HOW TO AVOID DANGEROUS CLIMATE CHANGE

A Target for U.S. Emissions Reductions

Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

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Executive Summary

Substantial scientific evidence indicates that an increase in the global average temperature of two to three degrees Celsius (°C) above pre-industrial levels (i.e., those that existed prior to 1860) poses severe risks to natural systems and human health and well-being. Sustained warming of this magnitude could, for example, result in such large-scale, irreversible changes as the extinction of many species and the destabilization and extensive melting of the Greenland and West Antarctic ice sheets—causing global sea level to rise between 12 and 40 feet. In light of this evidence, policy makers in the European Union have committed their countries to a robust long-term target of limiting warming to 2°C above pre-industrial levels.

The United States, under the United Nations Framework Convention on Climate Change, is committed to working with more than 180 other nations to bring about the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [human-caused] interference with the climate system." There is also growing momentum within the United States to pursue deep reductions in emissions of carbon dioxide (CO_2) and other heat-trapping gases that cause global warming. California, Florida, Hawaii, Minnesota, New Jersey, Oregon, and Washington have all enacted laws or established policies setting global warming pollution reduction targets, while states in both the Northeast and West have signed agreements to achieve regional targets. Now the U.S. Congress is considering several bills that propose a variety of global warming emissions reduction targets.

This report provides an analytic basis for evaluating these bills and setting a sound long-term U.S. emissions reduction target consistent with avoiding dangerous climate change. Our analysis focuses on a goal of stabilizing the concentration, or level, of heat-trapping gases in the atmosphere at or below the CO_2 equivalent of 450 parts per million (450 ppm CO_2eq—a measurement that expresses the concentration of all heat-trapping gases in terms of CO_2).

Current science indicates that this stabilization target provides a medium chance (about 50 percent) of keeping the global average temperature from rising more than 2°C, or 3.6 degrees Fahrenheit (°F), above pre-industrial levels, and a 33 percent chance of rising more than 3°C. Therefore, **a 450 ppm CO_2eq stabilization target should represent the upper limit on concentrations of heat-trapping emissions set by any policy that seeks to avoid dangerous climate change**.

Given current levels of heat-trapping gases in the atmosphere, meeting this stabilization target will likely require atmospheric concentrations to peak above 450 ppm CO_2eq briefly before returning to the target. Recent studies indicate that, to follow such a path while still maintaining a reasonable chance of keeping temperatures from rising more than 2°C, cumulative *global* emissions must not exceed approximately 1,700 gigatons (Gt) CO_2eq for the period 2000–2050. Constraining cumulative global emissions (i.e., those of industrialized and developing nations) in this way will require reductions on the order of 40 to 50 percent below 2000 levels by 2050.

After accounting for the most aggressive reductions that can be reasonably expected of developing nations, the industrialized nations will have to reduce their emissions 70 to 80 percent below 2000 levels by 2050. Industrialized nations' cumulative emissions over this period must be no more than 700 $GtCO_2$eq (about 40 percent of the global budget).

This 70 to 80 percent range for reductions by 2050 assumes that industrialized nations' emissions peak in 2010 and those from developing nations peak between 2020 and 2025. A delay in the peak of either group would require even faster reduction rates to stay within the global emissions budget.

This analysis explores several means of determining the United States' share of the industrialized nations' emissions budget, including allocations based on the current U.S. share (among industrialized countries) of population, gross domestic product (GDP), and heat-trapping emissions. Using these criteria, **the U.S. cumulative emissions budget is identified as 160 to 265 GtCO_2eq for the period 2000–2050, of which approximately 45 GtCO_2eq has already been emitted**.

Given our aggressive assumptions about reductions by other nations and the fact that 450 ppm CO_2eq represents an upper limit needed to avoid a potentially dangerous temperature increase, we argue that **the United States should reduce its emissions *at least* 80 percent below 2000 levels by 2050**.

The costs of delay are high. To meet this minimum target, the United States must reduce its emissions an average of 4 percent per year starting in 2010. If, however, U.S. emissions continue to increase until 2020—even on a "low-growth" path projected by the Energy Information Administration (EIA)—the U.S. reduction rate would have to accelerate to approximately 8 percent per year on average from 2020 to 2050. This amounts to a doubling of the annual reductions that would be required if we started promptly. By 2030, the cumulative emissions of the same EIA projection would nearly exceed the 265 GtCO_2eq upper limit of the U.S. emissions budget for 2050.

Of the current climate policy proposals before the U.S. Congress, only the Global Warming Pollution Reduction Act (S. 309) and the Safe Climate Act (H.R. 1590) would require reductions consistent with staying below *the upper limit* of the U.S. cumulative emissions budget (265 GtCO_2eq). All of the other bills under consideration—the Lieberman-Warner proposal, the Global Warming Reduction Act (S. 485), the Climate Stewardship Act (H.R. 620), and the Low Carbon Economy Act (S. 1766)—would exceed that limit. The amounts by which these bills would go over the budget may not appear to be great, but if every nation went over its budget by a similar amount, the result would be a greatly increased risk of dangerous climate change.

Furthermore, no proposal currently before Congress would come close to meeting the proposed lower end of the U.S. emissions budget range (160 GtCO_2eq for the period 2000–2050). Several of the proposals—S. 309, H.R. 1590, and the Global Warming Reduction Act (S. 485)—do provide for periodic review by the National Academy of Sciences to maintain or strengthen U.S. targets as needed to meet the goal of preventing a 2°C temperature increase—an essential element of any robust climate policy. Other proposals provide for review but fail to specify the 2°C goal or allow the targets to be strengthened if necessary.

As this analysis demonstrates, the United States must quickly overcome its current impasse on climate policy if we are to avoid the risks of dangerous climate change. Many solutions are already available, including greater energy efficiency, increased use of renewable energy, and reductions in deforestation. These changes can be encouraged by a wide range of market-based and complementary policies, such as cap-and-trade programs, renewable electricity standards, efficiency standards for electricity and vehicles, and incentives for cleaner technologies and international cooperation on emissions reductions.

The way forward is a fully engaged United States, committed both to deep reductions of its own heat-trapping emissions and supporting the efforts of developing countries that are attempting to reduce their emissions while sustaining economic growth.

I. Introduction

As a steady stream of new scientific findings highlights the growing risk of dangerous climate change, considerable momentum is building for the United States to set national policies that cap and reduce emissions of carbon dioxide (CO_2) and other heat-trapping gases. Policy makers weighing the available options for an effective climate policy must grapple with the following fundamental question:

> *To avoid dangerous climate change, what should be the long-term U.S. target for reducing emissions?*

Remarkably, no rigorous assessment exists that can answer this question for policy makers. In the absence of such an assessment, current climate policy proposals before the U.S. Congress set widely divergent national emissions targets (see the appendix). A coalition of U.S. businesses including Alcoa, Caterpillar, DuPont, and General Electric, working with environmental groups as part of the U.S. Climate Action Partnership, recently called on Congress to "specify an emission target zone aimed at reducing emissions by 60%-80% from current levels by 2050."

In addition, several states are setting their own reduction targets and policies. California has set a goal of reducing its emissions 80 percent below 1990 levels by 2050, while New Jersey has set a state target of 80 percent below 2006 levels by 2050.[1] Both states have also passed legislation putting the first phase of their plans (reducing emissions to 1990 levels by 2020) into law. Minnesota has set into law an emissions reduction target of 80 percent below 2005 levels by 2050. In Florida, Governor Crist has signed an executive order requiring electric utilities to reduce emissions 80 percent below 1990 levels by 2050.

Achieving the deep reductions envisioned in these policies and proposals will require a concerted effort to move away from our current national pathway of increasing emissions. Absent such an effort, U.S. energy-related emissions of CO_2 are projected to grow 20 to 45 percent between 2007 and 2030 (EIA 2007).

This paper draws upon the best available science to provide a rationale for a sound long-term U.S. emissions reduction target. We focus on a goal of stabilizing the concentration, or level, of heat-trapping gases in the atmosphere at or below the CO_2 equivalent of 450 parts per million (450 ppm CO_2eq).[2] Stabilizing at this level would provide a medium chance (about 50 percent) of avoiding the increasingly dangerous consequences expected if the global average temperature were allowed to rise more than two degrees Celsius (°C), or 3.6 degrees Fahrenheit (°F), above pre-industrial levels (i.e., levels prior to 1860; see Figure 1, p.4, and Box 1, p.6).

We next identify a global emissions budget consistent with this concentration limit, and determine a practical share of this budget for the United States and the rest of the industrialized world (based on an assessment of various aggressive emissions reduction scenarios for developing nations). We used 2050 as our target date for U.S. reductions because this has been the most commonly used long-term reference period in climate policy proposals to date.

Finally, we assess how current climate policy proposals for U.S. emissions reductions compare with the targets presented in this analysis.

Figure 1a. Probability of Exceeding 2°C Increase in Global Average Temperature

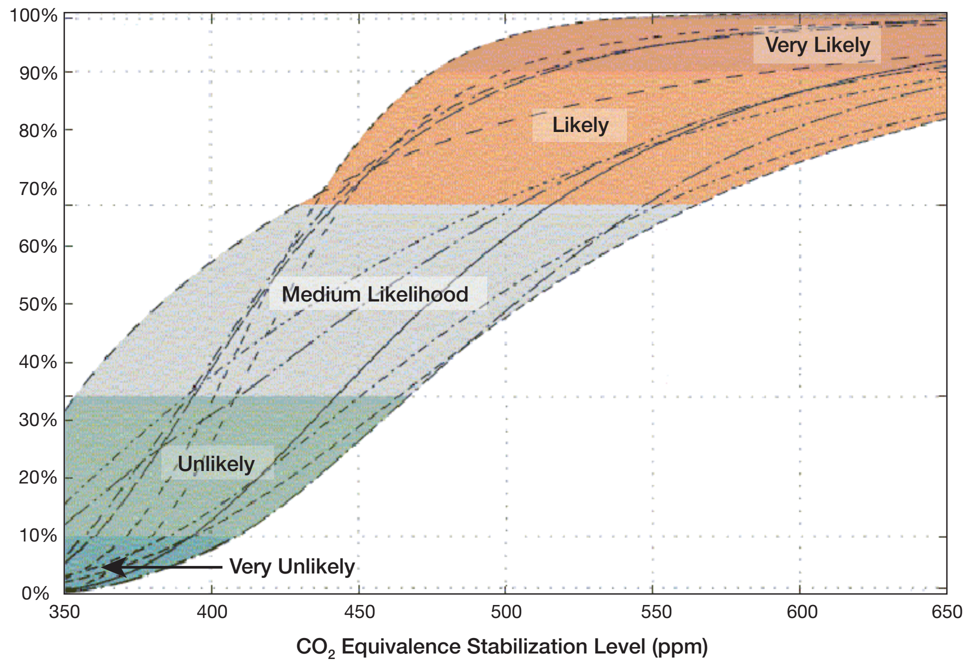
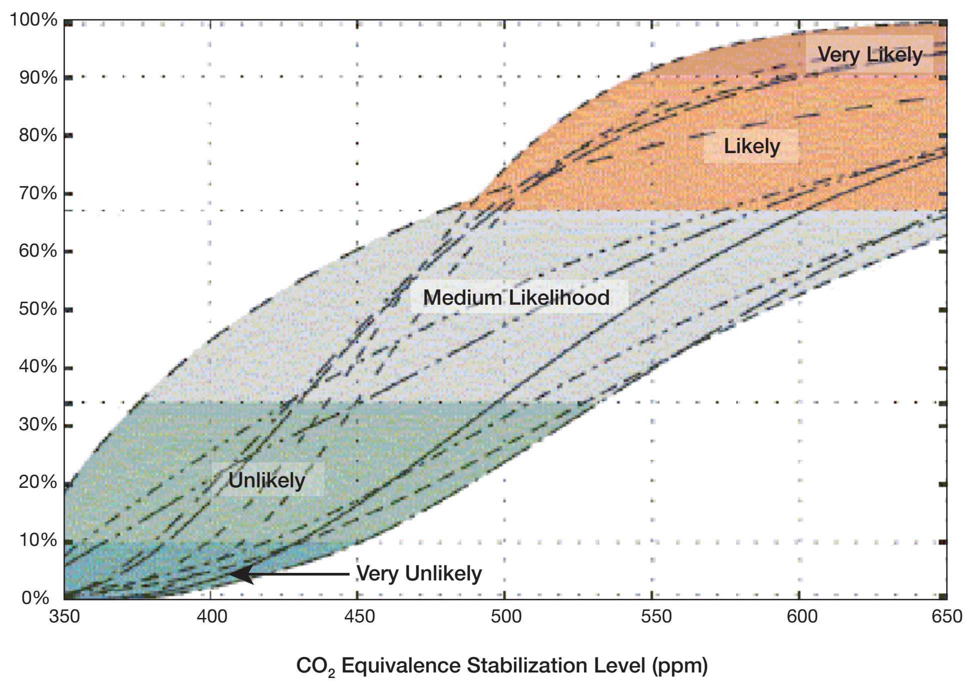


Figure 1b. Probability of Exceeding 3°C Increase in Global Average Temperature



The probability of exceeding a 2°C and 3°C increase in global average temperature at different CO_2-equivalent stabilization levels. The dashed lines represent different published estimates of climate sensitivity (here defined as the amount global average temperatures are expected to rise as a result of a doubling in atmospheric concentrations of CO_2). Source: modified from Meinshausen (2006) and Meinshausen et al. (2006).

II. Setting a Global Limit on Heat-trapping Emissions

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC), as stated in Article 2, is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [human-caused] interference with the climate system" (UNFCCC 1992). This is the long-term climate policy commitment agreed to by more than 180 nations including the United States.

However, because "dangerous anthropogenic interference" is not well defined under the UNFCCC (Oppenheimer and Petsonk 2005), policies to prevent dangerous change may differ in the criteria used to define "dangerous." These criteria can be informed by scientific assessments of the risks associated with rising emissions and temperatures, but they are ultimately determined by societal values regarding what risks are unacceptable (and therefore "dangerous"). By some measures, current atmospheric levels of heat-trapping gases may already be causing dangerous climate change (e.g., Poumadere et al. 2005).

Policy makers in the European Union have weighed the risks identified by scientific research and committed their countries to a long-term target limiting warming to 2°C above pre-industrial levels (European Council 1996, 2005), a target recently reaffirmed by the International Climate Change Taskforce (ICCT 2005). As new scientific information points to potentially dangerous consequences if the global average temperature increases more than 2°C above pre-industrial levels (Box 1, p.6), this target remains a robust policy goal.

Establishing a temperature target, however, does not answer the question: what limit on atmospheric concentrations of heat-trapping gases will constrain warming from rising more than 2°C above pre-industrial levels? It is not currently possible to predict precisely how much the global average temperature will rise with increasing atmospheric concentrations of heat-trapping gases. There are a number of natural "feedback" mechanisms built into the climate system that can amplify or dampen warming trends, and many of these are not yet fully understood. The likely range of climate sensitivity (how much the global average temperature will rise in response to a given increase in atmospheric CO_2 levels) is 2°C to 4.5°C (3.6°F to 8.1°F) for a doubling (from pre-industrial levels) of CO_2 concentrations in the atmosphere (Meehl et al. 2007). However, scientific assessments conclude that it is still possible that climate sensitivity could be greater than 4.5°C (e.g., Meehl et al. 2007; Hegerl et al. 2006; Stainforth et al. 2005).

The uncertainty regarding climate sensitivity requires the selection of an appropriate atmospheric concentration limit based on a risk perspective (i.e., the desired level of certainty for keeping temperature increases below 2°C). Figure 1a depicts the chances of exceeding a temperature threshold of 2°C at different stabilization levels and Figure 1b depicts the chances of exceeding 3°C.

If atmospheric concentrations of heat-trapping gases are stabilized at 400 ppm CO_2eq, it is unlikely (less than a one-third chance) that the long-term global average temperature increase will exceed 2°C. At 450 ppm CO_2eq, there is a medium likelihood of exceeding 2°C (approximately a 50-50 chance), but it is unlikely that warming will exceed 3°C (less than a one-third chance). However, if concentrations stabilize at 500 ppm CO_2eq, it is likely (greater than a two-thirds chance) that warming will exceed 2°C, and there is at least a

(*continued on p.8*)

Box 1. What Happens If Temperatures Increase More Than 2°C?

A growing body of scientific evidence links global average temperature increases of greater than 2°C above pre-industrial levels (i.e., prior to 1860) with a number of potentially severe climate impacts on social and natural systems (Parry et al. 2007a; Hansen et al. 2006) (Figure 2). The magnitude of many of these impacts and the risk of irreversible impacts grows with increasing temperature.

For example, ice sheets in Greenland and West Antarctica store vast quantities of frozen water that, if melted, would cause the global sea level to rise by meters. While these ice sheets may still be adding ice and snow in their cold, dry interiors, their edges and surfaces are beginning to melt more rapidly and extensively. Sustained warming between 1.6°C and 5.2°C could initiate widespread destabilization of these ice sheets (Meehl et al. 2007; Alley et al. 2006; Gregory and Huybrechts 2006; Overpeck et al. 2006), leading to sea level rise of two to seven meters (6.6 to 23 feet) from Greenland melting and 1.5 to 5 meters (5 to 16.4 feet) from West Antarctica melting. While the full rise in sea level may take centuries to occur, even one meter (three feet) of sea level rise would significantly change global coastlines, threatening major cities including Mumbai, New York, and Tokyo, and inundating some small islands.

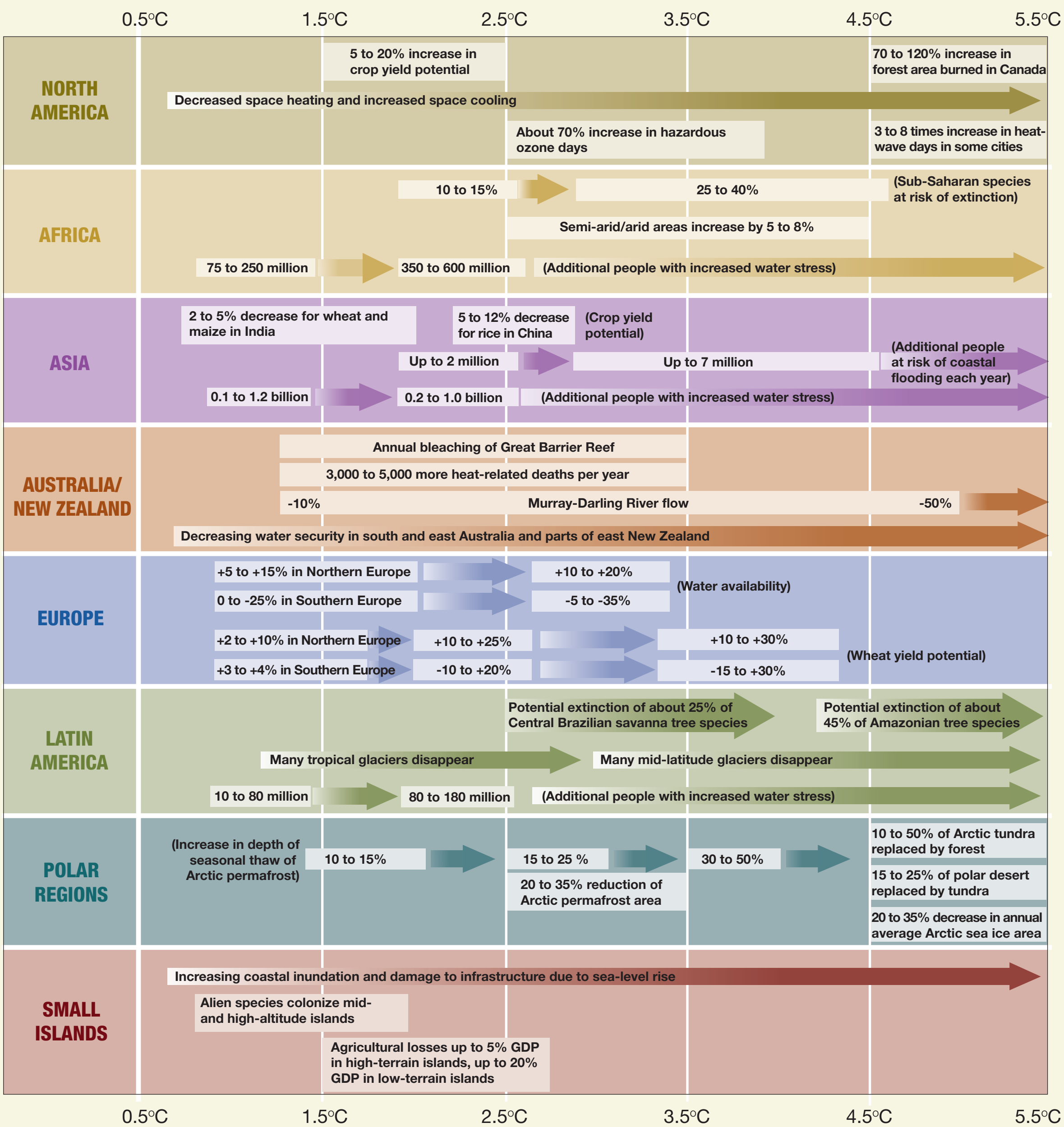
A 2°C to 3°C level of warming has been linked to species extinctions and sweeping changes in world ecosystems. In this temperature range, the Intergovernmental Panel on Climate Change (IPCC) has estimated that approximately 20 to 30 percent of species could risk extinction (Fischlin et al. 2007). Some parts of the biosphere may switch from a carbon sink (which absorbs more CO_2 than it emits) to a carbon source (which emits more CO_2 than it absorbs), further increasing atmospheric levels of CO_2 and exacerbating the warming caused by human activities (Scholze et al. 2006). This level of temperature increase is also above the thresholds at which many coral reefs would become bleached (McWilliams et al. 2005; O'Neill and Oppenheimer 2002). In addition, increasing atmospheric CO_2 concentrations lead to increasing ocean acidification, with potentially significant impacts on marine ecosystems.

Warming in this range has also been linked to increases in the severity of many climate impacts—some of which are already intensifying—including floods, droughts, heat waves, fires, the spread of infectious diseases, and heat-related deaths (Rosenzweig et al. 2007). For example, 1 to 2 billion people would be at risk of increased water scarcity (IPCC 2007a).

In the continental United States specifically, drought-prone ecosystems are projected to expand approximately 11 percent in area for each degree Celsius of additional warming (Field et al. 2007). Water resources in California would be highly threatened, as the Sierra Nevada snowpack is projected to decrease 60 percent from the 1961–1990 historical average under the drier conditions associated with a 2.4°C increase in global average temperature (CCCC 2006; Hayhoe et al. 2004). That same temperature increase would cause many cities across the northeastern United States to experience a projected tripling in the number of days featuring extreme summer heat (high temperatures above 32°C or 90°F), increasing the risk of heat-related illness and death among vulnerable populations (Frumhoff et al. 2007).

Rising sea levels will threaten U.S. coastal communities and ecosystems by increasing the impact of storms on coastal areas (Field et al. 2007). A 2.4°C increase in global average temperature, for example, would result in a conservatively projected 7- to 14-inch rise in sea level, causing Boston and Atlantic City, NJ, to experience coastal flooding equivalent to today's 100-year flood almost every year on average (Frumhoff et al. 2007).

Figure 2. Regional Climate Impacts Worsen as Temperature Increases



Examples of the projected consequences associated with different increases in global average surface temperature above pre-industrial levels. Placement of text boxes indicates the range of temperature change in which the consequences would occur; arrows indicate increasing intensity of the consequences as temperature rises. Adaptation measures are not included in these estimations. Source: modified from Parry et al. (2007b).

medium likelihood (approximately a 50-50 chance) that the global average temperature will rise more than 3°C above pre-industrial levels.

Given these probabilities and the growing evidence that the risk of dangerous impacts increases if Earth warms more than 2°C above pre-industrial levels (Box 1, p.6), society should view a 450 ppm CO_2eq stabilization target as the upper limit for a policy that will satisfy any reasonable definition of "dangerous" climate change. We have therefore focused this analysis on U.S. emissions reductions needed to stabilize heat-trapping gases at or below this level.

III. Different Pathways to the Stabilization Target

Atmospheric concentrations of CO_2 have risen from approximately 280 ppm at the outset of the Industrial Revolution to more than 385 ppm today. Concentrations of other heat-trapping gases have also increased, but recent studies indicate that their current influence on rising temperatures may be roughly offset by the cooling effect of reflective sulfate aerosols and other fine particulate matter that enter the atmosphere both from the burning of fossil fuels and natural sources such as volcanic eruptions (Meehl et al. 2007). Because aerosols stay in the atmosphere for a short period of time (on the order of 10 days, versus about 100 years for a molecule of CO_2), reductions in fossil fuel use and improvements in air quality are expected to diminish their net cooling effect (Meehl et al. 2007). Absent this effect of aerosols, today's atmospheric concentrations of heat-trapping gases would be approximately 450 ppm CO_2eq already—and rising 2.7 ppm per year (Hoffman et al. 2006).

Given these already high (and increasing) levels, stabilizing concentrations at or below 450 ppm CO_2eq is likely to be feasible only if we allow concentrations to initially rise above the target before returning to it later (by reducing emissions from human activities to levels below the rate at which heat-trapping gases are captured through natural processes such as photosynthesis). Fortunately, inertia inherent in the climate system's response to increasing emissions, which is largely the result of the oceans' capacity for storing a massive amount of heat, causes temperature increases to lag several decades behind increases in concentrations of heat-trapping gases.

Therefore, it is possible for concentrations to exceed the final stabilization goal, peak, then decline back to the targeted level without the full temperature increase that would correspond to sustained concentrations at the peak—provided the peak is sufficiently modest and brief. For example, Meinshausen et al. (2006) report that peaking at 500 ppm CO_2eq by 2050 (which would still require significant emissions reductions) and slowly returning to 450 ppm CO_2eq by maintaining emissions below the rates of natural uptake would provide a medium chance of avoiding a 2°C increase.[3]

Several studies suggest that to stabilize between 400 and 450 ppm CO_2eq with a higher peak, the global cumulative emissions budget must be on the order of 1,700 gigatons (Gt) CO_2eq for the period 2000–2050 (van Vuuren et al. 2007; Baer and Mastrandrea 2006; Meinshausen et al. 2006).[4] To stay within this budget, global emissions would have to be reduced on the order of 40 to 50 percent below 2000 levels by 2050 (den Elzen and Meinshausen 2006).[5]

The analysis here is based on a 450 ppm CO_2eq multi-gas global emissions pathway proposed by Meinshausen et al. (2006),[6] with a cumulative budget for the period 2000–2050 of 1,690 $GtCO_2$eq.[7] This pathway leads to atmospheric concentrations peaking at 500 ppm CO_2eq around mid-century, with concentrations stabilizing at (and potentially below) 450 ppm CO_2eq through continued reductions in CO_2 emissions from human activities after 2050.[8]

To maintain worldwide economic growth while staying within the required emissions budget, the global economy must undergo a profound technological transformation and substantially reduce its emissions from fossil fuels. The global economy is already moving in the direction of less carbon-intensive growth (Nakicenovic 2000), but because there is an absolute limit on the cumulative volume of heat-trapping gases that can be emitted before exceeding the proposed 450 ppm CO_2eq stabilization limit, a far more rapid shift away from fossil fuels will be necessary in the coming years (IPCC 2007b).[9]

The phaseout of energy-related emissions must proceed rapidly to mid-century, and continue more gradually throughout the second half of the century. This initially rapid decrease is essential if we are to minimize the size and timing of the peak in atmospheric concentrations above 450 ppm CO_2eq.

IV. Complementary Targets for Industrialized and Developing Nations

Given a global emissions budget (the overall amount of carbon that can be released into the atmosphere worldwide), the next task is to allocate each nation's share of responsibility for the budget—first, by dividing the budget between industrialized and developing nations as a whole, and then, among individual nations. Several proposals suggest that the most equitable approach would be to allocate global emissions reductions by population (e.g., Meyer 2000). Others have suggested that emissions allocation should be based on relative capacity for emissions reductions (Athanasiou et al. 2006), relative gross domestic product (GDP) (Vattenfall 2006), current carbon intensity (the level of emissions compared with GDP) (Herzog et al. 2006; Pizer 2005), historic emissions levels (otherwise known as "grandfathering," as was done in the U.S. acid rain program) (Burtraw et al. 2005), historical responsibility for emissions (the so-called Brazilian Proposal) (UNFCCC 1997), or a subset of these criteria (CAN 2003).

This is a discussion that could clearly continue for some time. Unfortunately, the world no longer has the luxury of engaging in a persistent stalemate. The risks of the temperature increase discussed above and the scale of emissions reductions needed to avoid those risks clearly show that the United States and other signatories to the UNFCCC must rapidly establish a consensus on the equitable and effective allocation of emissions among nations.

In the absence of such a consensus, and for the purposes of this analysis, we submit that any practical allocation strategy must accept the following realities:

- Avoiding the potentially dangerous consequences of a 2°C increase in the global average temperature will require an absolute limit on total cumulative heat-trapping emissions over the coming decades (a "cumulative emissions budget").
- Staying within this cumulative emissions budget will require a global economic transition away from fossil fuel-intensive growth by mid-century, as well as significant reductions in emissions from deforestation, particularly in tropical countries (Gullison et al. 2007).
- To accomplish this transformation, industrialized nations must lead the world in developing the necessary clean energy technologies and infrastructure and creating more effective mechanisms for disseminating that technology and capacity to developing nations. These mechanisms should encourage communication in both directions, since some developing countries are also making significant contributions to the development of clean energy technologies (as well as reductions in deforestation).
- Timing is critical—industrialized nations need to transform their economies over the next few decades and partner with developing nations to ensure that these countries' economic growth follows a much cleaner path than the one the industrialized world took to get where it is today.

Given these realities, a *practical* emissions reduction strategy must be one in which the total cumulative emissions of industrialized nations are sufficiently constrained between now and 2050 so that the remaining global emissions budget can be achieved with aggressive but realistic expectations about emissions reductions in developing nations. This paper makes no assumptions about specific policies for tackling climate change or which countries would be likely to implement or pay for such policies. But it is clear that the United States and other industrialized nations must not only transform their own economies but also help facilitate emissions reductions in developing countries. This can be done through a combination of expansion of carbon market mechanisms, technology transfer, direct financial assistance, and other means. In fact, the sooner industrialized countries can dramatically expand such activities, the sooner developing countries will be able to reduce their emissions.

For the purposes of this analysis, we define "aggressive but realistic expectations" about developing nations' emissions reductions in the following terms:

- Developing nations' average annual emissions peak between 2020 and 2025—10 to 15 years after those of industrialized nations. This time lag accounts for industrialized nations' historically far greater contribution to global emissions; it is also consistent with the principle of "common but differentiated responsibilities" embodied in the UNFCCC. A lag of more than 10 to 15 years would require increasingly steep and unrealistic global reduction rates.
- During this 10- to 15-year period, developing nations' average annual emissions continue to increase at a relatively slow rate, following a "low-growth" emissions trajectory defined by the Energy Information Administration (EIA 2007).[10] Such a trajectory can be facilitated by the mechanisms described above.
- Once developing nations' emissions peak, their average annual reduction rates match those of industrialized countries.

In order to divide the global emissions budget of 1,690 GtCO_2eq for the period 2000–2050 between industrialized and developing nations according to the above criteria, the industrialized nations must reduce their emissions an average of 70 to 80 percent below 2000 levels by 2050 (Table 1, p.11). The share of the budget for all industrialized nations must fall between 600 and 700 GtCO_2eq for that period.

The 70 to 80 percent range for emissions reductions by 2050 assumes that industrialized nations' emissions peak in 2010 and those from developing nations peak between 2020 and 2025. Delays in these peaks would require increasingly unrealistic reduction rates in global emissions to remain within the global budget (Table 1).

Given these aggressive assumptions, the United States' high per capita emissions relative to the industrialized country average (about double), and the fact that 450 ppm CO_2eq represents an upper limit needed to avoid a potentially dangerous temperature increase, we argue that the United States should aim to reduce its emissions *at least* 80 percent below 2000 levels by 2050.[11]

Figure 3a (p.12) displays emissions pathways that assume industrialized nations' emissions peak in 2010 and developing nations' emissions peak in 2020 (allowing a cumulative emissions budget of 700 $GtCO_2$eq for industrialized nations).[12] In this case, the average developing nation would be required to reduce its emissions on the order of 25 percent below 2000 levels by 2050. China, however, would likely have to reduce its emissions at a significantly higher rate since it currently accounts for about one-third of the developing world's emissions from energy use (EIA 2007).

The current disparity in per capita emissions between industrialized and developing countries is reduced under this scenario, but not eliminated by 2050 (Figure 3b, p.12). Although this analysis does not consider scenarios beyond 2050, an equitable solution beyond this date would be to move toward equal per capita emissions for all countries.

The annual rate of reduction needed to achieve the 2050 targets will depend on when developing nations' emissions peak. If, for example, their total emissions peak by 2020 according to the above criteria, then the average reduction rate required by both developing and industrialized nations will be approximately 3.5 percent per year. However, if developing nations' emissions peak in 2025, then the required global average reduction rate would be nearly 5 percent per year.

Given the daunting challenge of such rapid rates (den Elzen et al. 2006)—especially in light of the fundamental development needs of growing populations—this analysis suggests that meeting the 450 ppm CO_2eq stabilization target would be greatly facilitated if emissions from rapidly industrializing nations such as China and India peak no later than 2020. The rapid economic growth projected for these countries over this time frame means that a 2020 peak will require significant reductions in the carbon intensity of their economies.

While not fully addressed in this analysis, aggressive near-term reductions in deforestation rates in key forest-rich developing countries such as Brazil and Indonesia can be a significant complement to reductions in energy-related emissions and increase the prospects for stabilization at or below 450 ppm CO_2eq (Gullison et al. 2007).

Table 1. Emissions Reductions Required in Industrialized Nations by 2050

		Emissions Peak (Industrialized Nations)	
		2010	2020
Emissions Peak (Developing Nations)	2020	70%	80%
	2025	80%	90%
	2030	90%	95%

The differing average percentage reductions (below 2000 levels) needed to achieve a 450 ppm CO_2eq stabilization target, depending on when emissions peak for both industrialized and developing nations. For total cumulative emissions not to exceed the global budget, the reduction requirements of developing and industrialized nations must be interdependent. This analysis assumes that once emissions have peaked for both industrialized and developing nations, the two groups will have equal average annual reduction rates.

Figure 3a. Emissions Reduction Pathways

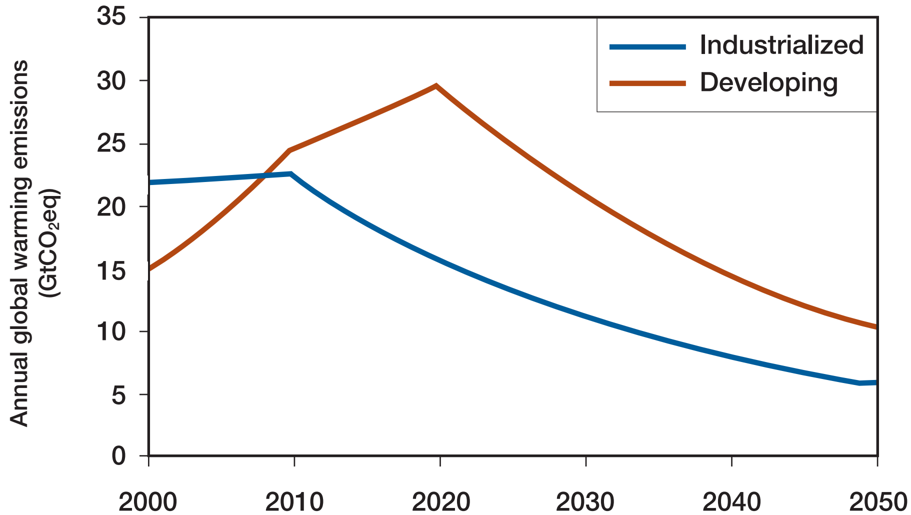


Figure 3b. Emissions Reduction Pathways (Per Capita)

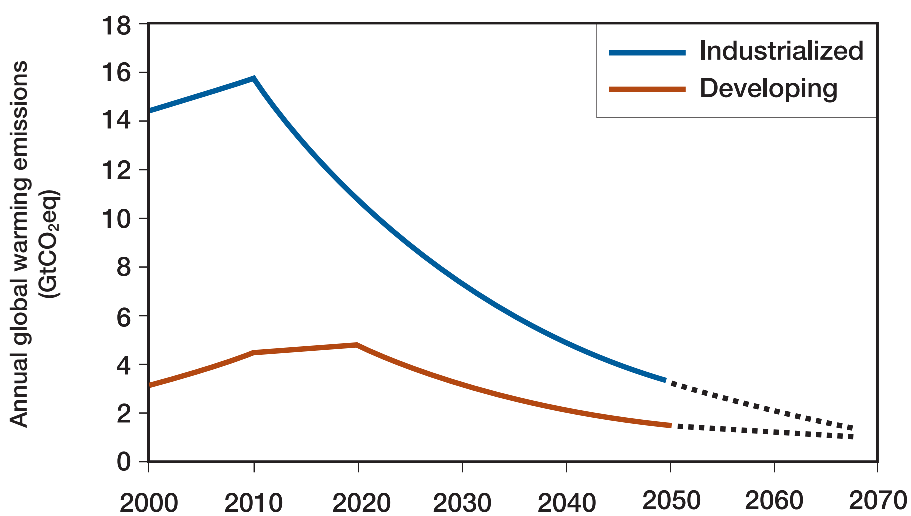


Figure 3a depicts emissions pathways for industrialized and developing nations that satisfy a cumulative emissions budget for the period 2000–2050 consistent with a 450 ppm CO_2eq stabilization target. Industrialized nations' emissions of the three key heat-trapping gases (CO_2, methane, nitrous oxide) peak in 2010 while developing nations' emissions peak in 2025, allowing an emissions budget of 700 $GtCO_2$eq for industrialized nations as described in the text. Pre-peak emissions represent the EIA Low Projection for energy-sector emissions (EIA 2007). Figure 3b depicts the same emissions pathways from a per capita perspective. Although this analysis does not consider scenarios beyond 2050, an equitable solution beyond this date would be to move toward equal per capita emissions, as illustrated here.

V. The U.S. Share of the Global Emissions Budget

Having allocated the cumulative emissions budget for the period 2000–2050 among industrialized and developing nations, we now ask what share of the industrialized nations' budget should the United States assume? This will determine how quickly U.S. emissions must be reduced, and what pathway our reductions should follow. There are a number of ways the U.S. allocation could be determined; we explored three alternative methods based on the United States' current share of (a) population, (b) GDP, and (c) heat-trapping emissions (in CO_2eq terms) among all industrialized nations.

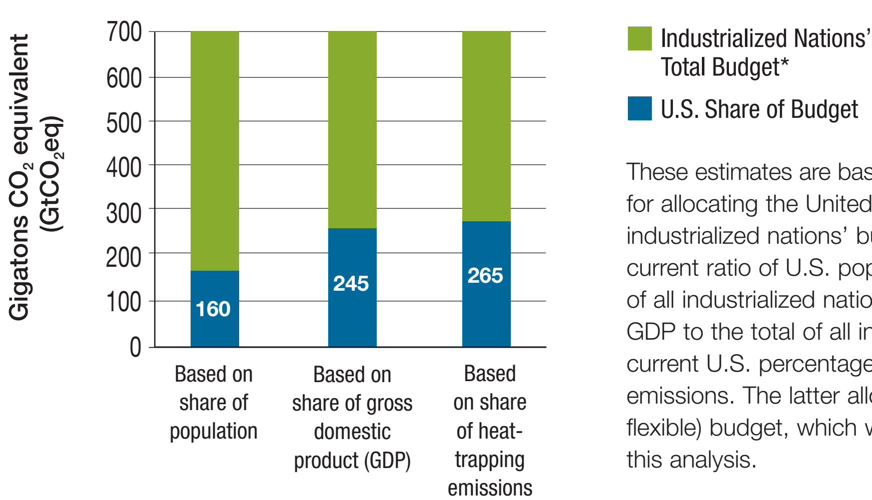
According to the above criteria, the U.S. cumulative emissions budget for the period 2000–2050 ranges from 160 to 265 GtCO_2eq (Figure 4), assuming that industrialized nations' emissions peak in 2010 and developing nations' emissions peak between 2020 and 2025. Allocation based on current population would require the lowest (or most strict) U.S. budget: 23 percent of the industrialized nations' total, or 160 GtCO_2eq. Allocation by current GDP would require 35 percent of the total, and allocation by current heat-trapping emissions would allow the highest (or most flexible) budget: 38 percent of the total, or 265 GtCO_2eq.

In summary, a U.S. reduction strategy consistent with stabilizing atmospheric concentrations at or below the 450 ppm CO_2eq target must:

1) **Reduce emissions at least 80 percent below 2000 levels by 2050**. This is equivalent to reductions of at least 78 percent below 1990 levels or at least 82 percent below current (2007) levels.

2) **Constrain cumulative emissions between 160 and 265 GtCO_2eq for the period 2000–2050**—of which approximately 45 GtCO_2eq had already been emitted by the end of 2005.[13]

Figure 4. Defining the U.S. Cumulative Emissions Budget for the Period 2000–2050



These estimates are based on three different methods for allocating the United States' share of the total industrialized nations' budget of 700 CO_2eq: the current ratio of U.S. population to the total population of all industrialized nations, the current ratio of U.S. GDP to the total of all industrialized nations, and the current U.S. percentage of industrialized nations' total emissions. The latter allows the highest (i.e., most flexible) budget, which we have used throughout this analysis.

*All heat-trapping emissions including those from land use and land cover changes. The budget assumes industrialized nations' emissions peak in 2010 and developing nations' emissions peak in 2020.

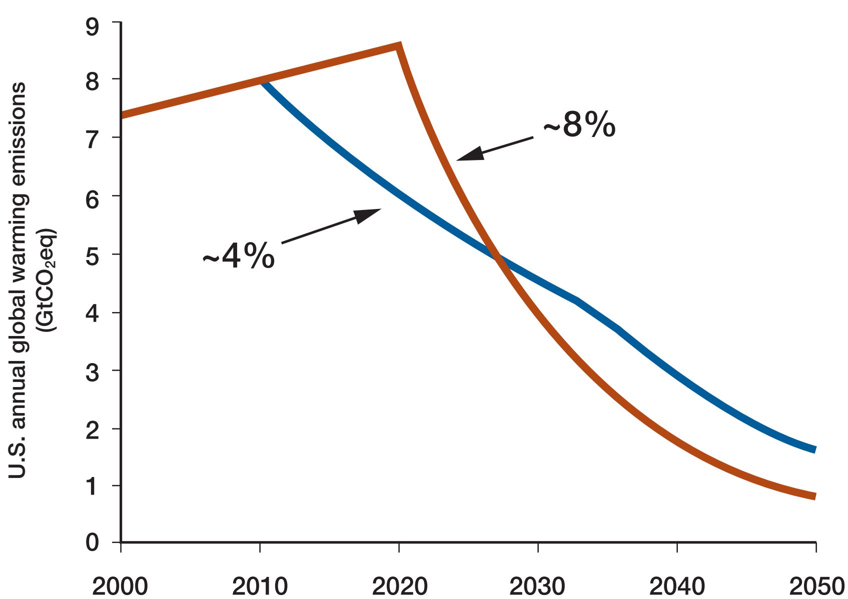
VI. What We Need to Do

What then is a reasonable emissions pathway that would stay within the given U.S. emissions budget? It is clear that a continued increase in emissions in the near term would require dramatically greater reductions over a shorter time frame later. Furthermore, these rapid later reductions would likely be more difficult and expensive to achieve than gradual changes over a longer period of time.

For example, to achieve the minimum 80 percent reductions below 2000 levels by 2050, the United States must reduce its emissions an average of 4 percent per year starting in 2010. However, if U.S. emissions continue to increase up until 2020 as projected by the EIA Low Projection (EIA 2007), the annual average rate of reduction would have to be raised to approximately 8 percent per year from 2020 to 2050. This amounts to about double the annual reductions required by an "early start" plan (Figure 5). Furthermore, if the United States follows the EIA Low Projection path, it will exceed the 160 $GtCO_2$ budget by 2020, and nearly exceed the 265 $GtCO_2$ budget by 2030.

In other words, an "early start" plan that requires reductions to begin in 2010 could reduce average reduction rates to less than half what would be required with a 2020 start. This does not imply, however, that there is only one possible pathway to meet the U.S. reduction target. Several examples are discussed in Box 2.

Figure 5. Implications of Delay



Reductions in U.S. annual emissions that would be required based on a start date of 2010 (blue line) or 2020 (red line). This analysis assumes that U.S. emissions would follow the EIA Low Projection (EIA 2007) until emissions reductions begin. Initiating reductions in 2010 would require a 4 percent reduction rate through 2050 to stay within a cumulative emissions budget of 265 $GtCO_2eq$ (consistent with a 450 ppm CO_2eq stabilization target). Delaying reductions until 2020, however, would not only require a faster reduction rate (at least 8 percent) to stay within the same budget, but deeper reductions as well. (The areas under each curve have been constrained so that cumulative emissions do not exceed 265 $GtCO_2eq$.) Note that to stay within a 160 $GtCO_2eq$ emissions budget would require even steeper reduction rates.

Box 2. Other Ways to Hit the Target

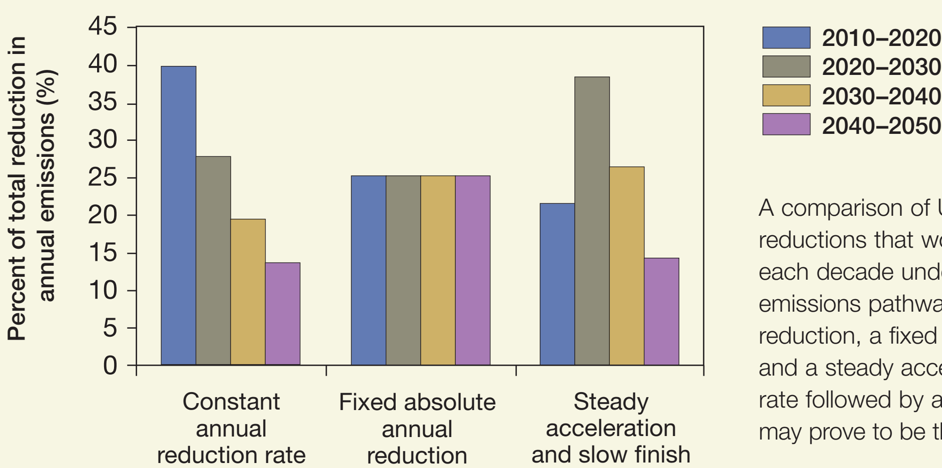
Both globally and at the national level, there are a number of possible pathways that would succeed in achieving the emissions reduction target and staying within the cumulative emissions budget discussed here. For example, if U.S. reductions begin in 2010, the minimum target of 80 percent below 2000 levels by 2050 could be achieved by a constant annual reduction of either 4 percent per year or 0.16 $GtCO_2eq$ per year in absolute terms, which is equivalent to 2 percent of 2007 levels (Figure 6). Alternatively, the United States could pursue a steady increase in reduction rates, beginning at 3 percent per year in the first two decades and rising to 5 percent per year in the final two decades (Frumhoff et al. 2007; Moomaw and Johnston 2007).

While these approaches may be appealing for their apparent simplicity, they are not necessarily optimal pathways. For example, it might be preferable for the United States to complement a steadily accelerating reduction rate with absolute reductions that peak and then decline (Figure 6). This would allow initial emissions reduction efforts to focus on energy efficiency, renewable energy, and advanced vehicle technologies—solutions that are already within our reach and have considerable near-term potential (IPCC 2007c).

Over time, it may be possible to deploy additional technologies, such as carbon capture and storage, that will require significant investments in research and development before deployment at a significant scale becomes both feasible and effective. Finally, it might be reasonable to anticipate lower absolute reductions toward the end of the budget period, as these final reductions could be the hardest to achieve.

An effective emissions reduction strategy should also include sufficient shorter-term benchmarks, or interim targets, to ensure that the current pathway will not exceed the cumulative budget and that the country is making effective progress toward low-emissions growth. These interim targets would also send an important market signal to businesses and investors who will be making decisions about long-life capital investments. Such targets are an important feature of existing state policies and key federal legislative proposals.

Figure 6. Timing of U.S. Emissions Reductions under Alternate Pathways



A comparison of U.S. emissions reductions that would be required in each decade under three different emissions pathways: a constant rate of reduction, a fixed reduction percentage, and a steady acceleration of reduction rate followed by a slower rate. The latter may prove to be the most feasible option.

VII. Would Any Existing Proposals Get the Job Done?

The standard we have recommended can be used to judge the adequacy of existing climate policy proposals (in terms of whether the emissions reductions would be sufficient to prevent atmospheric concentrations of heat-trapping gases from rising above the level at which the risks of dangerous climate change are unacceptably high). A number of bills currently being considered would set both short- and long-term U.S. emissions reduction targets (see the appendix). Figure 7 compares the emissions pathways of these proposals with that of the target proposed in this analysis. Figure 7a compares emissions over the period 2000–2050 with the EIA Low Projection (EIA 2007)[14] and pathways consistent with staying within the cumulative U.S. emissions budget range of 160 to 265 $GtCO_2eq$.

Figure 7b compares cumulative emissions for the period 2000–2050 under each of the proposals. Only H.R. 1590 (Waxman) and S. 309 (Sanders-Boxer) require reductions consistent with staying within the 265 $GtCO_2eq$ budget this analysis identifies as the least the United States should do to meet the 450 ppm CO_2eq stabilization target. For S. 1766 (Bingaman-Specter), a range of potential cumulative emissions is presented that illustrates the implications of reaching the price ceiling outlined in the bill. If that price ceiling is exceeded, emissions reductions would slow and the reduction targets established in the bill would not be met. The color gradient in the upper portion of the bar represents the uncertainty in total cumulative emissions if the bill's price ceiling were triggered; the total could approach the cumulative emissions projected under a low-growth "business as usual" scenario (EIA 2007).

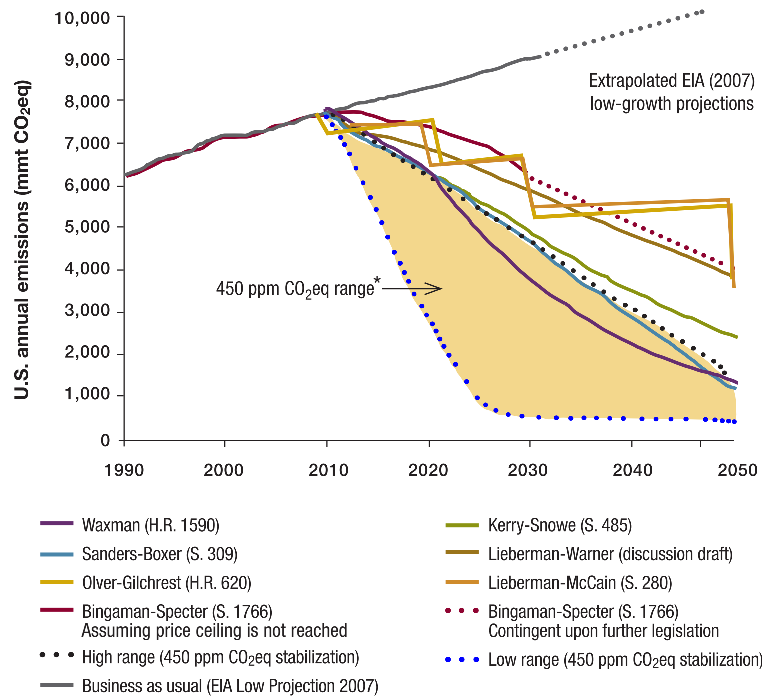
While the amounts by which S. 485 (Kerry-Snowe), the Lieberman-Warner proposal, and S. 1766 exceed the emissions budget may not appear to be great, if every nation of the world overshot its budget by a similar amount, the result would be a greatly increased risk of dangerous climate change. For example, Figure 1 (p.4) shows that a seemingly modest increase of 11 percent in the stabilization target (from 450 to 500 ppm CO_2eq) will increase the chances of a greater than 2°C increase in global average temperature from 50-50 to 70-30, and of a greater than 3°C increase from 30-70 to 50-50.

Significantly, not one of the proposals comes close to meeting the lower end of the U.S. emissions budget range (160 $GtCO_2eq$ for the period 2000–2050). Several (H.R. 1590, S. 309, S. 485) do provide for congressional review and periodic reports by the National Academy of Sciences to ensure the emissions reduction targets remain consistent with the goal of holding the increase in global average temperature below 2°C. Given the 30 percent probability that the global average temperature may even rise more than 3°C at the 450 ppm CO_2eq stabilization level, a requirement for periodic review is an essential element of any robust U.S. policy aimed at achieving emissions reductions consistent with avoiding dangerous climate change.

A comparison of federal climate policy proposals in terms of cumulative U.S. emissions relative to the U.S. emissions budget range of 160 to 265 $GtCO_2eq$ defined in this analysis. Only H.R. 1590 (Waxman) and S. 309 (Sanders-Boxer) do not exceed the upper limit of the budget, and even these proposals result in emissions well above the low end of the range possible with a 450 ppm CO_2eq stabilization target.

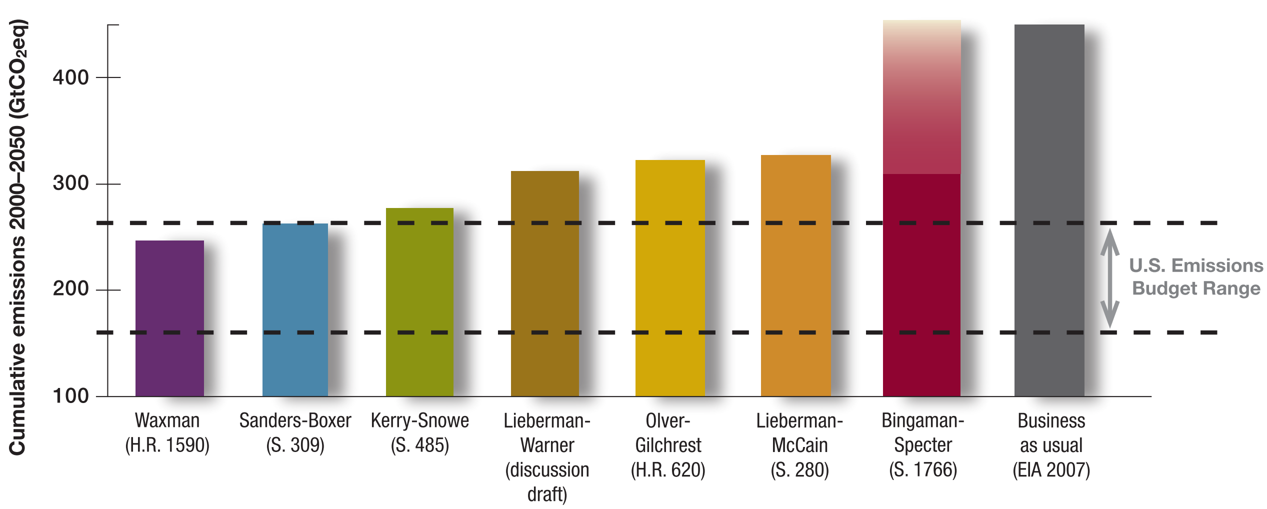
For S. 1766 (Bingaman-Specter), the potential range of cumulative emissions for 2000–2050 is provided. The lower portion of the bar indicates cumulative emissions for S. 1766 under the best-case scenario, in which the bill's price ceiling is never triggered, all emissions reduction targets out to 2030 are met, and all of the conditions needed to achieve the 2050 target are met, including international action, a recommendation by the president to Congress, and additional congressional legislation. This scenario also assumes that the 2050 target reduces total (economy-wide) U.S. emissions 60 percent below 2006 levels, even though earlier targets reduce emissions for only 85 percent of the economy. The color gradient in the upper portion of the bar represents the uncertainty in the additional cumulative emissions that would occur if the bill's price ceiling were triggered. (The darker the color, the more likely it is that total cumulative emissions would reach that level.) The gradient is for illustrative purposes only and does not represent explicit modeling of the price ceiling's effect on emissions decisions. The range depicted here assumes that if the price cap is triggered, the total cumulative emissions could approach those projected by the EIA under a low-growth "business as usual" scenario.

Figure 7a. U.S. Emissions Reductions under Federal Proposals



*The upper bound of this area was defined as the lowest average annual emissions reductions from 2010–2050 that would keep total cumulative U.S. emissions from exceeding the upper limit of the U.S. emissions budget defined in this study. The lower bound was defined as the lowest average annual emissions reductions from 2010–2050 that would keep total cumulative U.S. emissions from exceeding the lower limit of the budget.

Figure 7b. Cumulative U.S. Emissions in 2050 under Federal Proposals



VIII. The Way Forward

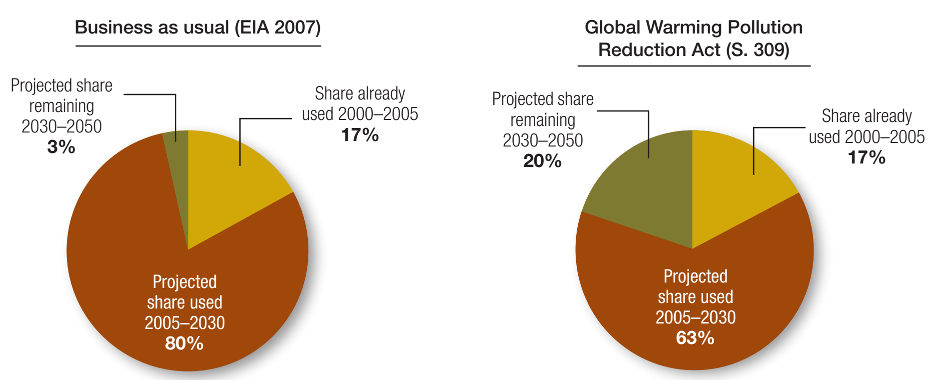
In summation, global heat-trapping emissions must be reduced between 40 and 50 percent from 2000 levels by 2050. This target will maintain a medium probability of preventing the global average temperature from rising more than 2°C above pre-industrial levels, which would greatly increase the risk of dangerous climate change. In this study we have developed a U.S. emissions reduction target consistent with that goal: at least 80 percent below 2000 levels by 2050, with a total emissions budget of 160 to 265 $GtCO_2eq$ for the period 2000–2050.

There are a number of possible emissions pathways consistent with these criteria. However, a clear message emerges from this analysis: if smaller near-term reductions are pursued or reductions continue to be delayed, we risk exceeding the U.S. emissions budget within a much shorter time frame—as soon as 2030 on one business-as-usual pathway (EIA 2007) (Figure 8).

As this analysis demonstrates, the United States must quickly overcome its current impasse on climate policy if we are to avoid dangerous climate change. Quick action would provide a longer time frame for reducing emissions, which in turn would allow greater flexibility in both the choice and cost of mitigation options. In addition, optimal long-term investment decisions could be made in earlier decades, so that new technologies could be developed and deployed in later decades.

Many solutions are already available, including greater energy efficiency, increased use of renewable energy, and reductions in deforestation. These changes can be encouraged by a wide range of market-based and complementary policies, such as cap-and-trade programs, renewable electricity standards, efficiency standards for electricity and vehicles, and incentives for cleaner technologies and international cooperation on emissions reductions. The way forward should emphasize economic growth that is not dependent on fossil fuel use and responsible choices that nations, companies, and individuals can make to lower the risk of dangerous climate change while permitting economic development to continue in a sustainable manner.

FIGURE 8. Spending the U.S. Cumulative Emissions Budget



Under a "business as usual" scenario, the United States would use nearly all of its emissions budget by 2030, requiring unrealistically drastic cuts thereafter to achieve the 450 ppm CO_2eq stabilization target by 2050. In contrast, the emissions cuts required by S. 309 (the Global Warming Pollution Reduction Act) would allow reductions to proceed in a more gradual fashion, providing greater flexibility in the method and timing of reductions.

Box 3. Lessons Learned in California

Motivated by the energy crisis of the 1970s, California has instituted a broad range of policies to encourage energy conservation. As a result, the average Californian consumes 40 percent less electricity than the average American (EIA 1999), and the state's consumers saved $56 billion in energy costs between 1975 and 2003 from building and appliance efficiency standards alone (Brown 2005). These trends have not hurt California's economic growth—the state ranks as the eighth largest economy in the world (California Legislative Analyst's Office 2006). Its technology sector has been a major source of growth, during the boom years of Silicon Valley and now as a hub for the development of clean energy technologies.

Along with several other states, California is also leading the way in meeting the climate challenge. Governor Schwarzenegger acknowledged the serious economic and environmental risks of climate change by signing the Global Warming Solutions Act (AB 32) in 2005. The bill mandates emissions reductions to 1990 levels by 2020 and the state also has a long-term reduction goal of 80 percent below 1990 levels by 2050. To meet these goals, the state is considering a broad array of new policies and measures in addition to strengthening existing ones.

For example, California has a renewable electricity standard that requires the state's utilities to produce 20 percent of their electricity from renewable sources by 2010; it also includes a stated goal of extending the standard to 33 percent by 2020 (CAT 2006). State regulations governing new motor vehicles aim to reduce heat-trapping emissions from cars and trucks 18 percent by 2020 and 27 percent by 2030.[15] And several initiatives under way to encourage sustainable land-use planning could also help California meet its reduction targets (CAT 2006).

According to a report commissioned by the governor on the potential of different policies to contribute to California's 1990 levels by 2020 target, this goal is not only achievable but would also produce net economic gains (CAT 2006). Preliminary macroeconomic analysis shows that implementation of these strategies would result in a net increase of 83,000 jobs and $4 billion in revenue—above and beyond business-as-usual growth—by 2020 (CAT 2006). These gains are a direct result of cost savings from reduced energy use and the beneficial impact of technological innovation.

Notes

[1] 2006 levels are approximately 20 percent above 1990 levels according to data from the U.S. Environmental Protection Agency.

[2] CO_2-equivalent units are used to compare the cumulative heat-trapping effects of a given concentration of different gases and aerosols (over a specific time frame) with an equivalent concentration of CO_2.

[3] With a median estimate of climate sensitivity to heat-trapping emissions, this scenario stays under 2°C. However, higher possible levels of sensitivity would cause temperatures to increase more than 2°C.

[4] These budgets are estimated based on CO_2-equivalent emissions from all greenhouse gases. In Meinshausen et al. (2006), emissions for all gases are reported explicitly. Data can be downloaded from *http://www.simcap.org*. In Baer and Mastrandrea (2006), only CO_2 emissions are reported explicitly, but we scale these emissions to CO_2-equivalent units by assuming the same ratio of CO_2 to non-CO_2 gases found by Meinshausen et al. In that study, the ratio of global fossil CO_2 to global CO_2eq (i.e., all CO_2 including land use and land cover change, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) is approximately 1.4.

[5] The IPCC Fourth Assessment Report includes a summary of stabilization scenarios from energy/economic models, not including scenarios that peak above the final stabilization level. Without such a peak, scenarios included in the summary that stabilize at approximately 450 to 500 ppm CO_2eq require 50 to 85 percent reductions in global emissions below 2000 levels (Fisher et al. 2007).

[6] This pathway was generated using standard carbon cycle assumptions with climate feedbacks, and considered all emissions of CO_2 and other key heat-trapping agents (non-CO_2 greenhouse gases, ozone precursors, and sulfate aerosols). The non-CO_2 emissions were generated using the "equal quantile walk" method, an approach derived from the relationships between CO_2 and non-CO_2 gases in the existing multi-gas IPCC baseline and stabilization scenarios (Meinshausen et al. 2006). Note that we use the emissions budget from this pathway, but do not constrain our analysis to the year-to-year emissions followed by the pathway (provided the cumulative budget is still reached). Note also that because the 500 ppm CO_2eq peak associated with this pathway is dependent on the magnitude and timing of emissions reductions, changes to the magnitude and timing of reductions may induce concentrations to peak at a level other than 500 ppm.

[7] This budget refers to all greenhouse gas emissions including those from land use and land cover changes.

[8] There are many different global emissions pathways that can stay within the same cumulative emissions budget, with different timing of reductions and varying rates of reduction among different heat-trapping gases. As previously discussed, we use the Meinshausen et al. (2006) budget as a constraint, but do not constrain the timing of reductions to match the pathway defined in the Meinshausen et al. study.

[9] The timing and scale of required reductions in energy-sector emissions will also be affected by the future trajectory of CO_2 emissions from deforestation in developing countries (which currently accounts for almost 20 percent of human-caused heat-trapping emissions). Gullison et al. (2007) estimate that aggressive but achievable reductions in deforestation could avoid the release of up to 180 $GtCO_2$ by 2100.

[10] As previously described, we calculated CO_2eq as the sum of all greenhouse gases including land use and land cover change. We estimated non-fossil CO_2 and non-CO_2 emissions assuming the regional constituent ratios found by Meinshausen et al. (2006). The average ratio for the industrialized world is 1.3 CO_2eq to CO_2; the average ratio for developing nations is 1.7.

[11] This is equivalent to reductions of at least 78 percent below 1990 levels, or at least 82 percent below current (2007) levels.

[12] As previously discussed, there are multiple pathways that will lead to the same cumulative emissions. One example is displayed in Figure 3.

[13] Based on U.S. emissions for the period 2000–2005 (EPA 2007).

[14] The EIA Low Projection is used for consistency with the budget analysis.

[15] Implementation of this regulation requires a waiver under the Clean Air Act from the U.S. EPA; the waiver was still pending at press time.

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Appendix

Emissions Reduction Targets in Federal Multi-Sector Climate Bills

This table describes the regulated sectors and emissions reduction targets required by seven major federal climate bills. Targets for the year 2050 are compared with the 2000 emissions levels provided in the April 2007 Environmental Protection Agency (EPA) Inventory of U.S. Greenhouse Gas Emissions and Sinks for 1990–2005.

	H.R. 1590 Waxman (D-CA): **Safe Climate Act of 2007**	**H.R. 620** Olver (D-MA)-Gilchrest (R-MD): **Climate Stewardship Act of 2007**	**S. 280** Lieberman (I-CT)-McCain (R-AZ): **Climate Stewardship and Innovation Act of 2007**	**S. 309** Sanders (I-VT)-Boxer (D-CA): **Global Warming Pollution Reduction Act**	**S. 485** Kerry (D-MA)-Snowe (R-ME): **Global Warming Reduction Act of 2007**	Lieberman (I-CT)-Warner (R-VA): **America's Climate Security Act of 2007** (proposal language only)[1]	**S. 1766** Bingaman (D-NM)-Specter (R-PA): **Low Carbon Economy Act of 2007**
Coverage	Economy-wide. Regulated entities to be determined by the EPA; provides for regulatory standards for electricity generation, fuels, and transportation.	Covered sectors include electric power, industrial or commercial facilities that emit more than 10,000 metric tons (mt) CO_2eq per year, and petroleum refineries or importers in the transportation sector that release more than 10,000 mt per year. According to the EPA inventory, the covered sectors represent 85% of the economy, but coverage will likely be significantly lower because of exempted sources.[1]	Covered sectors include electric power, industrial or commercial facilities that emit more than 10,000 metric tons (mt) CO_2eq per year, and petroleum refineries or importers in the transportation sector that release more than 10,000 mt per year. According to the EPA inventory, the covered sectors represent 85% of the economy, but coverage will likely be significantly lower because of exempted sources.[1]	Economy-wide. Regulated entities to be determined by the EPA; provides for regulatory standards for electricity generation and transportation.	Economy-wide. Regulated entities to be determined by the EPA; provides for regulatory standards for electricity generation, fuels, and transportation.	Covered sectors include electric power, transportation, and industrial entities (as defined in the EPA inventory) that emit more than 10,000 metric tons (mt) CO_2eq per year. According to the EPA inventory, these sectors represent 80% of the economy, but coverage will likely be significantly lower because of exempted sources.[1]	Petroleum refineries, natural gas processing plants, fossil fuel importers and producers, and non-CO_2 gas importers, as well as coal facilities that use more than 5,000 tons of coal per year (mainly utilities). According to the emissions reduction target chart in the bill (Sec. 101), these sectors represent 85% of the economy. The bill sets a ceiling on the price of emissions allowances, allowing covered sources to pay into a fund instead of making emissions reductions if the price ceiling is exceeded.[1]
Emissions Reduction Targets							
2010	Emissions reductions begin.	Starting in 2012, emissions from covered sectors must be 6,150 million metric tons (mmt) CO_2eq.[4]	Starting in 2012, emissions from covered sectors must be 6,130 million metric tons (mmt) CO_2eq.[4]	Emissions reductions begin; 2% annual reduction 2010–2020.	Emissions reductions begin.	2005 levels by 2012 for covered sectors.[4]	Emissions reductions begin in 2012.
2020	1990 levels by 2020, with a 2% annual reduction 2011–2020.	From 2012–2019, emissions stay at 6,150 mmt CO_2eq.	From 2012–2020, emissions stay at 6,130 mmt CO_2eq.	1990 levels by 2020.	1990 levels by 2020.	10% below 2005 levels for covered sectors.	2006 levels.
2030	5% annual reduction 2021–2050.	From 2020–2029, emissions must be 5,232 mmt CO_2eq for covered sectors.	From 2021–2030, emissions must be 5,239 mmt CO_2eq for covered sectors.	One-third of 80% below 1990 levels.	2.5% annual reduction 2021–2030.	30% below 2005 levels for covered sectors.	1990 levels.
2040	5% annual reduction 2021–2050.	From 2030–2039, emissions must be 3,858 mmt CO_2eq for covered sectors.	From 2031–2040, emissions must be 4,100 mmt CO_2eq for covered sectors.	Two-thirds of 80% below 1990 levels.	3.5% annual reduction 2031–2050.	50% below 2005 levels for covered sectors.	
2050	5% annual reduction 2021–2050, reaching 80% below 1990 levels by 2050 (83% below 2000 levels).	Beginning in 2050 and thereafter, emissions must be 1,504 mmt CO_2eq for covered sectors (57% below 2000 levels).[4]	Beginning in 2050 and thereafter, emissions must be 2,096 mmt CO_2eq for covered sectors (47% below 2000 levels).[4]	80% below 1990 levels by 2050 (83% below 2000 levels). If CO_2eq concentrations exceed 450 ppm or if global average temperatures increase by 2°C above pre-industrial levels, reduction targets would accelerate.	3.5% annual reduction 2031–2050, reaching 65% below 2000 levels by 2050.	70% below 2005 levels for covered sectors (47% below 2000 levels).[4]	Conditional target of at least 60% below 2006 levels by 2050, contingent on sufficient international action as determined by interagency review, presidential recommendation to Congress, and subsequent congressional action.

(*footnotes on next page*)

[1] The information presented here could change once the proposal is introduced as legislation.

[2] Some external analyses suggest that exempted and other uncapped sources could reduce the bill's coverage to as little as 74% of the economy. However, our analysis assumes complete sector coverage for simplicity.

[3] If the price ceiling is exceeded, emissions reductions could slow or cease. In that event, the bill's emissions reduction targets would not be met.

[4] We assume emissions levels specified in the bill pertain to covered sectors only. We assume uncovered sectors grow at the "business as usual" rate projected by the Energy Information Administration's low-growth scenario (EIA 2007).

[5] Section 101 of the bill sets emissions levels for each year from 2012–2030. The bill's 2012 emissions level is consistent with 85% of the economy-wide emissions for that year as projected by the EIA. For this reason, we assume the bill's covered sectors represent 85% of the economy, with uncovered sectors growing at the "business as usual" rate projected in EIA 2007.