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Climate Change: Current Issues and Policy Tools

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Summary

Members of Congress increasingly face hearings, legislative proposals, mark-ups, and votes concerning whether and how to address human-induced climate change. Contentious debates scrutinize issues of science, economics, values, geopolitics and a host of other concerns. Deliberations also weigh the appropriateness of alternative policy tools and program designs. The economic stakes are potentially large – with both the costs of regulatory actions and the "costs of inaction" ranging, by some estimates, into trillions of dollars over several decades.

A major international assessment released in 2007 concluded that the Earth's climate had warmed unequivocally over the past century, and that elevated levels of so-called "greenhouse gases" (GHG) were likely responsible for a major portion of the observed warming. Elevated concentrations of GHG in the atmosphere are due mostly to human activities, especially emissions from use of fossil fuels, clearing of land, and some industrial processes. Continued population and economic growth, with dependence on fossil fuels and needs for expanding agricultural lands, are expected to drive GHG emissions and induced climate change over the 21st Century to levels never experienced by human civilizations. While benefits may accrue to some people who may experience a limited amount of climate change, the aggregate effects are expected to become increasingly adverse, with people living in dry regions or along low-lying coasts, and people with low incomes, expected to be especially vulnerable. Adaptations can moderate the impacts and expand opportunities, but at a cost. Besides the overall costs of climate change, key concerns include the distributional effects within and across generations, how to value ecological impacts, and the potential for abrupt and irreversible changes. While important uncertainties remain concerning future climate change and its impacts, many experts are convinced that the evidence calls for U.S. action to abate GHG emissions. Others argue that mandatory controls would be premature or unnecessary.

For decision-makers considering actions to address climate change, an assortment of policy instruments is available; studies suggest that a combination could be most effective in achieving various climate policy objectives. Current domestic policy attention has focused on "cap and trade" strategies to reduce GHG emissions, with additional policy tools aimed at promoting the technology development considered necessary to slow climate change significantly. In parallel, growing attention is being given to characterizing and supporting adaptations to expected future changes, as well as to strategies to gain effective international engagement in reducing GHG. One significant obstacle to consensus is concern about the potential costs of abating GHG emissions, since deep reductions would require extraordinary changes in energy use and technologies. Recent studies suggest that efficiently designed GHG programs could moderate the costs of reducing U.S. GHG emissions; technically and politically, though, an "efficiently designed" program may not be realistic. Policy options can ease the adjustments required and modify the distribution of costs – or potential wealth embodied in distribution of emission allowances – across specific sectors or populations. A core challenge of policy design, then, is balancing the climate effectiveness of a policy, the economic costs, and its distributional effects.

Contents

Introduction 1

Part One: Current Climate Change Issues 3
Climate Change Science 3
Observed Changes in Global Climate 3
Causes of Observed Climate Change 3
Sources of GHG Emissions, and Removals from the Atmosphere 4
Projections of Greenhouse Gas-Induced Climate Change 7
Potential Impacts of Projected Climate Change 7
Proposed Greenhouse Gas Concentration Targets 9
Program Design and the Costs of GHG Mitigation 10
Distributional Impacts of Programs 11
Climate Change and Other Policy Issues: Commonality or Conflict? . 11
U.S. Costs of GHG Mitigation 11
Global Costs of GHG Mitigation 12
Benefits of Mitigating Climate Change 13
Inadequate data, tools and understanding of impacts 13
Global Costs of Climate Change 14
Potential Costs of Climate Change to the U.S. Economy 15
"Co-Benefits" and Trade-offs of GHG Mitigation 16
Importance of the Distribution of Losses (or Gains) 17

Part Two: The International and Domestic Policy Fields 18
Status of International Cooperation on Climate Change 18
The United Nations Framework Convention on Climate Change 18
The Kyoto Protocol 18
The United States Rejected the Kyoto Protocol 18
"Common but Differentiated Responsibilities" 19
The Bali Action Plan 19
Current Domestic Policy on Climate Change 19
Goal 19
Federal Policies 20
Funding 20
Legislative Actions 20
Regional, State and Local GHG Policies 21
Climate Change Litigation 21

Part Three: The Policy Tool Box 23
Regulatory and Market Tools to Reduce Greenhouse Gases 23
Source-by-source regulations 23
Market mechanisms 24
Design Choices in Cap-and-Trade Programs 25
Distributing the Revenues from Taxes or Sales 26
Market Facilitation Tools 27
Tools to Stimulate Technological Change 27
Unintended Consequences for Technology Incentives 29
Options to Ease the Economic Transition 29
International Policy Tools 30

Tools to Stimulate Adaptation to Climate Change 31

Choices Ahead for Policy-Makers 32

Further Information 32

Climate Change: Current Issues and Policy Tools

Introduction

The Earth's surface has warmed by 1.1° to 1.5° Fahrenheit since the Industrial Revolution and precipitation has increased over the past century, although some regions have become wetter while some have become drier. Increases in ocean temperatures, altered wind patterns, extreme weather events, melting glaciers and sea ice, and timing of seasons have also been observed. The Intergovernmental Panel on Climate Change (IPCC) in 2007 declared that "[w]arming of the climate system is unequivocal...." and that most of the observed change since the 1970s is likely due to greenhouse gases emitted as a result of human activities.[1] Experts project that, if greenhouse gas (GHG) emissions are not abated well below current levels, the Earth's climate will warm further – to levels never experienced by human civilizations. If, and as, the climate moves further from its present state, it will reconfigure the patterns to which current human and ecological systems are adapted, and the risk of abrupt changes will increase.

Understanding of the magnitude, causes, and implications of climate change continues to grow. But alongside efforts to further that understanding, a sense of urgency is spurring many international, national, regional, and local policymakers, industry leaders, non-governmental organizations (NGOs), and citizens to mobilize toward more concrete actions. Concern about poorly understood but potentially catastrophic impacts of human-induced climate change drives the impetus to identify, evaluate, and initiate concrete policy actions to address human activities – such as the emissions of greenhouse gases (GHG), land use changes, and forestry practices – believed to contribute to climate change. In parallel, growing attention is being given to characterizing and supporting adaptations to changes already observed or expected future changes.

Domestic actions to address climate change are moving independently across many fronts. In the 110th Congress, numerous bills have been proposed to address climate change research and policy; one bill (S. 2191) that would cap and reduce greenhouse gas emissions has been reported by the Senate Committee on Environment and Public Works and is scheduled for action soon by the Senate. The Supreme Court in 2007 ruled that the Administration must consider regulating greenhouse gases from motor vehicles as air pollutants, and President George W. Bush in 2008 proposed a qualified national goal for U.S. greenhouse gas emissions to peak by 2025 and then decline. States and localities have moved forward with their

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[1] Intergovernmental Panel on Climate Change Working Group I. Climate Change 2007: The Physical Basis. Cambridge, UK: Cambridge University Press, 2007. (p. 1).

own plans and regulations in lieu of a strong national framework. Primary concerns are the costs, which could reach trillions of dollars over coming decades, depending on policy choices; the distribution of those costs; and the effectiveness of policies, with the knowledge that U.S. greenhouse gas reductions would achieve success only if sufficient international cooperation can be achieved as well.

Debate internationally has revived over how nations may commit to mitigation, adaptation and technology actions beyond 2012, the end of the current commitment period of the Kyoto Protocol to the United Nations Framework Convention on Climate Change. Negotiations are aiming to produce a post-2012 decision by the end of 2009. U.S. domestic policy development could influence and support international cooperation or introduce impediments, depending on how the interplay is managed. The stakes are potentially high: the effectiveness of mitigating human-induced climate change depends on action by all major emitters, while the costs of delay, deferral or ineffectiveness have been projected by some analysts to reach many trillions of dollars over coming decades.

This report does not discuss or analyze current legislative proposals. Rather, it introduces the reader to fundamentals of the climate change issue. Part One summarizes current understandings and controversies concerning the science, economics, international cooperation, and other aspects of the climate change policy problem. Part Two is a brief update on the status of domestic and international policies. Part Three outlines the policy toolbox seen as being available to policymakers to address the challenge as they define the emerging legislative agenda.

Part One: Current Climate Change Issues

Climate Change Science[2]

Observed Changes in Global Climate. The Earth's surface has warmed by 1.1° to 1.5° Fahrenheit since the Industrial Revolution (measured since 1880), with most warming occurring since the 1970s. Precipitation has increased over the past century, although some regions have become wetter while some have become drier. These results are consistent with scientists' understanding of how heightened greenhouse gas concentrations affect climate regionally. Increases in ocean temperatures, altered wind patterns, extreme weather events, melting glaciers and sea ice, and timing of seasons have also been observed. The Intergovernmental Panel on Climate Change (IPCC) in 2007 declared that "[w]arming of the climate system is unequivocal. ...Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes."[3]

Causes of Observed Climate Change. Although there is significant natural variability in the Earth's climate, scientists recognized more than a century ago that pollution from human activities could theoretically warm the Earth.

Greenhouse gases (GHG) in the Earth's atmosphere allow the Sun's short wave-length radiation to pass through to the Earth's surface. Once the radiation is absorbed by the Earth and re-emitted as longer wave-length radiation, GHG trap the heat in the atmosphere. This is often called the "greenhouse effect." The natural presence of GHG (especially water vapor and carbon dioxide) in the atmosphere warms the Earth to habitable temperatures.

Studies show that solar variability has contributed some of the observed changes in global temperature, especially early in the 1900s. A few studies conclude that, at most, solar variability has contributed 10 to 40% of the observed change of the 20th century.[4] Further research would be required to quantify how some suggested influences, for example, galactic cosmic rays, contribute to observed climate changes.

Most scientists conclude that a majority of the Earth's warming since the 1970s is due to GHG emissions from human activities, especially use of fossil fuels, clearing of land, and some industrial processes. While scientists agree that GHG in the atmosphere are responsible for trapping the Sun's radiation and raising the Earth's temperature to current levels, some scientists disagree that projected increases in GHG concentrations would raise temperatures significantly.

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[2] For further information, see CRS Report RL34266, *Climate Change: Science Update 2007* and CRS Report RL33849, *Climate Change: Science and Policy Implications,* both by Jane A. Leggett.

[3] Intergovernmental Panel on Climate Change Working Group I. Climate Change 2007: The Physical Basis. Cambridge, UK: Cambridge University Press, 2007. (p. 1).

[4] A number of peer-reviewed references are available from CRS upon request.

Sources of GHG Emissions, and Removals from the Atmosphere

Beyond water vapor (which is thought not to be directly influenced by humans), the best-understood greenhouse gases include:

- carbon dioxide (CO_2),
- methane (CH_4),
- nitrous oxide (N_2O), and
- certain fluorinated compounds, including chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC), hydrofluorocarbons
- (HFC), perchlorofluorocarbons (PFC) and sulfur hexaflouride (SF_6).[5]

These GHG remain in the atmosphere for decades to thousands of years and are generally well-mixed around the globe; hence, their warming effects are largely global and persist for decades to millenia. The long atmospheric residence also means a long lag between policies to abate GHG emissions and their full effects on the climate system.

When emissions of the long-lived GHG are greater than their removals by, for example, photosynthesis, the GHG accumulate in the atmosphere: the GHG concentrations increase. The increases of concentrations of specific GHG since the Industrial Revolution (measured since about 1850) include:

- CO_2 by more than 33%, from about 280 parts CO_2 per million (ppm) to current levels of over 380 ppm,
- Methane (CH_4) by about 150%, although the rate of increase has declined over the past decades to essentially no growth (but variable year-to-year), and
- Nitrous oxide (N_2O) by 16%;
- essentially all concentrations of CFC, HCFC, HFC, PFC, and SF_6.

Human-related GHG emissions are partly offset by human-related carbon removals and sequestration in growing forests, some agricultural soils, and other reservoirs. Such "sinks" offset about 11% of U.S. GHG emissions in 2005.

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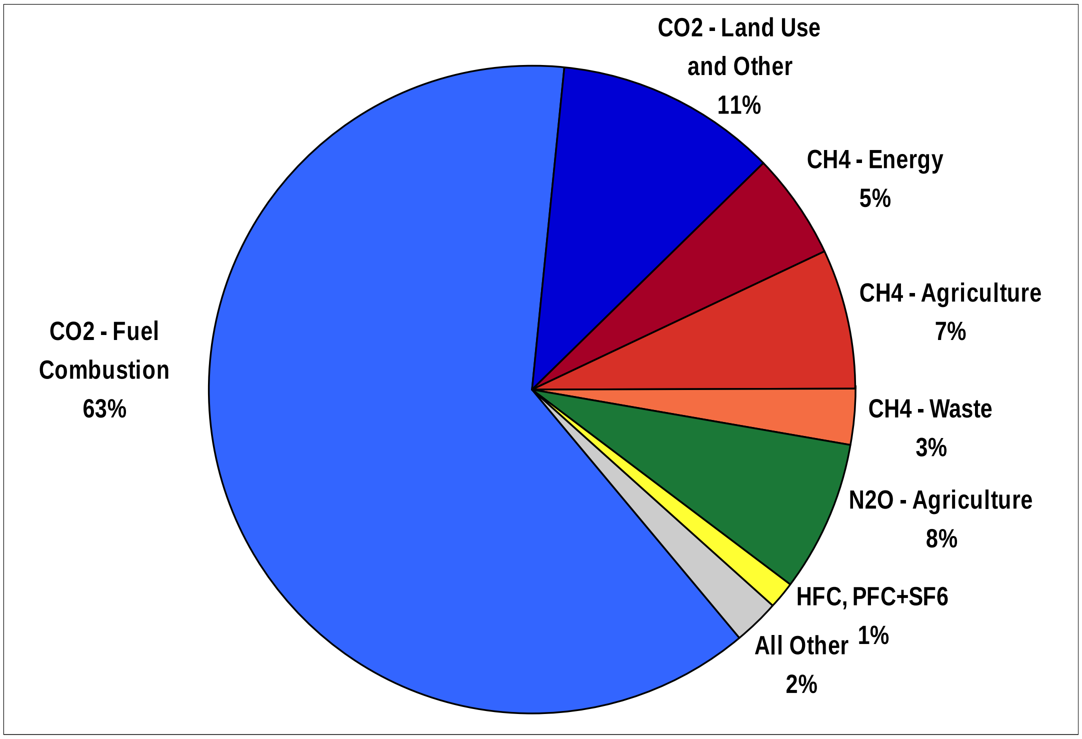
[5] Additional pollutant emissions indirectly affect climate change, largely on the local to regional scale; they include carbon monoxide (CO), nitrogen oxides (NO_x) other than N_2O, and non-methane volatile organic compounds (NMVOC), and particulate matter or aerosols. Perhaps more important, human-induced climate change and land uses may indirectly affect water vapor in the atmosphere, influencing both global and regional climate change, including the distribution of precipitation, and are likely to alter the reflectivity of the Earth's surface. Compared to other effects, these effects are poorly understood, though they may have large impacts.

Figure 1: Estimated Sectoral and Greenhouse Gas Shares of Global Emissions in 2005



Source: CRS graphic with estimates from International Energy Agency, *CO_2 Emissions from Fuel Combustion 1971-2005*, 2007, online database. Data extracted January 16, 2008.

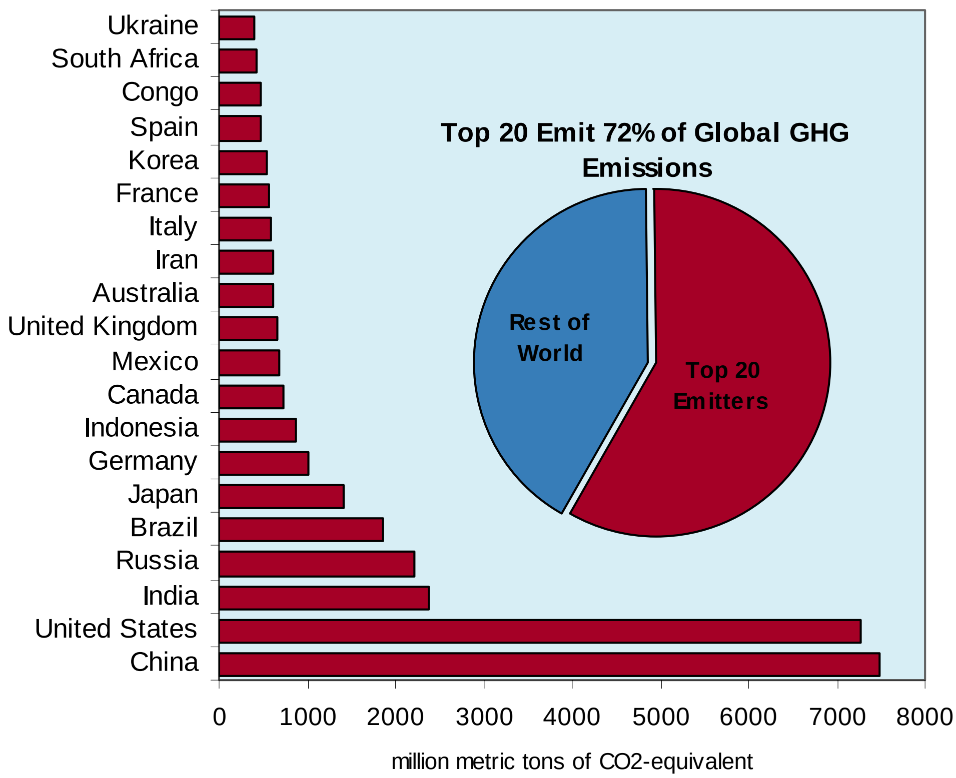
For the year 2005, CO_2 constituted approximately 74% of the global, human contribution to long-lived GHG emissions;[6] CH_4 was about 16%, and N_2O was about 8% (**Figure 1**).

Globally in 2005, the top 10 emitting countries contributed about 60% of global GHG emissions, and the top 20 emitting countries contributed about 72% of global

[6] These shares exclude emissions of CFC, HCFC and other substances that are controlled to protect the stratosphere. In policy discussions, these emissions typically are not counted as "GHG"; also, they are generally estimated as *potential* emissions when they are manufactured, not as actual emissions, so the method to count them is different from other GHG. Reducing them would, however, help to reduce climate change.

GHG emissions.[7,8] China probably is now the leading[9] emitter of human-related GHG, likely having recently surpassed the United States (**Figure 2**). Most experts expect that Chinese and other developing countries' GHG emissions will continue to grow more rapidly than those of the United States and other already industrialized countries.

Figure 2. Estimated Top 20 Emitters of Greenhouse Gases in 2005



Source: CRS graphic with emission estimates from International Energy Agency, op. cit.; data extracted May 5, 2008.

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[7] See also CRS Report RL32721, *Greenhouse Gas Emissions: Perspectives on the Top 20 Emitters and Developed Versus Developing Nations*, by John Blodgett and Larry Parker.

[8] According to agreed international guidelines, countries report emissions from international bunker fuels (for international travel and shipping) but do not include them in country totals. Emissions from international bunker fuels were almost 1000 metric tons of CO_2e in 2005, and are almost as much as the 6th largest emitting country in the world.

[9] This conclusion is based on uncertain estimates of GHG emissions internationally. While the supporting data are not precise, experts have high confidence that if recent trends prevail, China will be the largest net source of GHG by the end of the decade.

Projections of Greenhouse Gas-Induced Climate Change[10]

The climate-related impacts borne by human and ecological systems will depend on the combination of natural climate variability plus human-induced climate changes.[11] Scientists project that, during the 21st Century, it is very likely that rising GHG emissions, as expected with current trends and policies, and the resulting higher concentrations in the atmosphere, will raise the global average temperature above natural variability by at least 1.5° Celsius (2.7° Fahrenheit) above 1990 levels. The estimates considered most likely by many scientists are for GHG-induced temperature increases around 2.5 to 3.2°C (4.5 to 5.8° F) by 2100. There is a small but not trivial likelihood that the GHG-induced temperature rise may exceed 5°C (9° F) above natural variability by 2100. In context, the global average temperature is estimated currently to be approaching or exceeding the highest level experienced since the emergence of human civilizations.

Future climate change may advance smoothly or sporadically, and some regions are likely to experience more fluctuations in temperature, precipitation, and frequency or intensity of extreme events than others. Almost all regions are expected to experience warming; some are projected to become warmer and wetter, while others would become warmer and drier. Sea levels could rise between 7 and 23 inches by 2100, not including the effects of possible accelerated melting of the Greenland or Antarctic ice sheets. Patterns consistent among different models have led to some common expectations: GHG-induced climate change would include more heat waves and droughts; decreased extreme cold episodes; and increased summer warming and dryness in the central portions of continents. Scientists also expect precipitation to become more intense when it occurs, thereby increasing runoff and flooding risks.[12]

Potential Impacts of Projected Climate Change

A wide band of uncertainty surrounds projections of impacts, and in particular, critical thresholds for non-linear or abrupt effects. Some impacts of climate change are expected to be beneficial in some locations with a few degrees of warming (e.g., increased agricultural productivity in some regions, less need for space heating, opening of the Northwest Passage for shipping and resource exploitation). Most impacts are expected to be adverse (e.g., lower agricultural productivity in many regions, drought, rising sea levels, spread of disease vectors, greater needs for cooling). Risks of abrupt, surprising climate changes, with accompanying

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[10] For further information, see CRS Report RL34266, *Climate Change: Science Update 2007* and CRS Report RL33849, *Climate Change: Science and Policy Implications*, both by Jane A. Leggett.

[11] Natural climate cycles and forcings, such as volcanoes, will continue; the combined natural and human-induced changes may result in stable or declining observed temperatures for some periods, as projected by some through 2015, likely followed by more rapid increases due to the natural cyclic increase plus the GHG-induced increase.

[12] Kevin E. Trenberth et al., "The Changing Character of Precipitation," *Bulletin of the American Meteorological Society* (September 2003), p. 1205.

dislocations, are expected to increase as global average temperature increases, and could push natural and socio-economic systems past key thresholds of tolerance.

Some populations will have the resources to migrate and adapt successfully — even profit from new opportunities that will emerge — while others could lose livelihoods or lives. Adaptations can help mitigate impacts and damage costs, but also impose costs, often on those who can least afford them. Because climate change will occur with different magnitudes and characteristics in different regions, resulting dislocations and disparities across locations may have implications for political stability and security.

Some experts and stakeholders believe that likely ecological disruptions are among the most compelling reasons that humans must act to reduce their interference with the climate system. As the degree and distribution of climate changes continue, ranges of species are likely to change. Climate change is highly likely to create substantial changes in ecological systems and services in some locations, and may lead to ecological surprises. The disappearance of some types of regional environments also raises risks of extinctions of species, especially those with narrow geographic or climatic distributions, and where existing ecological communities disintegrate. One study[13] projects that, under a high climate change scenario, 12 to 39% of the Earth's land areas may experience climates not found at present, while 10 to 48% of land areas' existing climates may disappear from the Earth by 2100. In the low climate change scenarios, 4 to 20% of land areas experience new climates and 4 to 20% see existing climates disappear. The researchers concluded, "[t]here is a close correspondence between regions with globally disappearing climates and previously identified biodiversity hotspots; for these regions, standard conservation solutions (e.g., assisted migration and networked reserves) may be insufficient to preserve biodiversity."

Many different views exist regarding how much concern to give to ecological impacts:[14] some people value the impacts only according to the services that natural systems provide to humans (for example, for recreational activities or provision of food); other people emphasize ethical perspectives, for example, for stewardship of the Earth's resources. Likewise, some people emphasize the relatively mild impacts possible for the United States,[15] while others give weight to the catastrophic impacts likely for at least some populations in other countries. Such differences in values are behind many of the controversies in the public debates about how to address climate change, and what part of the global effort the United States should undertake.

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[13] John W. Williams, Stephen T Jackson, and John E. Kutzbach, "Projected distributions of novel and disappearing climates by 2100 AD," *Proceedings of the National Academy of Sciences of the United States of America* 104, no. 14 (April 3, 2007).

[14] See also CRS Report 98-738, *Global Climate Change: Three Policy Perspectives* by Larry Parker and John Blodgett.

[15] See discussion later of projected costs of climate change to the United States. While highly uncertain, projected climate change could have relatively mild impacts on the United States in aggregate, although some regions and populations will be more adversely affected than others; some populations may benefit from climate change.

Growing attention to impacts and possible adaptations has led, in the 110th Congress, to proposals in a number of bills that would increase research and programmatic attention on possible impacts of climate change and options for adaptation. Some bills are cross-sectoral, including some that propose to repeal and replace the Global Change Research Act of 1990; others are targeted to specific concerns, such as drinking water or wildlife. Some proposals are aimed at increasing research on impacts and adaptation, while others are intended to provide authority and resources to plan and carry out specific adaptations in selected sectors.

Proposed Greenhouse Gas Concentration Targets

The wide range of uncertainty regarding how much GHG emissions may rise, how much the climate may change, and how risky those changes may be (and how they are distributed among different populations) results in a broad spectrum of views regarding whether and how deeply to reduce GHG emissions.

To limit future risks, many experts propose targets to cap or "stabilize" the concentrations of GHG in the atmosphere; any level of stabilization is associated with a wide range of possible temperature outcomes. Current CO_2 concentrations are over 380 parts per million (ppm); future projections in the absence of changes from current policies range from about 550 ppm to almost 1000 ppm by 2100. Most debate concerning the appropriate level at which to stabilize GHG concentrations is around levels of 450, 550 or 650 ppm by 2100. Some people advocate targets as low as 350 ppm (lower than current concentrations), while others oppose setting stabilization targets altogether. Preferences for alternative targets are partially explained by differing views of how great the adverse impacts of climate change would be, associated with different stabilization targets, and differing views of how to address risks.[16]

The "Stern Report," discussed further in the economics sections below, concluded that,

> [s]tabilising [atmospheric concentrations] at or below 550 ppm CO_2 e[17] would require global emissions to peak in the next 10 - 20 years, and then fall at a rate of at least 1 - 3% per year....By 2050, global emissions would need to be around 25% below current levels. These cuts will have to be made in the context of a world economy in 2050 that may be 3 - 4 times larger than today - so emissions per unit of GDP would need to be just one quarter of current levels by 2050. To stabilise at 450 ppm CO_2e, without overshooting, global emissions would need to peak in the next 10 years and then fall at more than 5% per year, reaching 70% below current levels by 2050.[18]

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[16] Views on appropriate targets may also be partially explained by different perceptions of the challenges and costs of reducing GHG emissions.

[17] CO_2e means "carbon dioxide equivalents," which is an aggregate of all GHG with each gas weighted by its effect on climate change compared to CO_2.

[18] Stern, Nicholas. *The Economics of Climate Change*. Stern Review Report. London: HM Treasury, October 30, 2006. [http://www.hm-

(continued...)

While technologies exist today to begin such a trajectory, the target would require development and deployment of new technologies over the longer term.

Program Design and the Costs of GHG Mitigation

Greenhouse gas control programs raise concerns about costs: that the costs may be large; that the costs of mitigation may exceed the benefits of mitigation; or, that the distribution of costs may not be "fair." Many studies show that costs would be influenced by the:

- stringency of the reductions,
- timing of its reductions, and
- flexibility allowed by the program design.

Designing "flexibility" in a GHG mitigation program (e.g., allowing trading of emission permits; generation by non-covered sources of emission reduction credits or "offsets" against allowances;[19] banking or borrowing of permits; etc.) can significantly lower costs, according to economic modeling.[20]

Modeled estimates of costs for a given GHG reduction program typically vary because of differences in the models used; and methods and assumptions, regarding, among other factors:

- economic and energy growth rates without policies;
- future energy resource availability and prices;
- availability, efficiencies and costs of technologies;
- specific assumptions about program design (such as the scope of emission trading or offsets allowed; whether emission permits are given or auctioned; uses of any revenues, etc.);
- responsiveness of people's choices and technology development to policy incentives; and
- the scope of costs and "co-benefits" counted in the analysis.

Some but not all differences among results represent irreducible uncertainties; specification (e.g. of program design) and study of appropriate assumptions can allow one to build more confidence in some estimates than others. Many insights may be gained from the sensitivity analyses provided, which illustrate how costs and distributional impacts may vary with alternative judgments regarding the future and the specific program designs. Studies indicate that mitigation and adaptation efforts

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[18] (...continued)
treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm]. Executive Summary, p. xi.

[19] See CRS Report RL34436, *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns*, by Jonathan L. Ramseur.

[20] See CRS Report RL33799, *Climate Change: Design Approaches for a Greenhouse Gas Reduction Program*, by Larry Parker; and CRS Report RL34489, *Climate Change: Costs and Benefits of S. 2191*, by Larry Parker and Brent D. Yacobucci.

could also support other policy objectives ("co-benefits"), such as improving energy security and reducing health costs of pollution. Such co-benefits are discussed in a later section.

Distributional Impacts of Programs. Critical to many policy-makers in GHG mitigation and design of program are the distributions of costs on specific industry sectors and employment groups, U.S. regions, and income groups. One particularly challenging issue is how to address concerns regarding possible harm to trade and competitiveness of those countries and industries that shoulder the responsibilities of GHG reductions. To the degree that those industries (or companies within industries) increase their costs with mitigation measures, they may experience a price disadvantage in relation to competitors without GHG requirements or competitors that are advantaged by GHG regulation (for example, sources that have positioned themselves to reduce emissions at lower costs than their competitors).

Other groups that are likely to be disproportionately impacted by policies to limit GHG emissions include low income populations, which typically spend more of their incomes on energy bills, and may not have choices or control over factors that determine their energy dependence (such as renters). Alternatively, some groups may gain disproportionately from GHG controls. For example, manufacturers that specialize in high-efficiency vehicles would experience different costs, market share, and profitability than manufacturers that specialize in high-powered vehicles. Some groups may benefit from certain policy designs, for example, depending on whether existing GHG emitters are given (rather than sold) their emission permits ("allowances"). These "equity" issues may drive policy design, and could make the emerging policy overall more costly, but with more acceptable distributional effects.

Climate Change and Other Policy Issues: Commonality or Conflict? Because GHG emissions are related to so many sectors, climate change policy inevitably affects other national policy objectives, such as public well-being, reliable energy services, affordable food supply, and prudent management of natural resources. Many technologies and policy options can serve all or many policy objectives. For example, economical investment in energy efficiency can support all the goals above. Other options, such as promoting ethanol production from corn, may involve difficult trade-offs. Cross-issue analysis can help to maximize win-win choices and avoid conflicts, but may be under-utilized due to lack of resources, disciplinary or jurisdictional obstacles, or uneven input into policy processes.

U.S. Costs of GHG Mitigation. Analyses by the Energy Information Administration and the Environmental Protection Agency suggest that efficiently designed GHG reduction legislation could reduce U.S. GHG emissions from the reference case by about one-quarter by 2030, at a cost of roughly 0.3 to 3.8% of the business-as-usual Gross Domestic Product (GDP), with half the modeled cases at 1% of GDP or less. Technically and politically, though, an "efficiently designed" program may not be realistic. CRS analysis (Parker and Yacobucci)[21] found from

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[21] See CRS Report RL34489, *Climate Change: Costs and Benefits of S. 2191* by Larry (continued...)

various studies that the uncertainties about the future reference ("business-as-usual") cases for incomes per capita were greater than impact on them by the GHG mitigation proposed by S. 2191, the "Lieberman-Warner" bill, which was reported out of the Senate Committee on Environment and Public Works in 2007.

Beliefs about the effectiveness of measures in S. 2191 to stimulate technological advance are an important difference among several cost analyses of the bill. Parker and Yacobucci found that

> In its analysis, [Clean Air Task Force] CATF expresses confidence in S. 2191's various technology and efficiency provisions and models the bill assuming EIA's Best Available Technology (BAT) case, banking, and offsets. In contrast, [the American Council for Capital Formation/National Association of Manufacturers]ACCF/NAM states that it is "unlikely" that technology, new energy sources, and market mechanisms (e.g., carbon offsets, banking) will be sufficiently available to achieve S. 2191's emission targets. Accordingly, ACCF/NAM's assumptions differ substantially from CATF's and other studies by excluding banking, significantly capping the availability of various technologies, and assuming higher construction costs.

This difference was among the main reasons that the CATF produced a cost estimate at -0.9% (a reduction) of Gross Domestic Product per capita in 2030, compared to the ACCF/NAM's -2.6 to -2.7%.[22]

Regarding the effects of S. 2191 on international trade and the possible movement abroad of manufacturing (and its emissions, termed "leakage"), the Environmental Protection Agency provided the only analysis to date: it found no "leakage" if currently developing countries were to undertake action to maintain their 2015 GHG emission levels beginning in 2025, and to return their GHG emissions to 2000 levels by 2050. In a worst case scenario, EPA's analysis of a no-international-actions-to-2050 scenario projected that developing countries' projected GHG emissions would be about 1% higher, equivalent to U.S. emission leakage rates of approximately 11% in 2030 and 8% in 2050.[23] U.S. exports were projected to decline, but imports might increase or decrease, depending on assumptions.

Global Costs of GHG Mitigation. The Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report (2007), found that most economic analyses indicate that policies aiming to stabilize GHG concentrations in the atmosphere at 590 to 710 parts per million (ppm) of CO_2-equivalent could incur small aggregate costs — or possibly some gains — to economic growth. Achieving the lowest concentrations analyzed (e.g., 450 ppm) could dampen growth, with 90% of the studies indicating costs less than 3% of cumulative Gross World Product projected for 2010 to 2030, or less than 0.12 percentage points of the average annual

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[21] (...continued)
Parker and Brent D. Yacobucci.

[22] Ibid, p. 29. Reduction is relative to the same model's reference case baseline for 2030.

[23] EPA, *EPA Analysis of the Lieberman-Warner Climate Security Act of 2008: S. 2191 in 110th Congress* (March 14, 2008) p. 84.

growth rate. While the IPCC represents the consensus of a wide range of experts and governments, some other experts question its findings and conclusions.

Policy choices would determine how the costs, or changes in growth, would be distributed across and within regions internationally. In addition, adaptation efforts are considered necessary because of climate changes occurring now and likely in the future that are attributed to past GHG emissions. Though adaptation costs typically are not factored adequately into economic analyses, the effects on economies and non-market processes of climate change policies will reflect both the costs of mitigation, the costs of adaptation, and residual damages or benefits.

Benefits of Mitigating Climate Change

Inadequate data, tools and understanding of impacts. Many people implicitly wish to compare the benefits of proposed action[24] with the costs of that action; however, data and appropriate tools are inadequate to compare reliably and quantitatively the benefits and costs of abating climate change. Benefits analysis has received relatively little attention in the United States, with most analyses coming from other countries. A number of studies have attempted to estimate the benefits of mitigating GHG emissions, with a wide range of partial estimates. More rare are the few studies that integrate both mitigation and impacts of climate change, though the likely interaction between them is well recognized in the research community.[25]

No studies of benefits are comprehensive: all omit some sectors and types of impacts; all face challenges in quantifying and monetizing non-market effects; all require applying assumed (typically monetary) values to disparate nations and people potentially affected; and most do not address "multiplier effects"[26] or variability and uncertainties in their methods. Further, the most commonly used metric of impacts is change in Gross Domestic Product or Gross World Product, although these are poor measures of the well-being of people and the world's natural systems.

Moreover, the capability does not exist to assess all the nuanced and interacting ramifications of a changing climate. For example, although adverse climate change in many developing countries could exacerbate political instabilities and increase threats to U.S. security, calculating the magnitude and timing of added security risks — and the value of lessening them — would be guesswork. Furthermore, because many projections place the Earth's future climate into a range never experienced by

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[24] The benefits of policies to reduce climate change are not the same as the damages that could be caused by climate changes without the policy. In particular, some amount of climate change will occur no matter how quickly policies strive to reduce emissions; this would make benefits smaller than the future costs of climate change. In addition, there may be co-benefits or secondary costs of policies that may increase or decrease benefits of a policy.

[25] For example, climate change is expected to alter vegetation patterns, the transition of which would affect efforts to sequester carbon in soils and vegetation. Or, it may reduce demand for heating, potentially reducing benefits of improving heating efficiency.

[26] "Multiplier effects" here refers to the secondary and follow-on impacts of climate changes, as computable general equilibrium (CGE) models do for mitigation cost analyses.

human civilizations, observational evidence from the past is helpful but inherently not analogous to what may evolve; much will remain unknown no matter how much is invested in research. On the other hand, many flaws in current benefits analyses could be overcome with more study and improved analysis, and explicit methods for taking uncertainties into account (with value judgments) for more robust decision-making.

Global Costs of Climate Change. Almost all economists conclude that, while climate change in the near-term could have globally aggregated net benefits, further climate change would tend to decrease benefits while damages would increase. In net, they conclude that long-term climate change is likely to damage economic growth worldwide and incur cumulative costs that could reach many trillions of dollars.

The Costs of Climate Change Are Not the Same as the Benefits of Mitigation

Most studies estimate the potential *costs of climate change*, not the *benefits* – the costs of climate change that could be avoided by specific mitigation policies. However, mitigation policies are unlikely to avoid all future, GHG-induced climate change or its impacts. Therefore, the benefits of mitigation policies (i.e. the avoided impact costs) are likely to be less than the *total* costs of climate change impacts.

Benefits of Mitigation + Unavoided Damages = Total Costs of Climate Change

(This simplification ignores, however, that policies might be designed to garner benefits to other social objectives, such as improving energy security or avoiding deaths from air pollution.) Thus, attention to this difference may be warranted by people who wish to compare the costs and benefits of a proposed policy.

Nonetheless, most economists who have modeled both mitigation costs and its benefits conclude that well designed policies could have modest costs and save trillions of dollars over the coming century. Most economists would agree that the long-term costs of climate change merit some degree of near-term and mandatory action to reduce GHG. However, beyond those general points, there is a wide range of views and controversies.

The most comprehensive and rigorous review of the benefits of mitigating climate change is the "Stern Report," commissioned by the Government of the

United Kingdom and released in 2006.[27] The Stern Report has been strongly criticized by some notable economists, due to differences of views over methodological challenges, as well as to allegations of selectiveness of studies used. Other equally reputable economists have indicated their acceptance of the methods and/or provided analysis contending that the Stern estimates of possible climate change costs may be low. In brief, the Stern Report underscores that climate change policy must involve value-laden choices by public decision-makers.[28] In support of this, the Stern Report laid out a hierarchy of different valuation choices, leading to estimates of climate change damages ranging from 0 to 20% or more of global consumption "now and in the future."

Potential Costs of Climate Change to the U.S. Economy. Several studies of the potential costs (or benefits) to the United States of projected GHG-induced climate change have been conducted, though none is comprehensive and all suffer from the general challenges of applying economic and ethical methods to the issue. A recent review of economic studies of impacts in the United States by the University of Maryland's Center for Integrative Environmental Research stated the following "Five Key Lessons," which reflect commonly held views among climate impacts researchers:

- Economic impacts of climate change will occur throughout the country.
- Economic impacts will be unevenly distributed across regions and within the economy and society.
- Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.
- Climate change impacts will place immense strains on public sector budgets.
- Secondary effects of climate impacts can include higher prices, reduced income and job losses.[29]

The report cites a variety of regional studies that project costs of climate change impacts to localities or sectors in the tens of millions to hundreds of billions of dollars through the 21st Century. The report also concludes, "[t]here is, however, a lack of research that quantifies and compares these impacts, and a deficiency in using what is known about climate impacts to guide adaptation actions from the national level down to the local level. Thus, the full economic costs will likely be much higher than what is reported currently."

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[27] Stern, Nicholas. *The Economics of Climate Change*. Stern Review Report. London: HM Treasury, October 30, 2006. [http://www.hm-treasury.gov.uk/independent_reviews /stern_review_economics_climate_change/stern_review_report.cfm].

[28] Examples of choices more appropriately addressed by policy-makers than researchers include how to value impacts on current versus future generations; whether to give weight to impacts on particular populations, such as low-income populations or children; whether certain adverse impacts are not acceptable and might lead to maximum allowable degrees of change; etc.

[29] Ruth, Mathias, Dana Coehlo, and Daria Karetnikov. *The US Economic Impacts of Climate Change and the Costs of Inaction*. Center for Integrative Environmental Research, University of Maryland, October 2007. [http://www.cier.umd.edu/climateadaptation/].

Few studies have attempted to aggregate the economic costs of climate change to the United States across sectors in the absence of effective mitigation policies, and all of those studies qualify their results by recognizing the uncertainty and methodological questions. One such study, by economist Dale Jorgenson[30] and others, which examined a wide range of possible projections of climate change, though only market effects, concluded:

> Based on the market sectors and range of impacts considered for this analysis, projected climate change has the potential to impose considerable costs or produce temporary benefits for the U.S. economy over the 21st century, depending on the extent to which pessimistic or optimistic outcomes prevail. Under pessimistic assumptions, real U.S. GDP in the low climate change scenario is 0.6 percent lower in 2100 relative to a baseline that assumes no change in climate; in the high climate change scenario, the predicted reduction in real GDP is 1.9 percent [lower in 2100]. Under the additional "high and drier" climate scenario, however, real GDP is reduced more dramatically — by as much as 3.0 percent by 2100 relative to baseline conditions. Furthermore, under pessimistic assumptions negative impacts on GDP grow progressively larger over time, regardless of the climate scenario. In contrast, under optimistic assumptions real U.S. GDP by 2100 is 0.7 to 1.0 percent higher than baseline conditions across the low, central and high climate scenarios, but these benefits eventually diminish over time. Nevertheless, to the extent that responses in certain key sectors conform to the optimistic scenarios, there is a distinct possibility that some degree of climate change can provide modest overall benefits to the U.S. economy during the 21st century.

Many studies underscore a key point: the impacts of climate change on people and on ecosystems, and the benefits or damages, will depend heavily on the ability to adapt by different populations and systems, and the effectiveness of actions to adapt. Concerns about climate change, consequently, often emphasize the vulnerabilities of populations with low financial and technical resources, or that may be otherwise constrained in their adaptations (e.g., native cultures that are dependent on, and value, a habitat that may be eliminated by climate change, as in some Arctic populations).

"Co-Benefits" and Trade-offs of GHG Mitigation. Adding to the benefits of GHG mitigation would be many measures that would help to avoid climate change and would serve other national goals, such as improving energy security, abating the world food crisis, reducing pollution, and conserving critical natural resources and biodiversity. For example, actions to suppress demand for petroleum would help suppress global oil prices and total U.S. expenditures for energy. Such "co-benefits" of GHG mitigation would boost the value of abating climate change.

Offsetting the benefits would also be some trade-offs with other national or local goals, although many trade-offs could be minimized or eliminated through policy

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[30] Jorgenson, Dale W, Richard J. Goettle, Brian H. Hurd, and Joel B. Smith. *U.S. Market Consequences of Climate Change*. Prepared for the Pew Center on Global Climate Change. Arlington, VA, April 2004. [http://www.pewclimate.org/global-warming-in-depth/all_reports/marketconsequences].

design that is mindful of the relationships among issues. For example, incentives to reduce GHG emissions by increasing biofuel use could raise food prices (as in the present situation) and reduce food security, or could enhance food security by selectively encouraging feedstocks that do not compete for agricultural land and food products, and by improving agricultural efficiencies.

Importance of the Distribution of Losses (or Gains)

Experts agree that climate change, in the near term, will create both those who gain (e.g., agricultural producers in cool to moderate and wet climates) and those who will suffer (e.g., agricultural producers in hot and dry climates). Some people are likely to experience slow and moderate changes, while others are likely to experience such radical changes in their climate that their current way of life — and possibly their locales — becomes unsustainable. Some people will have the resources to migrate and adapt successfully — even profit from new opportunities that will emerge — while others could lose livelihoods or lives. The same would be true also with policies to mitigate GHG emissions (e.g., the potential effects on coal producers).

Embodied in any debate over climate change and what to do about it are the potential inequities of policies to mitigate or not to mitigate climate change. Despite these distributional hazards being fundamental to the debate, they are among the least researched of all climate change issues.

Part Two: The International and Domestic Policy Fields

The stage for upcoming policy deliberations is set by the existing frameworks internationally and domestically. The developing countries now contribute the major, and most rapidly increasing, share of GHG emissions globally.[31] Effectively abating climate change would require GHG reductions in all major countries. Additionally, some industries fear adverse trade impacts if their competitors in other countries do not have similar requirements to reduce GHG emissions. In the United States, these issues, along with concerns about U.S. leadership and sovereignty, figure into the debate over long-term GHG concentration targets and near-term emission controls. Legislative actions would be superimposed on existing federal programs and a patchwork of state and local policies to reduce a part of U.S. GHG emissions. One legislative challenge would be to create a coherent strategy from the current components.

Status of International Cooperation on Climate Change[32]

The United Nations Framework Convention on Climate Change. Internationally, 192 countries — including the United States — joined the 1992 United Nations Framework Convention on Climate Change (UNFCCC) to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Art. 2). Although science can help to identify the degree of "interference" and implications of climate changes at different concentration levels or degrees of temperature change, most scientists agree that the determination of "dangerous" is a political decision, not one that can be objectively decided by scientists.

The Kyoto Protocol. Agreeing that mandatory GHG reductions would be necessary to avoid "dangerous anthropogenic interference," most countries in 1997 signed the Kyoto Protocol. It sets legally binding GHG targets — an average 5% reduction below 1990 emissions levels during the period 2008-2012 — for 38 industrialized countries. The Kyoto Protocol has been ratified by 175 countries, including 37 of the 38 industrialized countries.

The United States Rejected the Kyoto Protocol. The United States signed the Kyoto Protocol in 2007. However, President Bush in 2001 announced that the United States would not become a Party to the Kyoto Protocol.[33] His principal arguments against it were (1) uncertainty of the science; (2) potentially high cost of GHG abatement programs; and (3) lack of GHG abatement commitments from developing countries. President Bush announced a U.S. policy to reduce the

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[31] Calculated from estimates for 2005 in International Energy Agency, *CO2 Emissions from Fuel Combustion 1971-2005*, 2007, online database. Data extracted May 30, 2008.

[32] See CRS Report RL33826, *Climate Change: The Kyoto Protocol, Bali 'Action Plan,' and International Actions* by Susan R. Fletcher and Larry Parker.

[33] Neither President Clinton nor President Bush sent the Kyoto Protocol to the Senate for ratification.

"greenhouse gas intensity" (ratio of emissions to economic output) of the U.S. economy by 18% from 2002 to 2012. This target represented up to a four percentage point increase above previous trends.

"Common but Differentiated Responsibilities". Both the UNFCCC and the Kyoto Protocol operate under the principal of "common but differentiated responsibilities." Effective efforts would need to be made by all large emitting nations in order to stabilize global GHG concentrations. Nations' views diverge concerning the Kyoto Protocol and "post-Kyoto" steps (post-2012): industrialized nations fear harm to their economic competitiveness if developing countries do not also limit emissions; developing nations, a growing source of emissions, typically argue that industrialized countries have emitted most GHG historically and can better afford to reduce emissions first and deeper. They argue that low-income nations must give first priority to alleviating poverty. The UNFCCC embodies the principle of "common but differentiated responsibilities" to reflect the agreement that each nation must contribute to addressing climate change, but that its priorities and the magnitude of its efforts should differ according to national circumstances. The differences of views concerning appropriate common responsibilities and differentiation are at the core of the international negotiations.

The Bali Action Plan. To negotiate the next round of international commitments, Parties to the UNFCCC agreed to the "Bali Action Plan" in December 2007. The Bali Action Plan established an Ad Hoc Working Group on Long-term Cooperative Action under the UNFCCC to complete and present its work to the 15th meeting of the Parties, in November-December 2009. The first session of the Ad Hoc Working Group met in April 2008. In parallel to the UNFCCC process, President Bush announced in May 2007 that the United States would convene a series of meetings of major economies (MEM) to develop a post-2012 framework to address climate change. To the "MEM" process, President Bush proposed a multilateral 'clean technology fund' totaling $3 billion to stimulate international investments in clean energy and adaptations to climate change. His FY2009 budget requests a first U.S. payment of $400 million to this fund. Japan has proposed a similar multilateral fund of $10 billion.

Current Domestic Policy on Climate Change

Goal. On April 16, 2008, President George W. Bush announced a new national goal for climate policy — to halt increases in U.S. emissions of GHG by 2025.[34] Emissions would begin to decline thereafter "so long as technology continues to advance."[35] According to the President, the United States would achieve this goal by

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[34] This is not the first quantitative GHG goal set for U.S. climate change policy: on April 21, 1993, President William J. Clinton "announce[d] our nation's commitment to reducing our emissions of greenhouse gases to their 1990 levels by the year 2000," consistent with the Article 4 aim of the UNFCCC. The challenge in meeting that aim with voluntary measures only led to agreement on mandatory GHG reduction obligations in the Kyoto Protocol.

[35] White House. *Fact Sheet: Taking Additional Action to Confront Climate Change. Press Release*, April 16, 2008. [http://www.whitehouse.gov/news/releases

(continued...)

regulatory measures and market incentives to encourage use of clean technologies. President Bush said that the United States would be willing to include this plan in a future international agreement as long as all other major emitting economies also include their plans in the agreement. Some stakeholders have criticized the new Bush policy for proposing any cap on future emissions, while others have criticized it as too little, too late.

Federal Policies. Current federal climate change policies provide incentives, but few requirements, to reduce GHG emissions. For example, a number of tax incentives are in place to encourage purchase of more efficient vehicles and to make efficiency improvements to buildings. Other incentives induce agricultural producers to enhance soil carbon. A suite of federal programs provides information, technical assistance and nominal awards to businesses, universities and other consumers to quantify and reduce their GHG emissions; such programs generally are intended to encourage emission reductions that are already economical but that do not occur because of market inefficiencies. Some GHG reductions are also achieved by existing regulations governing the energy efficiency of vehicles and appliances, methane emissions from landfills, and other controls. Again, these regulations have been put in place for reasons other than abating climate change. Large programs are devoted to developing new technologies that would be necessary to reduce GHG emissions below current levels. Many experts contend that voluntary efforts (such as the U.S. Climate Leaders Program), research on technologies, and existing regulatory and tax incentives cannot achieve the GHG reductions necessary to avoid "dangerous" climate change.

The United States and the European Union have proposed, for the Doha Round of the World Trade Organization (WTO) negotiations, a New Environmental Goods and Services Agreement (EGSA) to eliminate tariff and non-tariff barriers to environmental technologies and services. The proposal aims particularly at lowering the cost and increasing access to "clean energy" technologies.[36]

Funding.[37] Of the $6.4 billion in U.S. federal funding in FY2008 for climate change activities, almost all is for scientific and technological research and development. In addition, tax incentives that could help to reduce GHG emissions are forecast to reduce federal revenues by about $1.5 billion in FY2008. Funding for regulatory, voluntary and public education programs is a few percent of the total.

Legislative Actions. The Congress faces increasing pressure from the public to address the risks of climate change; avoid creating a patchwork of state and local requirements; provide certainty for investors in U.S. systems; and position the United States for competitiveness in the growing world markets for "clean" energy. In the

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[35] (...continued)
/2008/04/print/20080416-7.html].

[36] U.S. Mission to the European Union. "U.S., EU Announce New Climate Initiatives for WTO." [http://useu.usmission.gov/Dossiers/Environment/Nov3007_USTR_Environment.asp].

[37] See CRS Report RL33817, *Climate Change: Federal Funding and Tax Incentives* by Jane A. Leggett.

110th Congress, Members have introduced numerous bills to address various aspects of climate change.[38] These bills cover a wide spectrum, ranging from climate change research to GHG emissions cap-and-trade programs or emissions taxes. Additional bills focus on GHG reporting or registration. Several bills would authorize planning and carrying out of adaptations to expected climate change in specific sectors, nation-wide or internationally. Annual appropriations for climate change programs directly affect the federal level of effort for authorized activities.

As of the date of this report, the 110th Congress has enacted two broad pieces of legislation — an omnibus energy bill (P.L. 110-140) and a comprehensive appropriations act (P.L. 110-161) — that include climate change provisions. Both statutes increase climate change research efforts, and the energy act requires improvement in vehicle fuel economies, as well as other provisions that would reduce (or sometimes increase) GHG emissions. P.L. 110-161 directs the Environmental Protection Agency (EPA) to develop regulations that establish a mandatory GHG reporting program that applies "above appropriate thresholds in all sectors of the economy." In addition, in December 2007, the Senate Committee on Environment and Public Works approved a bill, S. 2191 – the "Lieberman-Warner" bill, that would require "economy-wide" GHG reductions. This bill is scheduled to go to the Senate for consideration in June 2008.

Regional, State and Local GHG Policies.[39] In the absence of a federal regulatory framework to address U.S. GHG emission reductions, a majority of states have established formal GHG mitigation policies, including targets for future reductions. California, Hawaii, and New Jersey have passed laws establishing mandatory, economy-wide GHG emission limits, while a number of additional states have set controls on CO2 emissions from particular sources. In several regions, including the Northeast, the Midwest and the West, states are working together to create regional schemes to cap GHG emissions and allow trading of emissions permits across borders. The increasingly complicated mosaic of state, local, and regional GHG initiatives may place growing pressure on the federal government to establish a coherent national regulatory strategy to address GHG emissions.

Climate Change Litigation. A proliferation over the past five years of litigation relating to climate change may also press the federal government toward actions to reduce GHG emissions. For example, the Supreme Court ruled in 2007 that the EPA must consider regulating CO_2 and other GHG emitted from motor vehicles as pollutants under the Clean Air Act.[40] Further litigation has been pursued, to challenge the Executive Branch to action, using the Endangered Species Act, the Energy Policy and Conservation Act and the Outer Continental Shelf Lands Act. A

[38] See CRS Report RL34067, *Climate Change Legislation in the 110th Congress* by Jonathan L. Ramseur and. Brent D. Yacobucci.

[39] See CRS Report RL33812, *Climate Change: Action by States To Address Greenhouse Gas Emissions*, by Jonathan L. Ramseur.

[40] *Massachusetts v. EPA*, 127 S. Ct. 1438 (2007).

few international-law claims have been filed against the United States as well.[41] However,

> [w]hether these new paths will yield results, only time will tell. It is clear, however, that if there is to be a government response to climate change at all, a solution from the political branches is more likely to be comprehensive and fully reflective of societal priorities than the typically narrowly targeted results of litigation.[42]

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[41] See CRS Report RL32764, *Climate Change Litigation: A Growing Phenomenon*, by Robert Meltz.

[42] Ibid., p.35.

Part Three: The Policy Tool Box

With growing consensus on climate change science and pressures from interest groups, many legislators are deliberating whether and how to address climate change. Some may prefer to continue to employ the existing set of research and voluntary programs. Available for others who are considering additional actions is an assortment of policy tools that they see as stimulating further reductions of GHG emissions and reducing risks to the economy, specific populations, and natural systems. Part Three of this report identifies a variety of policy tools potentially affecting these objectives:

- regulatory, including market-based, tools to reduce GHG;
- distribution of potential revenues from GHG programs;
- non-regulatory tools that help markets work more efficiently;
- tools to stimulate technological change;
- options to ease the economic transition to a lower GHG economy;
- instruments to encourage international actions; and
- tools to stimulate adaptation to climate change.

The following sections summarize some potentially applicable instruments in each of these categories that have been proposed or used in the past. Many of these tools are complementary, and proponents often contend that they would produce results more efficiently when carefully matched than any one alone.

Regulatory and Market Tools to Reduce Greenhouse Gases

Most experts agree that the most economically efficient way to reduce GHG emissions substantially is to put a price on emissions that reflects the costs (or risks) of those emissions to others. Putting a price on GHG emissions can be done with traditional source-by-source regulation, and/or with "market mechanisms."

Source-by-source regulations. From the earliest decades of air pollution controls, emission reductions have been achieved by setting emission performance standards on each source of pollution, or requiring that sources use a particular type of technology, such as the "best available control technology"; practice has successfully included "technology-forcing" regulation, as well, that sets future performance standards well beyond contemporaneously achievable levels. Regulatory controls have proven to be effective through decades of experience, though studies have demonstrated that the compliance costs might have been reduced if strategies had given priority to cost-effectiveness and flexibility. Even when regulators have been allowed by law to consider costs in setting emission regulations, they have had additional factors to consider and often have had weak information about the costs of technology for each individual source. Also, regulations can be difficult to adjust as circumstances change. Although in some circumstances source-by-source regulation may be most effective and efficient,[43] it often cannot achieve, by itself, a desired emission reduction target at the least possible cost.

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[43] In some instances, performance standards can be very efficient, for example, when transaction costs are high compared to the incremental cost of control.

Market mechanisms. Regulatory approaches that utilize aspects of commodity markets can achieve, in some cases, similar emission reductions but at lower overall cost. Bills introduced in the 110th Congress have proposed such "market mechanisms" to reduce GHG emissions because, for some sources, they can increase the efficiency of source-by-source regulation by allowing the least costly reductions first. Market mechanisms begin with regulations to reduce emissions, but then may allow flexibility in *who* makes the emission reduction, *when* the reductions are made, and *where* the emission reductions occur (outside of the regulated sources, or even internationally).

Two principal types of market mechanisms pertinent to GHG reductions are GHG or carbon taxes, or cap-and-trade systems. The key contrast between these two mechanisms is that:

- GHG taxes would provide certainty about the prices paid by sources, but uncertainty concerning how much GHG would be reduced;
- conversely, cap-and-trade systems provide certainty in how much GHG would be reduced, but not regarding the prices paid by sources.

Both emission fees and cap-and-trade systems potentially generate revenues – potentially in the billions of dollars annually. Issues regarding what to do with revenues will be introduced following brief discussion of some potentially contentious design issues.

GHG fees or carbon taxes. Fees would be charged to a source of emissions according to its total emissions. Theoretically, a source would reduce its emissions down to the level where it is no longer cheaper to make the reductions (per ton) than to pay the tax (per ton). There could be many variations on this basic model, including charging fees only on emissions above rates designated by source types. Aside from possible tax exemptions, emission fees would not allow flexibility in who or where GHG reductions would occur. A system might be designed to allow flexibility in when GHG reductions are made, though the principal flexibility would be the source's decision whether to make the reductions or pay the taxes. Many economists believe that emission fees or taxes would be the most economically efficient way to reduce emissions, though this might depend on micro-economic factors, and it would not guarantee an overall level of effectiveness for the program. Some people object to paying "taxes" in general, even if it is to correct an acknowledged problem.

"Cap and trade". In a cap-and-trade program, the regulator sets an overall cap on emissions, and must allocate responsibility for achieving the cap to individual sources, frequently termed "allowances" to emit. In cap-and-trade programs, the trade component allows entities to sell their unneeded emission "allowances," while emission sources that emit more than their allowances may comply by reducing their emissions and/or buying additional allowances.[44] Cap-and-trade programs allow

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[44] More detailed descriptions of how cap and trade programs may work are discussed in a (continued...)

flexibility in *who* makes the required emission reductions. Within cap-and-trade systems, are two additional types of flexibility:

- International credits or offsets: Flexibility in *where* reductions occur – in the United States or internationally – can also minimize costs, although some questions arise about enforceability, loss of program effectiveness, and financial flows. Allowing international credits or offsets, to the degree that GHG could be reduced reliably at lower cost in other countries, which could help reduce costs of complying with U.S. GHG requirements.

- Banking and borrowing: *When* flexibility could allow entities to save or "bank" unneeded allowances until they need them, or to "borrow" against their future allocations of allowances (with a charge for borrowing). Banking and borrowing could apply to source-by-source regulation as well as to cap-and-trade programs.

Design Choices in Cap-and-Trade Programs. Although there are numerous questions to resolve in designing a cap-and-trade program,[45] such as the level at which to set the cap, which sources to cover under the cap, whether to allow offsets from non-covered sources and other countries, etc., this section discusses two: how to allocate the GHG reduction requirements, and whether to set a ceiling or floor on the prices a source must pay for any allowances it wishes to purchase.

Allocating the GHG Reduction Requirements. Policy-makers would have to decide who would be responsible for reducing GHG emissions – this determines who pays for the reductions, not who actually makes the reductions. In a cap-and-trade system, allowances can be:

- given away (e.g. "grandfathered" to existing GHG sources, or given to non-source entities),
- sold at a fixed price,
- auctioned, or
- a combination of these techniques.

Allowances are a valuable commodity (because they can be sold). How this valuable commodity is allocated could potentially transfer billions of dollars of wealth across different groups. This transfer of wealth (from entities who need to buy allowances, to entities that sell them) could be many times greater than the economic cost of the GHG reductions. How to allocate allowances is therefore an important component — and among the most controversial — in the GHG reduction debate. Giving allowances to particular groups may be a tempting way to increase the acceptability

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[44] (...continued)
later section on program design, and in several CRS reports, including CRS Report RL33799, *Climate Change: Design Approaches for a Greenhouse Gas Reduction Program* by Larry Parker, and CRS Report RL33846, *Greenhouse Gas Reduction: Cap-and-Trade Bills in the 110th Congress* by Larry Parker and Brent D. Yacobucci.

[45] Ibid.

of a GHG control program, or to improve the "fairness" of the program, but it could distort incentives and reduce the efficiency of the program. One way (among others) to minimize the transfer of wealth in a GHG control program would be to sell allowances rather than to give them away. Sales, including auctions, would increase the efficiency of an overall GHG reduction. Selling the allowances at a fixed price becomes very much like an emission fee or tax program. Many proposals would give away some allowances to both sources of emissions and other entities (e.g. states, other sectors) and would auction some allowances.

"Safety Valves" and Allowance Price Floors. GHG allowances under a cap-and-trade program become a market commodity; the prices of most commodities rise and fall – sometimes with great volatility – as daily, seasonal or annual conditions vary. Variance would be expected with GHG allowance prices.

Prices could rise above anticipated levels if reducing GHG turns out to be more expected than projected, or if speculators bid up prices, or under other conditions. Some people concerned about the costs of GHG reduction programs advocate setting a ceiling on the maximum price a source might have to pay for allowances it may need to comply; some have termed this a "safety valve" on prices. If prices were to exceed a designated level for some period of time, either the regulatory authority could release additional allowances into the market through an auction, or sales at a fixed fee. While this would limit the overall cost of the program, it would also limit the overall GHG reductions (although these could be "borrowed" from future years), and it would reduce incentives for technological innovation: The profits that can be reaped when prices spike is part of the calculation that stimulates some investors to finance technological research.

Other stakeholders argue that, to stimulate technological advance, a floor should be set on the prices for allowances in the market (i.e., the regulator set a "reserve price" for allowances sold at auction, or would buy allowances in the market until the prices rise to the minimum acceptable level). While constraining how little the GHG program may cost, a price floor assures investors there is a minimum value for the services their technologies could provide.

Distributing the Revenues from Taxes or Sales. If emissions are taxed, or allowances are sold to sources at flat fees or by auction, public revenues could be generated — as much as hundreds of billions of dollars per year (depending on the size of the tax or the quantity of reductions required). A key policy issue associated with taxes, sales or auctions is what to do with the revenues. Revenues can be used to:

- offset reductions of other taxes, sometimes called "revenue recycling" (e.g. labor taxes);
- rebate to sources to help defray compliance costs of covered sources (e.g. according to their production levels);
- fund programs (or provisions) that could reduce transition costs, such as worker retraining and relocation programs, market facilitation programs, technology development programs, tax credits, loan guarantees, etc.;

- provide payments to address distributional concerns (e.g. tax credits to low-income consumers); or
- fund programs that may have little to do with reducing GHG emissions but that garner wider support for the legislation.

As discussed in a later section, how any revenues are used may help to minimize the overall costs of the GHG reductions, or, conversely, may lead to higher costs.

Market Facilitation Tools

Even when market mechanisms are used to help control emissions, markets do not work perfectly; complementary, typically non-regulatory, policies may help to achieve reductions at the lowest possible costs. Public or targeted information programs can help prepare people for the changes a GHG control policy may demand, and gain their support for it.

Additionally, technical assistance programs — like several existing federal voluntary programs, such as the Climate Leaders or Energy Star programs[46] — can help consumers and businesses to make efficient choices. Technical assistance programs may provide, for example, calculation tools, training, and access to information. Programs may work with equipment suppliers to commercialize products that are more efficient or emit fewer GHG, as has occurred with, for example, Energy Star home electronics initiatives, or the Mobile Air Conditioning Climate Protection Partnership. Most experts agree that such programs work best when targeted to address specific decision-makers or imperfections in the market, and that the GHG reductions they could yield by themselves are limited.

Perceived risks can sometimes make consumers and investors reticent to make changes or invest in new technologies. Risk-sharing policy tools can include loan guarantees, insurance, or tax incentives. Public information and education campaigns are additional tools that can support a policy's acceptability and effectiveness.

Tools to Stimulate Technological Change

Achieving deep GHG reductions from projected levels – necessary to avoid most projected climate change – would require extraordinary changes in how energy is used and supplied over time. The cost of reducing GHG emissions would depend critically on development and deployment of improved technologies that can reduce emissions at lower costs than current technologies. While public policies clearly have led to major technological advances in other fields (e.g. developing nuclear energy, putting a man on the moon), the link between policy tools and the technological advance that could be expected is unpredictable.

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[46] A number of federal voluntary programs help businesses, other institutions and consumer to identify how they contribute to GHG emissions and to identify and carry out changes that can lead to GHG reductions and frequently save money. For more information, see [http://yosemite.epa.gov/gw/StatePolicyActions.nsf/webpages/VoluntaryPartnershipPrograms.html].

Policy tools can act on the demand for new technologies, or on the supply. Two types of policy tools act primarily to stimulate demand for new technologies:

- "Technology-forcing" regulations[47] have effectively stimulated demand for better (and more cost-effective) technologies in the past. "...[T]echnology-forcing policies respond to the reality that the world is not static and that policy itself can create and shape the options society faces in meeting its needs."[48] However, economists prefer price incentives to stimulate technological change, because it decentralizes decision-making to consumers and suppliers, and is arguably more cost-effective.
- Tax incentives can reduce the price to purchasers of certain technologies. The Energy Policy Act of 2005 (P.L. 109-58), for example, extended numerous tax credits to individuals and businesses to make investments in energy efficiency or renewable energy generation that meet certain criteria, in order to accelerate technology deployment.

Other policy tools primarily act on the supply of technologies – increasing incentives for technology suppliers to conduct research and development (R&D) and to commercialize more advanced technologies:

- Subsidies to research and develop new or improved technologies is a common tool of federal policy, including current approaches to mitigating climate change. Federal appropriations of billions of dollars have been enacted in recent years to stimulate more efficient energy technologies; renewable, nuclear, and "clean coal" technologies; and approaches like alternatives to gasoline or diesel fuel for vehicles. These subsidies can take the form of tax credits for R&D, cost-sharing grants or contracts, direct investments, loan guarantees and others.
- Technology awards or prizes are sometimes offered to innovators that develop advanced technologies that meet specified criteria.
- Government procurement policies can drive technological development forward, by setting challenging standards for performance and guaranteeing purchase of that technology at a particular (attractive) price, or by purchasing a less-emitting technology even if it is not the lowest cost alternative. Both types of procurement policies have been used by the federal government to advance technologies that emit fewer GHG than more conventional technologies.

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[47] "Where a regulator mandates a standard that cannot be met with existing technology," according to Gerard, David, and Lester Lave. "Experiments in Technology Forcing: Comparing the Regulatory Processes of US Automobile Safety and Emissions Regulations." *International Journal of Technology, Policy and Management* 7 (2007): 1-14.

[48] Leone, Robert. "Technology-Forcing Public Policies and the Automobile." In *Essays in Transportation Economics and Policy*. Edited by J. Gomez-Ibanez, W. Tye, and C. Winston. Washington, DC: Brookings Institution 1999. pp. 291-323.

- "Manhattan Project"-like federal research has been proposed by some experts, who argue that a focused cadre of researchers, with sufficient resources and allowed to pursue high-risk, high-payoff projects could facilitate technological "breakthroughs" that could facilitate radical change in energy systems.

Some policy tools that may affect the advance of technologies could be indirect. For example, incentives to ensure a sufficient supply from universities of well trained scientists and engineers in GHG mitigation-related fields could be a component of promoting technological advance.

Unintended Consequences for Technology Incentives. Some policy choices to address one problem may have ancillary effects on technology incentives. For example, if a GHG cap-and-trade program were to set a "safety valve" to limit maximum costs – by setting a ceiling on the maximum price of GHG allowances – it would tend to discourage investors who might take technology development risks in order to capture the profits of high prices or of temporary price-spikes that often occur in markets. Price floors, on the other hand, may help reduce the risks to technology investors by making certain the minimum value the investment may have.

Options to Ease the Economic Transition

A major component of costs to mitigate GHG emissions results because the U.S. economy has optimized its infrastructure to depend on fossil fuels, particularly coal, and on private, petroleum-dependent vehicles for transportation. This has been efficient (disregarding existing subsidies), without factoring in the environmental, energy security and other "external" costs. Several policy mechanisms can help to ease the transition of the current economy to one optimized around low-GHG emissions:

- timing the total required GHG reductions to coincide with normal retirements of equipment and infrastructure and when new investments may be made;[49]
- trading, banking and borrowing of allowances allow sources to manage the timing of their reductions at least cost;
- market facilitation tools, described above, can help sources make optimal decisions, including information campaigns that help sources anticipate the regulatory regime;
- investment in appropriate infrastructure (important also for state, local and private entities) that enables deployment of emerging technologies; and

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[49] However, some experts suggest that much capital can be maintained to last for decades longer than its nominal "lifetime" and that the benefits of timing regulations to coincide with capital turnover may frequently be over-stated. See, for example, Lempert, Robert J., Stephen W. Popper, Susan A. Resetar, and Stuart L. Hart. *Capital Cycles and the Timing of Climate Change*. Arlington, VA: Prepared for the Pew Center on Global Climate Change, October 2002.

- regulatory and permitting regimes that are adequately prepared for new technologies in new locations (e.g. in permitting carbon capture and storage technologies, or resolving "solar rights" issues).

In addition, the private sector is concerned about the possible international competitiveness and trade impacts of GHG reductions in the United States. Some policy tools that could be applied, although some could encounter potential challenges under the World Trade Organization (WTO) rules, include:

- border tax adjustments that would raise the prices of imports from countries without GHG controls comparable to those of the United States;
- "international reserve" allowances that importers of certain goods must purchase (raising the cost of imports) if the country of origin does not apply GHG controls comparable to those of the United States;
- giving, over some period, allowances or revenues from sales of allowances to affected industries in order to facilitate adjustment;
- in the process of crafting domestic policies, negotiating with potentially affected WTO Members to seeks ways to avoid imposing restrictive import measures;
- working within the WTO to change or clarify rules to permit the imposition of import restrictions by countries adopting trade-vulnerable GHG control requirements; or
- working multilaterally to have GHG emission controls applied equitably to sources internationally (see discussion below) and to avoid WTO challenges.

The design of competitiveness-oriented policy tools would require caution to avoid challenge under WTO as unfair trade practices.

International Policy Tools

The effectiveness of U.S. policies to address climate change will depend on the collaboration of almost all other countries, especially the largest emitters. Some of the large emitters, such as Japan and nations of the European Union, already have committed to reducing their GHG emissions below year 1990 levels and have proposed further reductions beyond the current Kyoto Protocol (discussed in a later section). However, the United States, China and other large developing country emitters have not committed to quantified GHG reductions, and the position of Russia beyond 2012 remains a question. The United States can use a number of policy tools in order to encourage effective, global GHG reductions:

- Leadership and relationship-building;
- Strategic policy leverage (including quid pro quo);
- Capacity building and other technical assistance;
- Financial assistance;
- Agreement on standards for international investment;
- Contributions of research and technological developments.

There are additional options, and a multitude of variants in designing each of these policy tools.

Tools to Stimulate Adaptation to Climate Change

While most of this section, and this report, emphasizes options to mitigate GHG emissions and projected climate change, a growing set of legislative proposals aims to promote understanding of climate change impacts, and to stimulate effective adaptation to climate change. Included in the policy toolbox to promote efficient adaptation to climate change are, to name a few:

- research to improve characterization of future climate change,[50] its variability, and its potential implications for different sectors and ecosystems;
- public information, both broad and targeted to specific risks, including access to robust characterization of future climate conditions and associated risks;
- programs to develop practical tools to assist decision-makers to understand the implications of climate change for their areas of operation (e.g. water management, infrastructure engineering, disease vector prediction, etc.);
- financial or regulatory incentives to reduce risks (e.g., to discourage construction in vulnerable flood plains; to encourage insurers to include climate change risks in their premium schedules; etc.)
- improved emergency planning to reduce risks and respond to extreme weather events (e.g. droughts, tornadoes); etc.
- acquisition of key assets, such as easements in coastal zones or lands along wildlife migratory routes, that may be valuable for long-term adaptation.

Policy tools to encourage private and public sector adaptations, like the research to support them, are relatively undeveloped compared to work on GHG mitigation.

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[50] Current scientific uncertainty is very wide not just on human-induced climate change, but also on underlying natural variability. What humans and ecosystems will experience, and may need to adapt to, will be the combination of both influences on climate.

Choices Ahead for Policy-Makers

With the current flurry of activity to address GHG emissions at local, state and international levels, as well as the introduction of numerous GHG reduction bills in the 110th Congress, it seems likely that Members of Congress will have to decide whether the time is appropriate to legislate a climate strategy, and what forms legislation should take. In considering the alternatives, policy-makers may wish to answer for themselves such questions as:

- whether the risks of human-induced climate change are sufficiently certain to call for policy actions to mitigate the causes and/or adapt to perceived inevitable change;
- how a domestic policy package can be designed that balances the risks of climate change with costs that are accepted as reasonable and fairly distributed;
- how domestic policy would interact with international negotiations to avoid unacceptable climate risks while distributing the effort equitably among countries and sectors;
- when and how to promote appropriate adaptation by private and public decision-makers to the uncertain climate ahead.

Further Information

Reports for Members of Congress, providing more detailed information on topics introduced in this report, can be found on the CRS website, on the Climate Change Current Legislative Issues page: [http://apps.crs.gov/cli/cli.aspx?PRDS_CLI_ITEM_ID=2645&from=3&fromId=2522] or by calling 707-5700. crsphpgw