are the only Annex I countries failing to make commitments under the agreement • COP11/MOP1 (Montreal): Agreement to "dialogue on long-term cooperative action"[76] • United States launches six-nation Asia-Pacific Partnership on Clean Development and Climate along with Australia, Japan, South Korea, China, and India • G8 Gleneagles Plan of Action: Emphasized the need for industrialized countries to assist developing countries

75. The resolution stated that the United States would not be a signatory to any protocol or agreement regarding the UNFCCC, unless the protocol or agreement required developing countries (like Annex I countries) to limit or reduce greenhouse gases. S. Res. 98, 105th Cong. (1997), *available at* http://www.nationalcenter.org/KyotoSenate.html.

76. UNFCCC, Dialogue on Long-term Cooperative Action to Address Climate Change by Enhancing Implementation of the Convention, Decision 1/CP.11 (2005) [hereinafter UNFCCC, Diaglogue], *available at* http://unfccc.int/files/meetings/cop_11/application/pdf/cop11_00_dialogue_on_long-term_coop_action.pdf.

2006	• COP12/MOP2 Nairobi Declaration: aimed at creating sustainable development in Africa • United States Senate passes Lugar-Biden Resolution,[77] urging United States re-engagement in international negotiations under the UNFCCC
2007	• COP13/MOP3 scheduled for Bali, Indonesia • IPCC Fourth Assessment Report • Changes in United States Congress lead to the introduction of several pieces of national climate legislation • Group of 8 Industrialized Nations ("G8") pushes for fifty percent reduction in emissions by 2050, but proposes no specific commitments

2. Structure of the Kyoto Protocol

Recognizing the strong connection between impacts, warming, concentrations, and emissions of greenhouse gases (as shown in Figure 1),[78] the 1997 Kyoto Protocol ("Protocol") focused its attention on reducing emissions.[79] The Protocol called for industrialized countries to make binding commitments to reduce emissions, consistent with the Protocol's foundation of "common but differentiated responsibilities."[80] Emission reductions in developing countries were to be encouraged through technical support from the Global Environment Facility ("GEF") and the new Clean Development Mechanism ("CDM").[81] The Protocol did not, however, require the developing countries to set binding reduction targets.[82]

Viewed as a first step, the Protocol set the timeframe of the First Commitment Period from 2008 to 2012.[83] Rather than specifying an absolute cap on emissions for each country, the Protocol set targets based on historical distributions of emissions.[84] Each country with obligations negotiated its target, expressed as a percent reduction below

77. S. Res. 312, 109th Cong. (2006).

78. *See* Figure 1 *supra* Part I.B.

79. *See* UNFCCC, A Summary of the Kyoto Protocol [hereinafter UNFCCC, Kyoto Protocol Online Summary], http://unfccc.int/kyoto_protocol/background/items/2879.php; UNFCCC, CARING FOR CLIMATE, *supra* note 67.

80. Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 11, 1997, 37 I.L.M. 22 (entered into force Mar. 21, 2004) [hereinafter Kyoto Protocol], *available at* http://unfccc.int/resource/docs/convkp/kpeng.pdf.

81. UNFCCC, Kyoto Protocol Online Summary, *supra* note 79.

82. *See* UNFCCC, Kyoto Protocol Online Summary, *supra* note 79; UNFCCC, CARING FOR CLIMATE, *supra* note 67.

83. *See* UNFCCC, Kyoto Protocol Online Summary, *supra* note 79.

84. *See id.*

the baseline year of 1990.[85] However, given the timeframe of the agreement, the Protocol did not set targets at levels necessary to stabilize the climate; rather, the targets were based on each country's projections of what could be achieved during the timeframe.[86] Unfortunately for the planet, the nation most responsible for global warming—the United States—did not take responsibility for its share of the problem and did not ratify the Kyoto Protocol.

3. Kyoto Mechanisms

In an effort to reach agreement on emission-reduction targets, the Protocol incorporated several mechanisms to enable Annex I countries to meet their commitments and to engage all countries in addressing the climate change problem. First and foremost, actual emission reductions in Annex I countries were the main mechanism for meeting Protocol targets; the 2001 Marrakesh Accords affirmed this.[87] In addition, the Protocol established three "flexibility" mechanisms for reducing costs and engaging developing countries: (1) Emissions Trading ("ET"), (2) Joint Implementation ("JI"), and (3) CDM.[88] With ratification of the Protocol, Annex I Parties can gain credits through flexibility mechanisms to satisfy part of their emission-reduction commitment.[89]

ET is a mechanism available only to countries with binding targets (the Annex I countries).[90] The Protocol developed its now up-and-running EU Emissions Trading System ("ETS") after tough negotiations in Kyoto, and the program was launched rapidly when the Protocol took effect in 2005. Economic analyses show that the costs of meeting emission reduction targets can be reduced by allowing enti-

85. Each Annex I country negotiated a target, with the European Union ("EU") negotiating as a group with the UN and negotiating within the EU for individual country commitments. UNFCCC, Kyoto Protocol, Countries Included in Annex B to the Kyoto Protocol and Their Emission Targets, http://unfccc.int/kyoto_protocol/background/items/3145.php (last visited on Sept. 11, 2007). For example, the United States negotiated a seven percent reduction from 1990 levels by 2008–2012. *Id.* The Europeans pledged more, while Japan, which already has the lowest energy intensity among industrialized nations, negotiated a six percent reduction. *Id.*

86. *See* Kyoto Protocol, *supra* note 80.

87. *See* UNFCC, Kyoto Protocol Online Summary, *supra* note 79; UNFCCC HANDBOOK, *supra* note 73; UNFCC, COP 1-11 DECISIONS, *supra* note 73; Table 2 *supra* Part II.A.1.

88. For further information about the so-called Kyoto Mechanisms, see UNFCCC, Mechanisms Under the Kyoto Protocol: The Clean Development Mechanism, Joint Implementation and Emissions Trading, http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php (last visited Sept. 12, 2007) [hereinafter Kyoto Mechanisms].

89. *See* UNFCCC, Kyoto Protocol Online Summary, *supra* note 79.

90. *See* Kyoto Protocol, *supra* note 80, art. 17, 37 I.L.M. at 15.

ties with low-cost reductions to do more, while allowing entities facing high-cost reductions to pay the former to do more.[91] The EU ETS is too new to evaluate the savings and is still experiencing some wobbling as the carbon market and the system itself are being established.[92] Because the United States has not ratified the Protocol, United States entities cannot trade in the EU ETS or other trading systems established under the Protocol.

The two other flexibility mechanisms under the Protocol aim to engage other groups of countries, as well as reduce costs for countries with commitments. Following an economic line of thought, emission reductions in less-wealthy countries would likely be cheaper than in the industrialized countries. At the same time, poorer countries could benefit from an influx of technology and money.[93] JI is the mechanism established for Economies In Transition ("EIT"), such as the former Soviet republics, while CDM is aimed at developing countries such as China, India, and Brazil.[94] The Protocol established rather strict review procedures to verify emission reductions undertaken through these mechanisms; Annex I countries can ultimately use reduction credits to meet their emission-reduction targets.[95] Because the United States has not ratified the Protocol, United States entities cannot gain credits through CDM or JI.

One other important aspect of the Protocol and subsequent agreements was the recognition of carbon sequestration as a means of reducing atmospheric concentrations of CO_2.[96] Carbon sequestration refers to removal of carbon from the atmosphere, for example by plants or trees that take in CO_2 and incorporate the carbon into their cell mass, thereby keeping the carbon out of the atmosphere.[97] Conversely, plants and trees release carbon into the atmosphere when

91. One useful reference on the economic arguments behind climate change policy is RESOURCES FOR THE FUTURE (RFF), CLIMATE CHANGE ECONOMICS AND POLICY: AN RFF ANTHOLOGY (Michael A. Toman ed., 2001).

92. The official website for the European Union Emission Trading Scheme ("EU ETS") is http://ec.europa.eu/environment/climat/emission.htm (last visited Aug. 11, 2007). One helpful summary of the trading scheme is available from United Kingdom Department for the Environment, Food, and Rural Affairs ("U.K. DEFRA") at http://www.defra.gov.uk/ENVIRONMENT/climatechange/trading/eu/intro/index.htm (last visited Aug. 11, 2007).

93. One useful reference on the economic arguments behind climate change policy is RFF, *supra* note 91.

94. For further information, see Kyoto Mechanisms, *supra* note 88.

95. *See id.*

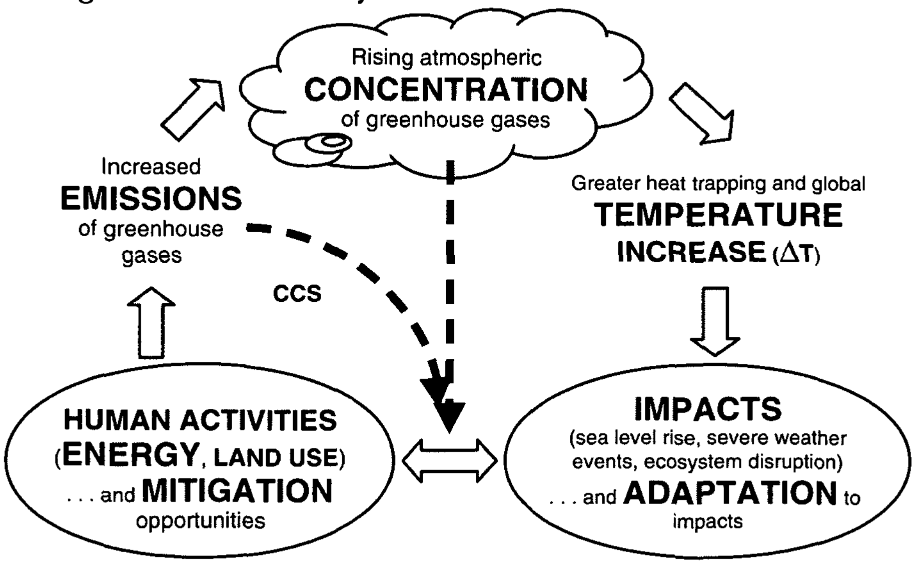
96. *See, e.g.*, UNFCCC, Kyoto Protocol Online Summary, *supra* note 79.

97. For more information, see Office of Science, U.S. Dept. of Energy, Carbon Sequestration, http://cdiac2.esd.ornl.gov/index.html (last visited Aug. 11, 2007).

they are removed or burned. The scientific understanding of biological carbon sequestration is not as strong as our understanding of physical and chemical climate processes. Thus, the inclusion of carbon sequestration—which involves biological removal of atmospheric CO_2 —as a recognized means of meeting Protocol emissions targets—which focus on the human emissions of CO_2 into the atmosphere—met with much debate. However, estimates of the release of CO_2 from agriculture and land-use changes indicate that carbon sequestration is an important mechanism for mitigating climate change.

Figure 2 illustrates how carbon sequestration fits into the flow diagram of human influence on the climate system. Figure 2 also illustrates another development in international climate discussion: carbon capture and storage ("CCS"). CCS involves the removal of CO_2 mainly from fossil-fuel combustion, and ferreting away the CO_2 in underground geological formations (as is done on a limited scale for enhanced oil recovery) or possibly other not-yet-tried places like the deep ocean.[98] The appeal of CCS is that use of fossil fuels could con-

Figure 2. Carbon Sequestration and Carbon Capture and Storage in the Climate System



Source: Author

98. For more information on CCS, see World Res. Inst., Carbon Capture and Sequestration (CCS), http://www.wri.org/climate/project_description2.cfm?pid=226 (last visited Aug. 11, 2007).

tinue. At the request of large coal-producing and consuming countries, the IPCC prepared a special report on CCS.[99]

There are several serious concerns, however, about CCS: the capture is thermodynamically difficult; the stability and capacity of storage options are not clear; a new and significantly large infrastructure would be needed to transport captured CO_2 in a highly pressurized state; and all the CCS efforts combined would not move us beyond fossil fuels. Suggestions that captured CO_2 be injected into the deep ocean are of even greater concern; aquatic life is already suffering from ocean acidification due to higher atmospheric CO_2 concentrations.[100] Thus, from a process view of the climate system, CCS is akin to sweeping the problem under the rug rather than solving it at the source.

4. Searching for a Post-Kyoto Framework

With the First Commitment Period (2008-2012) of the Protocol quickly approaching, the international community is already looking ahead to a post-Kyoto framework for addressing climate change. Formal negotiations on a new framework are expected to feature prominently at COP13 in 2007.[101] But the development of ideas for a future framework began even as handshakes were made in Kyoto in 1997.[102]

Any new framework must address two key issues in order to stabilize the climate: how to engage the world's largest emitters, notably the United States and large developing countries like China and India; and how to establish effective long-term targets for those countries. After years of stalemate,[103] there are now glimmers of change

99. *See* IPCC, SPECIAL REPORT ON CARBON CAPTURE AND STORAGE (Bert Metz et al. eds., 2005), *available at* http://www.ipcc.ch/activity/srccs/SRCCS.pdf.

100. *See, e.g.*, GERMAN ADVISORY ON GLOBAL CHANGE (WBGU), THE FUTURE OCEANS – WARMING UP, RISING HIGH, TURNING SOUR: SPECIAL REPORT (2006), *available at* http://www.wbgu.de/wbgu_sn2006_en.pdf.

101. For more information regarding COP13, see UNFCCC, United Nations Climate Change Conference, 3-14 December, Nusa Dua, Bali, Indonesia (COP13 and CMP 3), http://unfccc.int/meetings/cop_13/items/4049.php (last visited Aug. 11, 2007).

102. *See, e.g.*, PEW CTR. ON GLOBAL CLIMATE CHANGE, BEYOND KYOTO: ADVANCING THE INTERNATIONAL EFFORT AGAINST CLIMATE CHANGE (2003), *available at* http://www.pewclimate.org/docUploads/Beyond%20Kyoto.pdf.

103. As one example of stalemate, COP11 in Montreal in 2005 made only limited progress in even trying to discuss post-Kyoto. In Decision 1/CP.11, the United States delegation agreed to dialogue about the future only under the condition that nothing really come of it. UNFCCC, Dialogue, *supra* note 76. As a result, the language in the decision reads: "*Resolves* to engage in a dialogue, without prejudice to any future negotiations, commitments, process, framework or mandate under the Convention, to exchange experiences

coming from processes outside the UNFCCC. These are discussed in the following section.

B. Beyond the UN: Other International Responses

The UN climate negotiations have made important steps in creating the institutions to address climate change and working toward a comprehensive international agreement. From a physical environmental perspective, a comprehensive agreement is appealing because it can effectively meet the physical bottom-line, i.e., sufficient reductions in greenhouse gas emissions to stabilize atmospheric concentrations and avoid catastrophic climate change. From an international environmental policy perspective, a comprehensive international agreement is appealing because it avoids a number of policy pitfalls, including free riders[104] and leakage.[105]

However, the progress made in controlling greenhouse gases under current UN agreements is painfully slow and not yet sufficient. Unlike the oft-hailed precedent of protecting the Earth's ozone shield, which could be addressed by a comparatively narrow set of actions,[106] the climate change problem requires solutions across multiple sectors and is deeply interwoven with the fabric of industrially-based, energy-intensive economies. The pervasive nature of the problem means that many stakeholders must become involved, including those at the source of the problem: fossil fuel-based industry. An emerging view in the current international climate regime and in dis-

and analyze strategic approaches for long-term cooperative action to address climate change . . . ." *Id.*; *see* UNFCC, COP 1–11 DECISIONS, *supra* note 73.

104. The term "free riders" refers to those who benefit from a policy initiative without being subject to its requirements.

105. The term "leakage" refers to the movement of business or other activity outside of a regulated area.

106. The Montreal Protocol to protect the Earth's ozone layer in the upper atmosphere is frequently heralded as a success story of international environmental policy. *See* U.N. Indus. Dev. Org. ("UNIDO"), The Montreal Protocol – A Success Story, http://www.unido.org/en/doc/50444 (last visited Aug. 11, 2007). One of the reasons for success is that a solution could be found by substituting the man-made chemicals (chlorofluorocarbons) that destroy the ozone layer. *Id.* Another reason for success is that the Protocol targeted a relatively narrow set of industries and products, such as refrigerants, propellants, fire retardants, and fumigants. *See* PENELOPE CANAN & NANCY REICHMAN, OZONE CONNECTIONS: EXPERT NETWORKS IN GLOBAL ENVIRONMENTAL GOVERNANCE (2001) (analyzing the institutional strengths and limitations of the Montreal Protocol); ELIZABETH R. DESOMBRE & JOANNE KAUFFMAN, INSTITUTIONS FOR ENVIRONMENTAL AID: PITFALLS AND PROMISE (Robert O. Keohane & Marc A. Levy eds., 1996) (analyzing the financial implementation of the Protocol); Jimin Zhao, *The Multilateral Fund and China's Compliance With the Montreal Protocol*, 11 THE JOURNAL OF ENVTL. DEV. 331, 331–34 (2002) (analyzing implementation in developing countries).

cussions of a post-Kyoto framework is that a single, comprehensive international agreement with binding commitments may not be realized in the near term.[107]

As an alternative, or as a stepping-stone to a single comprehensive treaty, different groups of nations may commit themselves to different types of agreements and targets. Some have termed such an approach an "orchestra of treaties."[108] Rather than focusing targets primarily or exclusively on emissions—as in the Protocol—agreements could focus on the underlying activities that cause emissions: energy and land-use activities.[109] For example, nations could develop targets for energy consumption in power generation, or the carbon content of electric-power generation. Some individual nations and states already have such targets, in the form of efficiency standards for power generation, or in Renewable Portfolio Standards ("RPS") that require a share of electric power be produced from renewable energy like solar and wind.[110] Targets could also focus on the amount of energy consumed per physical unit of production, such as the energy needed to produce a ton of steel.[111]

107. Based on personal communication with observers of international climate negotiations over the past ten years. See Int'l Inst. for Sustainable Dev. ("IISD"), Earth Negotiations Bulletin, http://www.iisd.ca (last visited Oct. 8, 2007), for detailed reporting on climate and other international environmental negotiations.

108. Taishi Sugiyama et al., *The Coalition for Climate Technology Scenario*, *in* GOVERNING CLIMATE: THE STRUGGLE FOR A GLOBAL FRAMEWORK BEYOND KYOTO 35 (Taishi Sugiyama ed., 2005), *available at* http://www.iisd.org/pdf/2005/climate_governing.pdf.

109. *See* Figure 1 *supra* Part I.

110. For further information on Renewable Portfolio Standards in the United States, see Database of State Initiatives on Renewable Energy ("DSIRE"), http://www.dsireusa.org (last visited Aug. 10, 2007).

111. This is termed physical energy intensity and is distinctly different from economic energy intensity. Targets based on physical energy intensity can achieve real (physical) and quantifiable reductions in greenhouse gas emissions, because less energy is being consumed per unit of output. In contrast, economic energy intensity mixes a physical unit (energy) with a socially constructed unit (money) and does not necessarily lead to any physical reductions in energy consumption or greenhouse gas emissions. In fact, economic energy intensity in many countries has declined over the past several years even as energy consumption and greenhouse gas emissions have increased. This trend has been shown in numerous publications and presentations and highlighted again by Working Group III of the IPCC in the 2007 Fourth Assessment Report. IPCCC WG3, SUMMARY FOR POLICYMAKERS, *supra* note 21, fig. SPM 2. In other words, an economic energy intensity target often masks the physical reality and does not necessarily achieve needed reductions in greenhouse gas emissions. In fact, the economic energy intensity target (and later carbon intensity target) promoted by the United States Bush administration is actually worse than "business-as-usual;" i.e., the administration's target would lead to more energy consumption and more climate damages. Thus rather than a remedy, the administration's target proposes more harm. *See* Nat. Res. Def. Council, "Emissions Intensity" – Pollution by Any Other Name?, http://www.nrdc.org/globalWarming/fintensity.asp (last visited Sept. 12, 2007) (analyzing

Recognizing that some nations may undertake different paths as a prelude to, or parallel with, a post-Kyoto framework, the following sections examine three initiatives: (1) the Group of 8 ("G8"), (2) the Asia-Pacific Partnership, and (3) a collection of efforts to engage industrializing countries through development assistance.

1. Group of 8 Nations (G8)

The first notable action by the G8 on climate change came in 2005, when the G8 summit concluded with the Gleneagles Plan of Action.[112] At the 2005 Summit, G8 leaders recognized that "climate change is happening now, that human activity is contributing to it, and that it could affect every part of the globe."[113] Despite this statement and efforts by (then) Prime Minister Tony Blair to push for commitments to specific actions, the 2005 G8 agreement did not contain any timeline or measurable goals.[114] The G8 did, however, commission analyses from the International Energy Agency ("IEA") and the World Bank. The IEA's task was to examine, from a technological perspective, how greenhouse gas reductions could be achieved.[115] The World Bank's task was to determine how G8 financial support could be utilized to achieve necessary emission reductions.[116] Both groups issued reports in 2006.

Climate change again figured prominently on the G8 agenda at the June 2007 summit in Heiligendamm, Germany. Germany's Chancellor Angela Merkel (who holds presidency of the G8 in 2007) prioritized the issue, with the support of most G8 leaders including British Prime Minister Tony Blair.[117] In advance of the 2007 meeting and with an eye ahead to the 2008 G8 meeting in Tokyo, Japan announced a proposal for a post-Kyoto climate agreement, with the goal of cut-

intensity targets); *see also* Nat'l Ctr. for Energy Policy ("NCEP"), Energy Commission Proposes Plan to Cut Total U.S. Climate Emissions in First Year of Program (Apr. 19, 2007), http://www.energycommission.org/site/page.php?pressrelease=18 (providing new recommendations which move away from intensity targets).

112. G8 GLENEAGLES, PLAN OF ACTION: CLIMATE CHANGE, CLEAN ENERGY AND SUSTAINABLE DEVELOPMENT (2005), *available at* http://www.fco.gov.uk/Files/kfile/PostG8_Gleneagles_CCChangePlanofAction.pdf.

113. *G8 Climate Plan of Action Delivers Little Change*, ENVTL. NEWS SERV., July 8, 2005, http://www.ens-newswire.com/ens/jul2005/2005-07-08-02.asp.

114. *See id.*

115. INT'L ENERGY AGENCY ("IEA"), ENERGY TECHNOLOGY PERSPECTIVES (2006).

116. WORLD BANK, AN INVESTMENT FRAMEWORK FOR CLEAN ENERGY AND DEVELOPMENT (2006).

117. Richard Black, *U.S. Seeks G8 Climate Text Changes*, BBC NEWS, May 14, 2007, http://news.bbc.co.uk/1/hi/sci/tech/6651295.stm.

ting current greenhouse gas emissions in half by 2050.[118] Japan also offered a specific proposal for near-term climate action at the May 2007 meeting of energy ministers under Asia-Pacific Economic Cooperation ("APEC"), calling on APEC nations to work with IEA on sector-specific energy-efficiency targets.[119] The 2007 summit closed with a resolution to reach agreement on a post-Kyoto framework by 2009.[120]

The Bush administration, however, seemed to continue its efforts to evade and distract from real action on climate change. Roughly one month before the 2007 G8 meeting, the United States sought to strike language from draft meeting documents that stated: "climate change is speeding up and will seriously damage our common natural environment and severely weaken [the] global economy . . . . [R]esolute action is urgently needed in order to reduce global greenhouse gas emissions."[121] Just days before the G8 meeting, President Bush announced a new proposal to hold separate climate talks with the G8 plus seven nations.[122] Most world leaders met the Bush administration's latest proposal with skepticism, but some met it with openness.[123] The Executive Secretary of UNFCCC, Yvo de Boer, welcomed United States engagement—after the White House offered the promise that their talks would feed into the UN process rather than derail it.[124] However, the Executive Secretary noted that the United States proposal would not be productive unless it addressed three missing elements: (1) assistance for the sustainable development of poor nations; (2) enhancement of international carbon markets; and (3) support for the UNFCCC principle of industrialized nations' obligations to take the lead in combating climate change.[125] Others remained skeptical, noting past United States efforts to bypass UN negotiations

118. Joseph Coleman, *Japan Proposes Halving Emissions by 2050*, WASH. POST, May 24, 2007, *available at* http://www.washingtonpost.com/wp-dyn/content/article/2007/05/24/AR2007052400547.html.

119. Shigeru Sato, *Japan Will Urge APEC to Take Energy-Saving Measures (Update1)*, BLOOMBERG.COM, May 28, 2007, http://www.bloomberg.com/apps/news?pid=20601101&sid=AWNYkfb5wCq4&refer=Japan#.

120. Press Release, UNFCCC, G8 Document Re-energises Multilateral Climate Change Process Under the United Nations (June 7, 2007), http://unfccc.int/files/press/news_room/press_releases_and_advisories/application/pdf/20070607_g8_press_release_english.pdf.

121. Black, *supra* note 117.

122. Roger Harrabin, *U.N. Welcomes Bush's Climate Plans*, BBC NEWS, June 1, 2007, http://news.bbc.co.uk/2/hi/science/nature/6713543.stm.

123. *See id.*

124. *See id.*

125. *See id.*

by establishing an alternative venue for climate efforts, namely the Asia-Pacific Partnership.[126]

2. Asia-Pacific Partnership

Launched in January 2006 by the United States, just after the Protocol entered into force, the Asia-Pacific Partnership on Clean Development and Climate ("APP") functions outside the UN process and focuses on energy-technology cooperation rather than emissions targets.[127] The APP established eight public-private task forces for energy-intensive sectors: (1) Aluminum; (2) Buildings and Appliances; (3) Cement; (4) Cleaner Use of Fossil Energy (emphasis on carbon capture & storage); (5) Coal Mining; (6) Power Generation and Transmission; (7) Renewable Energy and Distributed Generation; and (8) Steel.[128] There are varying levels of participation by the six member countries in the different task forces, as well as varying levels of activity. For example, one sub-group within the Power Generation and Transmission Task Force has recently held study tours for engineers from all six countries to share experiences with maximizing efficiency in existing power plants.[129] The Cement Task Force has had some concrete activities,[130] and the Steel Sector Task Force is forging ahead as well.[131]

APP brings together a small group of large greenhouse gas emitters, engaging both developed and developing countries: the United States, Japan, and Australia, along with China, India, and the Republic of Korea.[132] These countries hold roughly half the world's population and cause roughly half of global greenhouse gas emissions. Real action on energy by this group of key nations—especially the United States and China—is essential for addressing the climate change problem. It is still too early to tell if APP will become an important group

126. *See id.*

127. For commentary on the APP, as well as climate response in China, see Jeffrey Logan et al., *For China, the Shift to Climate-Friendly Energy Depends on International Collaboration*, BOSTON REV. (2007), http://www.pewclimate.org/press_room/discussions/jlbostonreview.cfm.

128. For further information about the Asia-Pacific Partnership, see Asia-Pac. Partnership on Clean Dev. & Climate, http://www.asiapacificpartnership.org (last visited Aug. 11, 2007).

129. Personal Interview with Japanese Members, APP Power Generation and Transmission Task Force, in Tokyo, Japan (June 2007).

130. The pun on "concrete" action comes from a Cement Task Force member.

131. Personal Interview with Japanese Members, APP Steel Sector Task Force, in Tokyo, Japan (June 2007).

132. *See* Asia-Pac. Partnership on Clean Dev. & Climate, *supra* note 128.

for climate action, or a diversion from UN climate change negotiations and commitments.

3. Development Cooperation on Energy and Climate

Industrializing countries do not yet have emission-reduction obligations under the UN climate agreements. But many are undertaking initiatives to slow greenhouse gas emissions and to adapt to increasing impacts of climate change. International support for developing country initiatives can come from GEF, established in 1991, as well as from other sources of development aid and technical assistance.[133]

Large and small donors—including the United Nations Development Program ("UNDP"), the World Bank, the Asian Development Bank ("ADB"), the EU, and bilateral donors—have launched a host of programs on energy efficiency, renewable energy, and the development of overarching climate strategies.[134] For example, the UNDP is working with China through its End-Use Energy Efficiency Programme, using GEF funds.[135] The UNDP Programme in China coordinates initiatives in several energy-intensive sectors, including the development of energy efficient requirements for new industrial facilities, formulating targets and action plans (voluntary agreements) for industrial energy conservation, and implementing energy-efficiency standards and labeling for electric appliances and building materials.[136] This and other international cooperation efforts seek to support each country's domestic climate initiatives.

The EU, Japan, and other industrialized countries have pushed ahead with their own climate initiatives under UNFCCC, and they have supported developing-country activities as well. In contrast, the United States—at the federal level and in foreign policy—has used the lack of developing country commitments under UNFCCC as an excuse for limiting action.[137] The following viewpoint from Rajendra

133. For more information about GEF, see Global Env't Facility, About the GEF, http://www.gefweb.org/interior.aspx?id=50#id=18430 (last visited Aug. 11, 2007).

134. Stephanie Ohshita et al., *Cooperation Structure: The Growing Role of Independent Cooperation Networks, in* COOPERATIVE CLIMATE: ENERGY EFFICIENCY ACTION IN EAST ASIA 39 (Taishi Sugiyama & Stephanie Ohshita eds., 2006), *available at* http://www.iisd.org/publications/pub.aspx?pno=805.

135. *See id.* at 45.

136. *See id.* at 48–49.

137. In numerous statements from the White House and the State Department, the Bush administration has disregarded the UNFCCC agreement on industrialized countries taking the lead on climate change. Instead, the administration—along with some members of Congress—has stalled United States action, saying the United States should not take on binding commitments unless the developing countries do. *See* Table 2 *supra* Part II.A.1.

Pachauri, President of India's Tata Energy Research and Chair of the IPCC, conveyed a shared sentiment from many developing countries when he explained that "though India, like other developing countries, has not taken specific commitments to mitigate CO_2 emissions, it is making progress in this direction" through energy-price reform, energy-sector deregulation, and promotion of energy efficiency and renewable energy.[138] He also commented that the United States' "demands for developing-country commitments willfully ignore these signs of progress."[139]

C. International Comparison of Contributions to Climate Change

This section presents an international comparison of greenhouse gas emitters and highlights the two countries bearing the largest share of the problem: the United States and China. At the time of writing this Article, several media outlets announced that China had surpassed the United States as the world's largest emitter.[140] However, climate change is a cumulative problem—CO_2 lingers for hundreds of years—and cumulatively the United States has still caused the largest share of the problem.[141]

Figure 3 compares CO_2 emissions (in terms of million tons of carbon equivalent) among selected countries in 1990 and 2000, highlighting the large emitters and countries in the rapidly-growing Asian region.[142] The figure shows that the largest emitter during the period,

However, recognizing the need for *all* countries to take action, some United States government agencies have continued to cooperate with developing countries on climate and energy initiatives, despite the White House stance.

138. Seth Dunn, *Reading The Weathervane: Climate Policy From Rio to Johannesburg* (WorldWatch, Working Paper No. 160, Jane Petersen ed., 2002).

139. *Id.*

140. The announcement about China's new status as the world's largest carbon emitter came from a Dutch agency and was carried by many news venues. *See, e.g.*, John Vidal & David Adam, *China Overtakes U.S. As World's Biggest CO_2 Emitter*, GUARDIAN UNLIMITED, June 19, 2007, http://www.guardian.co.uk/china/story/0,,2106687,00.html.

141. *See* Dunn, *supra* note 138.

142. The following discussion is based on my analysis of data from the United States EIA. The 1990 data for Germany are the combined data for East and West Germany. The 1992 data for Russia are used here since 1990 data are only available for the Former Soviet Union as a whole. The two EIA data sources are (1) EIA, U.S. DEP'T OF ENERGY, INTERNATIONAL ENERGY ANNUAL 2001 (2001); and (2) EIA, U.S. DEP'T OF ENERGY, INTERNATIONAL ENERGY OUTLOOK 2003 (2003). For current 2007 reports, see EIA, U.S. DEP'T OF ENERGY, INTERNATIONAL ENERGY OUTLOOK 2007 (2007), http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2007).pdf. *See also* EIA, U.S. Dept. of Energy, International Energy Annual (IEA), http://www.eia.doe.gov/iea/ (last visited Aug. 11, 2007); EIA, U.S. Dep't of Energy, International Energy and Data Analysis, http://www.eia.doe.gov/international/ (last visited Aug. 11, 2007) (breaking down different energy sectors).

the United States, held its lead by a large margin. China was the world's second largest generator of CO_2 emissions in the year 2000, accounting for 12.1% of the world total. Japan and India accounted for 4.8% and 3.9%, respectively.[143] The entire Asian region still emitted less than the United States, which single-handedly accounted for 24.5% of the world total.[144] While Germany and Russia were able to decrease emissions during the past decade, other countries increased emissions. Despite its Protocol target of a six percent reduction of 1990 emissions, Japan increased by fifteen percent, while the United States increased by sixteen percent.[145] The increases were most dramatic in the Asian region, with CO_2 emissions from India growing sixty-one percent, South Korea eighty-two percent, and Indonesia eighty-one percent.[146] China's emissions grew by twenty-seven percent during the 1990–2000 decade, but the increase was lower than expected.[147]

The situation in China changed dramatically with a surge in Chinese power-plant construction, steel production, and cement production in the new millennium.[148] Since 2003, energy consumption in China has increased more rapidly than economic growth, resulting in an energy intensity above one.[149] Even as China has launched energy-conservation programs for industry, transportation, and other sectors, incredible growth in the steel and cement sectors has created large demand for coal and electricity.[150] Nearly sixty GW of new capacity were installed in 2005 alone and the majority of it coal-fired.[151] Based

143. Since the CO_2 emissions data are based directly on fossil fuel use, they mirror energy consumption and reflect fuel choices. The rank order of countries based on CO_2 emissions is nearly identical to the rank order based on energy. Germany and India switch places due to India's greater use of coal (a high-carbon fuel) and Germany's greater use of natural gas and renewable energy (low- and no-carbon fuels). Since coal yields more CO_2 emissions than natural gas or renewables per unit of energy, India has higher CO_2 emissions relative to its energy consumption than does Germany.

144. *See supra* text accompanying note 142.

145. *See* Dunn, *supra* note 138.

146. *See supra* text accompanying note 142.

147. *See* JEFFREY LOGAN, PAC. NW. NAT'L LAB., AN UPDATE ON RECENT ENERGY AND CARBON DIOXIDE TRENDS IN CHINA (2001), *available at* http://www.pnl.gov/aisu/pubs/engenvup.pdf.

148. For detailed Chinese energy statistics in English, see LAWRENCE BERKELEY NAT'L LAB. ("LBNL"), CHINA ENERGY DATABOOK (6th ed. 2004).

149. JONATHAN SINTON ET AL., LBNL, EVALUATION OF CHINA'S ENERGY STRATEGY OPTIONS (2005), *available at* http://china.lbl.gov/publications/nesp.pdf.

150. *See* Xie Ye, *China: Energy conservation to top government agenda*, CHINA DAILY, July 4, 2004, http://www.energybulletin.net/905.html.

151. Different figures have been reported for new power generation capacity in China in 2005 and 2006. For example, researchers at Stanford University estimate the addition of

on this, projections that China will surpass the United States in CO_2 emissions were revised from 2020 to as soon as 2008.[152]

Even with the June 2007 announcement of China surpassing the United States,[153] we should recognize that China's energy consumption—along with statistics measuring its energy consumption—fluctuates, sometimes significantly. Analysts have long been pondering upswings and downturns in Chinese energy consumption.[154] The present increases in energy and CO_2 emissions are significant, but it remains unclear how long the current surge will continue.

Notwithstanding the significance of Asia's greenhouse gas emissions in terms of the total amount emitted, other perspectives on time and place yield substantially different views. If one considers the cumulative burden of human-generated CO_2 during the past century, China contributed seven percent while the United States contributed thirty percent of the world total.[155] From an equity perspective, the contrast is even more striking. The Asian region is home to nearly half of humanity, with the populations of China and India each surpassing the one billion mark. Figure 4 shows carbon emissions on a per capita basis for the same group of countries depicted in the previous figure.[156] The people of Asian nations generate significantly less CO_2 than do Americans or citizens of other industrialized countries. Japan has the lowest per capita carbon emissions of the industrialized group.[157] In the year 2000, Americans emitted five times the global average, ten times more than the Chinese, and nineteen times more than the citizens of India.[158] The per capita gap between Americans and Chinese has narrowed since the turn of the new century, now roughly a four-fold difference, but still remains significant.[159] This in-

sixty to seventy GW. *See* CIVIC EXCH., ENERGY FORUM SUMMARY REPORT (2006), *available at* http://www.civic-exchange.org/publications/2006/EnergyForum.pdf; *see also* Stanford University, Program on Energy and Sustainable Development, http://pesd.stanford.edu (last visited Aug. 11, 2007).

152. *See* IEA, WORLD ENERGY OUTLOOK 2006 (2006) [hereinafter IEA, WORLD ENERGY OUTLOOK].

153. *See* Vidal & Adam, *supra* note 140.

154. *See* Jonathan Sinton & David Fridley, *What Goes Up: Recent Trends in China's Energy Consumption*, 28 ENERGY POLICY 671–87 (2000).

155. *See* Dunn, *supra* note 138.

156. *See supra* text accompanying note 142.

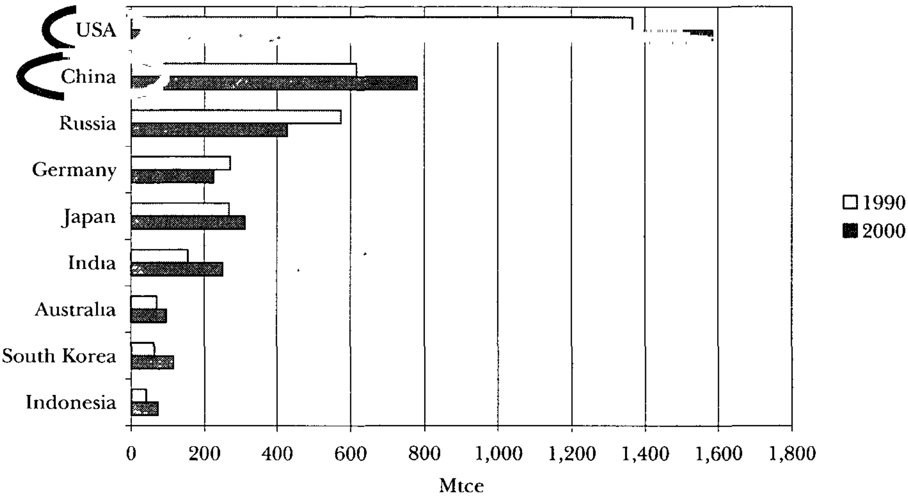
157. *See* Figure 4 *infra* Part II.C.

158. *See supra* text accompanying note 142.

159. Based on 2006 BP energy data. *See* Neth. Envtl. Assessment Agency, China Now No. 1 in CO2 Emissions; USA in Second Position, http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition.html (last visited Aug. 11, 2007) (comparing the factors influencing each country's CO_2 emissions).

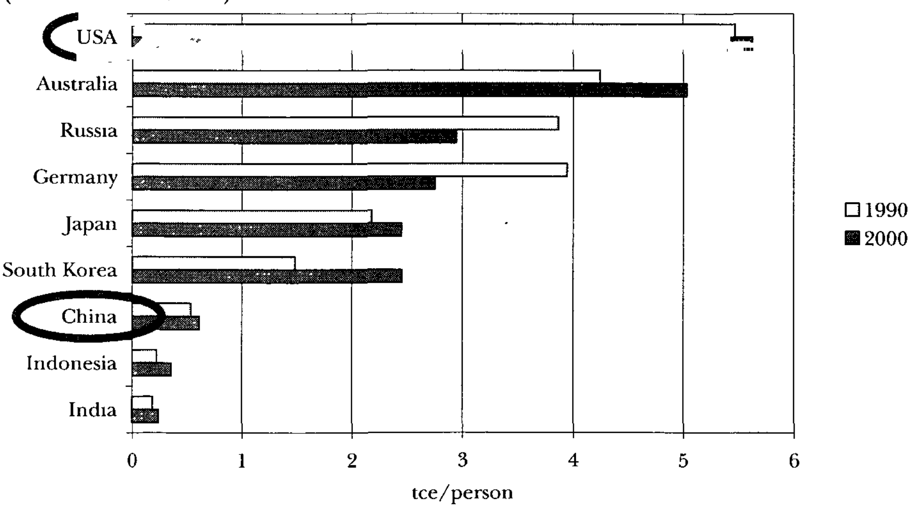
equity, as seen from the developing countries' perspective, has been one of the major stumbling blocks in international climate change negotiations.

Figure 3. Country Comparison of CO_2 Emissions (1990 and 2000)



Source: Ohshita analysis of EIA data, *supra* note 138. Mtce = million metric tons carbon equivalent.

Figure 4. Per Capita Country Comparison of CO_2 Emissions (1990 and 2000)



Source: Ohshita analysis of EIA data, *supra* note 138. tce/person = metric tons carbon equivalent per person (annual).

III. Solutions and Conclusions

A. Multiple Solutions Needed to Achieve Necessary Emission Reductions

As Pacala and Socolow have visualized with the concept of climate stabilization "wedges," we need a combination of solutions to cut worldwide emissions of greenhouse gases—there is no silver bullet.[160] Past and present reports by Working Group III of the IPCC on mitigation of climate change also highlight the need for a multi-pronged strategy of emission reductions.[161]

Two important reports released by the IEA in 2006 highlight the importance of energy efficiency—especially in transportation and use of electricity—in reducing greenhouse gas emissions. Both reports placed heavy emphasis on the climate-change implications of energy use among the world's largest consumers, notably the United States and China. The IEA *World Energy Outlook 2006* examined an Alternative Policy Scenario to curb human emissions of greenhouse gases—primarily CO_2—by 2030.[162] In that scenario, policies promoting more efficient production and use of energy could realize almost eighty percent of avoided CO_2 emissions worldwide. Of that large savings, nearly thirty-six percent comes from more efficient use of fuels in cars and trucks.[163] More efficient use of electricity in appliances, lighting, cooling, and industrial motors contributes another thirty percent.[164] Better efficiency in electric-power generation and other energy production accounts for thirteen percent.[165]

In *Energy Technology Perspectives*, IEA provides technology analysis and strategies for climate change mitigation in response to the request by the G8 after the Gleneagles Summit in 2005.[166] IEA developed accelerated technology scenarios for cutting future CO_2 emissions in half by 2050.[167] Even with the introduction of new tech-

160. S. Pacala & R. Socolow, *Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies*, 305 SCIENCE 968–72 (2004).

161. *See, e.g.*, IPCC WG3, SUMMARY FOR POLICYMAKERS, *supra* note 21. For a list of earlier assessments reports from IPCC Working Group III (Mitigation), see IPCC, Publications, Online reports, http://www.ipcc.ch/pub/online.htm (last visited Aug. 11, 2007).

162. *See* IEA, WORLD ENERGY OUTLOOK, *supra* note 152. The Alternative Policy Scenario would yield a sixteen percent reduction in CO_2 emissions by 2030, compared to 2004. *Id.*

163. *See id.*

164. *See id.*

165. *See id.*

166. *See* IEA, ENERGY TECHNOLOGY PERSPECTIVES: SCENARIOS & STRATEGIES TO 2050 (2006).

167. *See id.*

nologies a few decades from now, such as carbon capture and storage, the largest share of CO_2 reductions would still come from end-use energy efficiency, through the accelerated introduction of commercially-available energy-efficient technologies.[168]

Both IEA reports highlighted the economic favorability of making energy-efficiency investments sooner rather than later. Investments in energy efficiency are typically less than the cost of new energy supply. The IEA compared payback periods for investments in energy-efficiency policies and technologies over two timeframes: 2005–2015 and 2016–2030.[169] The estimates indicate that the payback period for developing countries such as China would be roughly one to two years for efficiency efforts made before 2015; in the timeframe beyond 2015, the payback period would more than double.[170]

In other words, the latest IEA reports reinforce what those working on energy and development have been emphasizing for years: the energy and environmental savings from efficiency improvements are huge, and the economic savings are higher when countries invest in efficient technology early on.

More often than news of energy efficiency, the press highlights possible future applications of cleaner coal technologies and nuclear power for energy supply. For countries with a heavy reliance on coal (like the United States and China), switching to low-carbon fuels (e.g., from coal to natural gas) and to zero-carbon energy (e.g., to wind and solar) is indeed necessary. These countries may also need to begin sequestering carbon from coal combustion in geological formations and trees. However, energy efficiency has immediate appeal in that technologies are already commercially available which meet local priorities along with global climate needs. In addition, energy efficiency has long-term appeal as well, because it sets more sustainable economic and technological paths in motion.

A. Conclusion: Moving Forward with Solutions

This broad sweep across the scientific and international context for United States initiatives on climate change concludes by reiterating three main points. First, there is an overwhelming consensus and scientific certainty on climate change. Arguments against action that are based on the claim of scientific uncertainty simply do not hold.

168. *See id.*

169. IEA, WORLD ENERGY OUTLOOK, *supra* note 152.

170. *See id.*

The phenomenon is real, and the understanding of the causes and outcomes is increasingly sophisticated.

Second, multiple solutions are needed to stabilize the climate, and those solutions must address the source of the problem to be effective. Multiple solutions are needed at all levels, from international climate initiatives, to United States initiatives at the federal, state, and local level. Solving at the source of the problem means managing energy demand through energy efficiency and conservation. Solving at the source also means cutting carbon in energy supply, by shifting to renewable energy and other no- or low-carbon energy sources.

To be effective, climate solutions must also consider the whole system. In dealing with past environmental problems, from water pollution to acid rain, we discovered that dilution was not the solution to pollution. We also learned that end-of-pipe technological fixes did not solve the problems; the most harmful particulate matter from combustion is not controlled by our technological advances.[171] And our current geo-engineering experiment of rapidly injecting massive amounts of carbon into the atmosphere is not going very well.

Third, action is needed immediately. Postponing state action because of the lack of federal policy does not make the problem of climate change go away, nor does finger pointing at other sectors or other countries. Analyses presented in this Article show that delay will only increase the damages and their costs.

A final example illustrates the costs of stalling when faced with environmental problems. Efforts in the 1970s to reduce smog and enhance domestic energy security led to requirements for technological change in automobiles, notably catalytic converters and measures to raise fuel efficiency. During that time, United States automobile manufacturers fought regulation and denied that technological solutions could be implemented. Japanese automakers, in contrast, saw an opportunity for gaining market share and took the road of innovation. The lesson is still well-remembered by Japanese industry and regulators: environmental challenges present a business opportunity.[172] United States automakers are now facing a remarkably similar situation with climate change. The global automobile market is growing

171. Small particulate matter, with a diameter of less than 5 microns (<PM5), is the most damaging because it penetrates furthest into the lungs. For more information, see U.S. Environmental Protection Agency, Frequent Questions, http://www.epa.gov/pm designations/faq.htm#0 (last visited Aug. 11, 2007). But most industrial control equipment is not guaranteed for particulates smaller than 2.5 microns. *Id.*

172. Based on personal communications with Japanese regulators and industry over the past decade.

most rapidly in China, and market shares will be determined in part by automakers' ability to meet stricter Chinese standards for fuel economy (as well as other pollutant emissions). United States automakers are not well poised to flourish in the Chinese market.[173] Will the industry be narrowly clever in its litigation efforts to stall technological change? Or will it be truly clever in seizing an opportunity for sustainable business? Let us hope that United States automakers and other emitters take the road thus far less traveled.

173. *See* AMANDA SAUER & FRED WELLINGTON, WORLD RES. INST., TAKING THE HIGH (FUEL ECONOMY) ROAD: WHAT DO THE NEW CHINESE FUEL ECONOMY STANDARDS MEAN FOR FOREIGN AUTOMAKERS? (2004), *available at* http://pdf.wri.org/china_the_high_road.pdf. For a more recent report on the competitive position of world automakers in a cleaner energy future see, *The Drive for Low Emissions*, ECONOMIST May 31, 2007, at 27.