# Climate Change: Conceptual Approaches and Policy Tools

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# Summary

Congress has, over the past three decades, authorized and funded federal programs to improve understanding of climate changes and their implications. Climate changes have potentially large economic and ecological consequences, both positive and negative, which depend on the rapidity, size, and predictability of change. Some of the impacts of past change are evident in shifting agricultural productivity, forest insect infestations and fires, shifts in water supply, record-breaking summer high temperatures, and coastal erosion and inundation.

People and natural systems respond to climate changes regardless of whether the government responds. Over time, the consequences of climate change for the United States and the globe will be influenced by choices made or left to others by the U.S. Congress.

Different factors contribute to climate change, their contributions depending on the time periods and geographic locations under examination. Current scientific evidence best supports rising atmospheric concentrations of "greenhouse gases" (GHG) (particularly carbon dioxide, methane, nitrous oxides) and other air pollutants as having driven the majority of global average temperature increase since the late 1970s. The increase in concentrations is due almost entirely to GHG emissions from human activities. Hence, the policy debate has focused on whether and how to abate GHG emissions from human-related activities. Locally, human-related air pollution, irrigation, the built environment, land use change, and depletion of ozone in the stratosphere may be more important but have small overall effect on global average temperature.

Policy proposals take different approaches to setting goals or managing climate change-related risks. This report describes four strategies for setting climate change policies: (1) research and wait-and-see, (2) science-based goal setting, (3) economics-based policies, and (4) incrementalism or adaptive management. Each may take into account the concerns, values, and skepticisms of some constituencies, but each also has limitations. It is unclear whether any single conceptual approach could cover all elements of the policy debate, though hybrid approaches may help to build political consensus over whether and how much policy intervention is appropriate.

If climate change merits federal action, a variety of generic policy tools may be available (some in use already) to achieve policy goals:

- regulatory, including market-based, tools to reduce GHGs;
- 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.

Analysts have elucidated the potential usefulness and limitations of each option. Many experts have concluded that, to achieve a given policy goal, strategies using complementary policy tools can increase cost-effectiveness, alleviate burdens on particular constituencies, and address additional concerns of policy-makers. This report seeks to support Congress as it debates and modifies the mix of federal programs that may influence the climate or adaptation to its changes.

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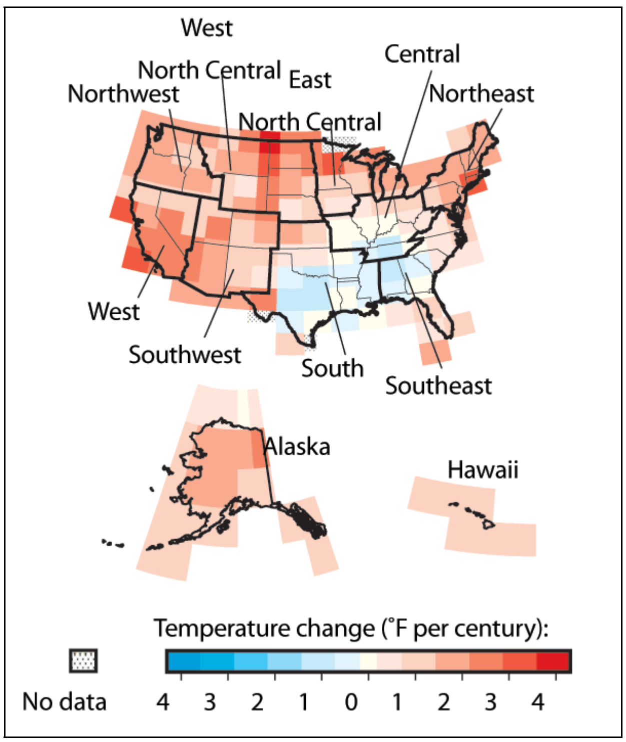
# Choices Ahead for Policy Makers

Regardless of the public conversation, the Earth's climate is changing. Changes are exhibited in observations of average temperatures over land and in the oceans, melting glaciers and ice caps, shifting precipitation patterns, modified growing seasons, shifting distributions of plants and animals, and a variety of additional observations. (Many but not all elements of climate show distinct trends.) Regional climates in the United States have shifted as well (**Figure 1**).[1]

A variety of factors contribute to the changes, their weights differing depending on the time periods and geographic locations under examination. In public media, the controversy over causes may appear much greater than the broad scientific agreement that exists: the scientific evidence best supports rising atmospheric concentrations of "greenhouse gases" (GHG) (particularly carbon dioxide, methane, nitrous oxides) and other air pollutants as having contributed to the majority of global average temperature increase since the late 1970s. (See box.) The rise of GHG concentrations is due to emissions from human-related activities.

**Figure 1. Rates of Average Annual Temperature Change, 1901-2005**

in degrees Fahrenheit per century




**Source:** National Climate Data Center, National Oceanic and Atmospheric Administration, Department of Commerce, as provided by the Environmental Protection Agency at http://www.epa.gov/climatechange/science/recenttc_tempanom.html.

[1] For analysis of climate change observations and science, see Board on Atmospheric Sciences and Climate. Advancing the Science of Climate Change. Washington DC: National Research Council, 2010, or CRS Report RL33849, *Climate Change: Science and Policy Implications*, by (name redacted).

Other air pollution, irrigation, the built environment, and depletion of ozone in the stratosphere may be more important for changing temperature and/or precipitation patterns in some locations over the past 30 years but have small overall effect on global average temperature. For short periods, such as a few years, volcanic eruptions and solar cycles may have noticeable influence. Over time scales of hundreds to tens of thousands of years, cycles of the Sun's radiation and the features of the Earth's orbit and wobble have dominated, triggering effects amplified by feedbacks in the climate system and visible in glacial cycles.

Regardless of causes, climate changes have potentially large economic and ecological consequences, both positive and negative, which depend on the rapidity, size, and predictability of change. Some of the impacts of past change are evident in shifting agricultural productivity, forest insect infestations and fires, shifts in water supply, record-breaking summer high temperatures, and coastal erosion and inundation.[2] People and natural systems respond to climate changes regardless of whether the government responds. Over time, the consequences of climate change for the United States and the globe will be influenced by choices made or left to others by the U.S. Congress.

**Sound Science Does Not Offer Proof**

As scientists may point out, "there is no such thing as a scientific proof. Proofs exist only in mathematics and logic, not in science…. The primary criterion and standard of evaluation of scientific theory is evidence, not proof.... The currently accepted theory of a phenomenon is simply the best explanation for it *among all available alternatives*."[3] Normal scientific methods aim at disproving a hypothesis; if evidence cannot disprove a hypothesis, it generally buttresses confidence in that hypothesis. The more a hypothesis has been challenged and remains standing in the face of growing evidence, the greater the scientific confidence in it.

For policy-makers seeking certainty about whether climate change is occurring and how "bad" it may be, understanding that science will not provide them now or later with "proof" may be an important concept. Decisions to act or not to act will be made in the context of accumulated and debated evidence of risks and uncertainties.

Congress has engaged, over the past three decades, in authorizing and funding federal programs to improve understanding of climate changes (past and predicted) and their implications. Science programs predominated prior to 1990. In 1992, the Senate gave its advice and consent to U.S. ratification of the United Nations Framework Convention on Climate Change (UNFCCC),[4] effectively agreeing to its objective:

> ... to achieve ... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

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[2] See, for example, Karl, Thomas R., and Thomas C. Peterson. *Global Climate Change Impacts in the United States*. Cambridge University Press, 2009.

[3] See, for example, the discussion in Kanazawa, Satoshi. "Common misconceptions about science I: 'Scientific proof.'" *Psychology Today*, November 16, 2008. http://www.psychologytoday.com/blog/the-scientific-fundamentalist/200811/common-misconceptions-about-science-i-scientific-proof.

[4] 138 CONG. REC. 33521-27 (Oct. 7, 1992).

This commitment is legally binding, though not practicably enforceable, and has guided some subsequent federal actions, including the first U.S. climate action plan in 1992, published under President George H. W. Bush.[5] Since the 1990s, some federal programs and many legislative proposals have sought to slow greenhouse gas (GHG)-induced climate change through regulatory, voluntary, and financial efforts to abate emissions. Many such proposals remain controversial and few have been enacted. In 2007, the Supreme Court ruled in *Massachusetts v. EPA* that the Clean Air Act's (CAA's) "sweeping" definition of "air pollutant" embraces "any air pollutant ... including any physical, chemical ... substance or matter which is emitted into or otherwise enters the ambient air."[6] Also, the Court ruled that EPA could not use policy considerations in deciding whether to regulate GHG emissions; EPA can avoid taking further action "only if it determines that greenhouse gases do not contribute to climate change or if it provides some reasonable explanation as to why it cannot or will not exercise its discretion." Following this decision, EPA found that GHG-induced climate change endangers human health and welfare and has acted to promulgate regulations to control six GHG.[7]

Most experts, and also the Obama Administration, would prefer new legislation strategically addressing GHG abatement, rather than authorities under the CAA, as a policy vehicle to address climate change. The 111th Congress debated bills that would have established comprehensive climate change policy, and that would have included new regulatory authority to cap emissions of GHG and to allow emissions sources the flexibility to trade the emissions allowances like a commodity ("cap-and-trade"). Debate in the 112th Congress has focused more on restricting authorities of the EPA to control GHG as pollutants under the CAA, or to reduce or eliminate funding for climate change-related federal programs.

New federal programs (especially in the Department of the Interior) aimed at planning for adaptation to climate change, regardless of its cause, have emerged in the 2000s. Many agencies and some in Congress consider projections of impacts and preparation to be among the stewardship responsibilities of the federal government for publicly held resources that may be affected by climate change, as well as for protecting human health and general welfare. Some of those in Congress who consider such programs to be warranted may not, however, fully support Administrative proposals for funding, in light of budget pressures or concerns about strategies or program design.[8]

Underlying efforts explicitly to address climate change are other programs enacted for other purposes that influence U.S. contributions and vulnerabilities to climate change. For example, regulations and financial incentives for agriculture, energy, and infrastructure shape these sectors' emissions of GHG, technological opportunities, and vulnerabilities in the face of changing seasonality, water availability and temperatures, inundation of flood plains, winds, and other climate-linked phenomena.

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[5] Council on Environmental Quality (CEQ). "U.S. National Action Plan for Global Climate Change." Department of State Publication 10026, December 1992.

[6] See CRS Report R40506, *Cars, Trucks, and Climate: EPA Regulation of Greenhouse Gases from Mobile Sources*, by (name redacted) and (name redacted), and CRS Report RS22665, *The Supreme Court's Climate Change Decision: Massachusetts v. EPA*, by (name redacted).

[7] See http://www.epa.gov/climatechange/endangerment.html.

[8] See, for example, H.Rept. 112-151 on H.R. 2584 RH (7/22/11), the appropriations bill for Interior and related agencies, in language concerning appropriations for the Fish and Wildlife Service, p. 25.

Ongoing public concerns[9] and international pressures for U.S. collaboration to mitigate and adapt to climate change are likely to keep climate change on Congress's legislative agenda for the foreseeable future. To support congressional considerations, this report outlines (1) conceptual approaches to setting goals for policies, and (2) brief descriptions of the principal "policy tools" that could be wielded to achieve policy goals.[10]

# Conceptual Policy Approaches

Neither domestically nor internationally have policy-makers converged on a common approach to setting goals or managing climate change-related risks. Some do not consider that there are sufficient risks of climate change to merit governmental intervention. For policy-makers who may wish to consider addressing climate change, this section articulates four competing strategies for setting climate change policies: (1) research and wait-and-see, (2) science-based goal setting, (3) economics-based policies, and (4) incrementalism[11] or adaptive management.

## Research and "Wait-and-See"

For several decades, policy-makers have been aware of the large range of projections of GHG-induced climate change and adverse impacts, as well as of the potentially large costs associated with avoiding GHG-induced climate change. In the face of these uncertainties, arguably the primary strategy followed by the U.S. federal government has been to support research and to "wait-and-see." Proponents assume that scientific research will yield more certainty about climate change[12] that would help make better policy decisions, and yield answers in a timeframe consistent with making effective policy decisions. They may also assume that investment in technology research will reduce GHG abatement costs, making it cheaper to reduce emissions later. Following this approach, the U.S. government has invested many billions of dollars in climate research and "clean" technologies over the past two decades, with a small fraction allocated to policies that directly mitigate the risks or promote adaptation to them.[13]

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[9] As examples of public opinion and activism, see at Gallup, "In U.S., Concerns about Global Warming Stable at Lower Levels," at http://www.gallup.com/poll/146606/concerns-global-warming-stable-lower-levels.aspx; Hubbard, Howard J., and Ken Hackett. "Letter to Representatives Harold Rogers and Norm Dicks and the House Appropriations Committee." Committee on International Justice and Peace, and Catholic Relief Services, July 29, 2011; and U.S. Chamber of Commerce. "U.S. Chamber Policy Priorities for 2011, Energy and the Environment," 2011.

[10] Most congressional focus has been on policies regarding GHG emissions, and this report gives most emphasis to corresponding policy options. This emphasis is not intended to suggest relative priorities between GHG mitigation and adaptation to climate change.

[11] Incrementalism is sometimes known as "muddling through," characterized in Lindblom's 1959 "The Science of 'Muddling Through'" Lindblom, Charles E. "The Science of 'Muddling Through.'" *Public Administration Review* 19, no. 2 (April 1, 1959): 79-88). The term is not meant to be derogatory, though it may be used as such by some people.

[12] See, for example, "The Climate Change Research Initiative" at http://www.climatescience.gov/about/ccri.htm. It says, "On June 11, 2001, the President announced that his administration would 'establish the U.S. Climate Change Research Initiative to study areas of uncertainty [about global climate change science] and identify priority areas where investments can make a difference.'"

[13] CRS Report RL33817, *Climate Change: Federal Program Funding and Tax Incentives*, by (name redacted).

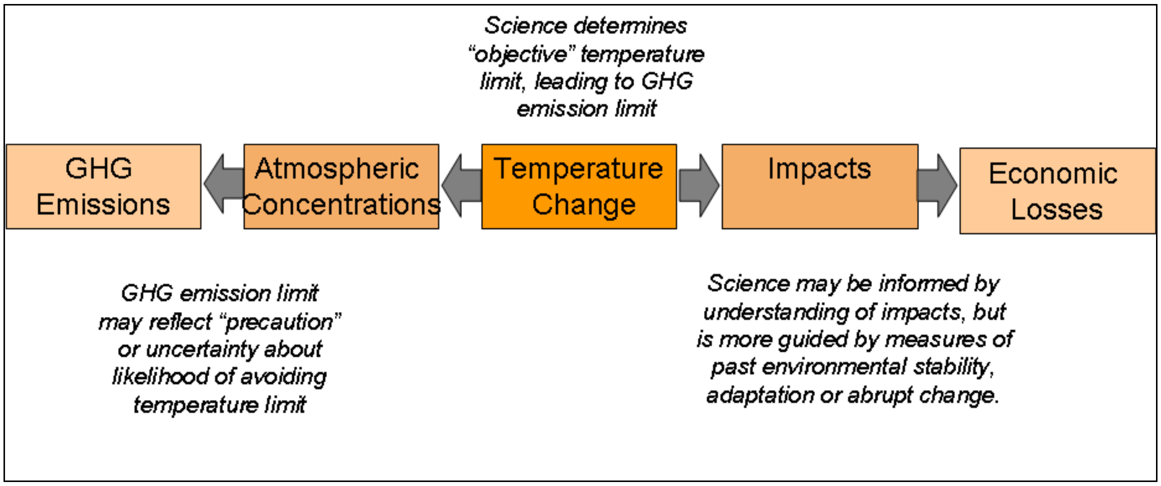
Some scientists and advocates for emissions abatement action have welcomed the resources for research, but also expressed the likelihood that research may well widen, not narrow, uncertainties. No matter how much is invested in research, critical uncertainties are likely to remain. Some people have argued that research cannot provide "right" policy answers and that this strategy constitutes avoidance of difficult decisions. In contrast, others have pointed to analysis that wrong actions taken in the context of uncertainties may result in unnecessary costs. Some have suggested that economic conditions in the future may make addressing climate change more affordable than the present: increasing incomes and improving technologies could make it easier for future generations to pay to address climate change than for people today.

Research has made significant scientific progress over the past three decades. Still, it may be easier to argue that uncertainties may now be better characterized but not narrowed; some may have widened. It is unclear that further research within the next decade or two will significantly narrow crucial uncertainties, such as prediction of precipitation patterns over the next 50 years (needed to estimate climate change risks, such as impacts on costs of agricultural production or flood control, as examples). If over that period GHG emissions continue to rise, future GHG policies would need to make greater and more rapid reductions in order to avoid any particular level of risk reduction. Federally supported research also has made new technologies available and reduced the costs of others. The lowering of technology costs during that period may or may not offset the added costs of starting later, with greater, more rapid GHG reductions to achieve a given level of risk reduction.

## Science-Based Goals

Some advocates propose a science-centric approach, looking to physical or biological criteria to identify appropriate policy goals. This assumes that science alone can provide an objective standard of a "safe" or "tolerable" level or rate for climate change, or at least an inflection point beyond which the projected damages of climate change may rise more steeply. Proponents of this approach may look to past rates of temperature change, past (i.e., pre-industrial) atmospheric concentrations of GHG, or indicators of ecosystem adaptability, for identifying the policy goal. Typically, the science-based approach draws on the estimated relationships between GHG emissions, GHG atmospheric concentrations, global average temperature changes, and projected impacts of climate change for identifying equivalent targets across these different parameters (**Figure 2** and **Table 1**).

**Figure 2. A Science-Centric Approach to Policy**




**Source:** CRS.

**Note:** This is a simple model of a far more complex process.

**Table 1** summarizes estimates of the amount that climate would change (Column 3, measured as the increase in the global mean temperature above the preindustrial levels) if GHG concentrations in the atmosphere were to rise to different levels (Column 1) and then stabilize there. $CO_2$ concentrations in 2011 are about 392 parts per million (ppm). GHG levels (Column 2, converted to $CO_2$-equivalents and added) are about 450 ppm. Today's concentrations (Columns 1 and 2) are comparable to the first level, but are projected to continue to rise indefinitely unless strong policy inducements reduce emissions eventually to net zero.[14] The estimates indicate that

- higher GHG concentrations would be associated with higher projected temperature increases;
- allowing GHG concentrations to rise higher would allow later abatement action—a delay in the years by which emissions would have to peak and then decline in order to stabilize concentrations at a given level;
- allowing higher GHG concentrations would allow high GHG emissions compared to emissions in the year 2000.

[14] In other words, emissions could rise as long as removals from the atmosphere increase to compensate, making emissions minus removals net out to zero.

**Table 1. GHG Emissions Levels for Different Levels of Stabilization of Atmospheric Concentrations and the Associated Equilibrium Global Mean Temperature Increases**

(using one "best estimate" of "climate sensitivities," not a range )

| CO2 concentration (ppm)[a] | CO2-equivalent concentration (ppm) | Global mean temperature increase above pre-industrial[b] (degrees **C**) | Global mean temperature increase above pre-industrial[b] (degrees **F**) | Peak Year of $CO_2$ emissions[c] | Change in global $CO_2$ emissions in 2050 (as % of 2000 emissions)[d] |
|---|---|---|---|---|---|
| 350-400 | 445-490 | 2.0-2.4 | 3.6-4.3 | 2000-2015 | -85 to -50 |
| 400-440 | 490-535 | 2.4-2.8 | 4.3-5.0 | 2000-2020 | -60 to -30 |
| 440-485 | 535-590 | 2.8-3.2 | 5.0-5.8 | 2010-2030 | -30 to +5 |
| 485-570 | 590-710 | 3.2-4.0 | 5.8-7.2 | 2020-2060 | +10 to +60 |
| 570-660 | 710-855 | 4.0-4.9 | 7.2-8.8 | 2050-2080 | +25 to +85 |
| 660-790 | 855-1130 | 4.9-6.1 | 8.8-11.0 | 2060-2090 | +90 to +140 |

**Source:** IPCC, Working Group 1 Report, Table SPM.5: "Characteristics of post-TAR stabilization scenarios."

**Notes:** The IPCC notes that, due to expected positive feedbacks in the climate system, stimulated by initial temperature increases, the emission reductions to meet a given stabilization target may be under-estimated. CO2 concentrations in 2010 reached about 390 ppm.

a. ppm means parts per million of volume.

b. Assuming a "best estimate" climate sensitivity of 3°C. In other words, these estimates use a relationship that a doubling of $CO_2$ concentrations would result in a long-term equilibrium increase of 3°C (5.4°F) of global mean temperature above pre-industrial temperature. The climate sensitivity is usually derived from the output of different climate models, as a means of comparison, not as an assumed input to the models. (Some simple models use this parameter as an input, in order quickly to replicate the results of the very complex climate models used for the IPCC scientific assessments, which can take months for one simulation.) Using the range of estimated climate sensitivities of 2° to 4.5° would yield a much wider range of emissions, concentrations, and temperature increases. Some climate "skeptics" argue that the climate sensitivity is more like 1°C, due to stronger negative feedbacks than in climate model processes. Also, the timeframe in which a projected temperature increase would occur varies. Generally, the lowest $CO_2$ concentrations may occur within a few years and the resulting temperature increase within a few decades, while the higher $CO_2$ concentrations and temperature increases would likely take decades to occur.

c. The "peak year" for $CO_2$ emissions is from models that try to estimate a "least cost" pathway for reducing GHG emissions to achieve a given long-term target (i.e., for the year 2050). These modeled pathways are based on input assumptions of how quickly economies may grow, amounts and types of fuel use, efficiencies of technologies, etc. The assumption is that later peaking would raise costs of achieving a target, if the target remains achievable.

d. Ranges correspond to the 15th and 85th percentiles of the distribution of scenarios.

Based on the kinds of estimates in **Table 1**, recent policy debates have included the following proposals for science-centric policy targets:

- preventing increases of global temperature that exceed 1.5°C or 2°C above 1990 levels;
- stabilizing atmospheric GHG concentrations at or below 350, 450, or 550 ppm (with current $CO_2$ concentrations at about 392 ppm);
- setting maximum GHG emission levels or "caps" (typically with an implicit concentration or temperature target) that would be progressively reduced, such as a cap by 2020 on the GHG emissions of industrialized countries at 30% below

their 1990 levels, or a global GHG emissions cap at 50% below 1990 levels by 2005; or

- setting years by which the emissions or some or all countries would peak and then decline.

A science-centric approach is embedded in the international negotiating framework. Countries agreed in the United Nations Framework Convention on Climate Change to an objective of avoiding “dangerous” climate change, often characterized as avoiding a particular temperature increase (first bullet above); negotiations have tended to focus on reducing emissions to levels compatible with achieving that objective of avoiding “dangerous” change. The U.S. congressional debate on climate change strategy has focused most strongly on percentage-reduction targets for GHG emissions and on which policy tools to use rather than debating what science-based policy goals might be.[15]

There are many challenges to using primarily science to set climate change policy targets. First, differing degrees of *confidence* in scientific findings affects different peoples’ willingness to take actions. Arguably, much of the U.S. public debate has been about whether to have confidence in the consensus[16] of climate change scientists.

Second, policy targets are easiest to communicate with simple metrics, but simple metrics may not clearly reflect the many complex dimensions of climate science. For example, although global average temperature is a common proxy for climate change (“global warming”), many risks may be more closely tied to other dimensions, such as changes in local temperature extremes, time of last frost, maximum spring river flow, storm severity, or sea levels. Other impacts may depend strongly on the changing character of precipitation, which may increase or decrease at different locations and times, more than on temperature change. Metrics alternative to global average temperature change are more difficult to characterize as policy targets, and averages may not correlate with adverse impacts.

Third, scientists, economists, and other experts differ in their views of which climate changes and impacts are important for setting policy. For example, should decisions emphasize what is happening (or not happening) now, or give weight to the distant impacts over many centuries of possible melting of most of Antarctica? Or, is it practical to consider that the Earth’s biomes[17] may shift and reorganize substantially over coming decades, when the full impacts of such changes may be impossible to predict? Some people may not weigh impacts occurring outside their state or country as heavily as those at home. Some may give more weight to impacts on humans than on other species or landscapes. Science does not offer tools for handling such policy considerations.

[15] Occasionally, alternative policy formulations have surfaced in domestic and international proposals, such as technology performance standards or levying equivalent carbon fees across countries, though support for these generally has been low.

[16] According to several dictionaries, “consensus” may mean “general agreement” or “judgment arrived at by most of those concerned,” or may mean unanimity. (*Merriam-Webster Dictionary*, online. 2011.)

[17] “Biomes” are the scientific classification of the Earth’s major ecological communities, “classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment” according to Campbell, N.A. 1996. Biology, 4th Edition. The Benjamin/Cummings Publishing Company, Inc., Menlo Park, California.

Fourth, policy-makers and stakeholders have very different preferences for accepting different risks and their willingness to accept risks.[18] As a 2011 National Research Council report states:

> It should be emphasized that choosing among different targets is a policy issue rather than a strictly scientific one, because such choices involve questions of values, e.g., regarding how much risk to people or to nature might be considered too much.[19]

Sometimes, scientific guidance for limits is available if there are thresholds above which adverse effects begin to occur or the rate of increase of adverse effects becomes more rapid or irreversible. These are called "critical thresholds" or "tipping points." Scientists have been examining a host of potential critical thresholds in the climate system: they exist in many ecological systems and could be catastrophic for some populations or systems, or possibly on a global scale (e.g., if the Amazon rainforest were to collapse and shift to a deciduous forest or savannah system). The effects of $CO_2$ emissions on ocean acidification, though not "climate change," may present thresholds with greater scientific certainty for setting policies than $CO_2$ effects on temperature. (See text box.[20])

**Ocean Acidification as a Possible Scientific Guide for $CO_2$ Limits**

The chemistry of the oceans is also being modified by GHG emissions. The oceans absorb 25%-40% of the carbon dioxide ($CO_2$) emitted annually. This helps remove $CO_2$ from the atmosphere, but has led to an increase of the oceans' acidity by about 30% over the past 150 years. This unprecedented trend, if it continues, could lead to profound biological and physical impacts—with implications for human dependence on the oceans for food and livelihoods. The U.S. Congress has not addressed $CO_2$ emissions abatement specifically to avoid ocean acidification, though the relationship between emissions and acidification is clear and the risks potentially easier to quantify than climate change.

For some, appropriate GHG emissions limits may be tied to assessment of technological feasibility (and technology costs). While technologies exist today to begin a trajectory of major GHG reductions, targets that would stabilize GHG concentrations would require development and deployment of new technologies over the longer term. Some congressional proposals have aimed at promoting new technology development and market penetration, though not with a stated quantitative objective.

An emissions-denoted policy target[21] may be easier than concentrations or temperature targets, given the range of climate changes that could occur with a given increase in GHG emissions. Also, the United States could not unilaterally achieve a federally set concentration or temperature target; it would require a global effort. Further, only emission limits are viewed as a practical basis for allocating responsibilities to the sources of emissions (i.e., private businesses), and for enforcing those limits.

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

[19] Board on Atmospheric Sciences and Climate. *Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia*. Washington DC: National Research Council, 2011. http://www.nap.edu/catalog.php?record_id=12877.

[20] See also CRS Report R40143, *Ocean Acidification*, by (name redacted) and (name redacted), or Kerr, Richard A. "The Many Dangers of Greenhouse Acid." *Science* 323, no. 5913 (January 23, 2009): 459a.

[21] For example, a target of a percentage reduction of emissions by some date relative to the level of another date.

## Economics-Based Approaches

While many scientists, environmentalists, and other stakeholders may advocate scientifically determined policy goals, other stakeholders frequently advocate that policies should be designed to maximize economic efficiency (or to maximize economic growth measured as Gross Domestic Product, GDP).

There are several economic approaches that could help define climate change policy, including cost-effectiveness analysis, cost-benefit analysis, or hedging.[22] This section focuses on a cost-benefit approach, which seeks to maximize the economic efficiency of policy.

### *Cost-Benefit Approach*

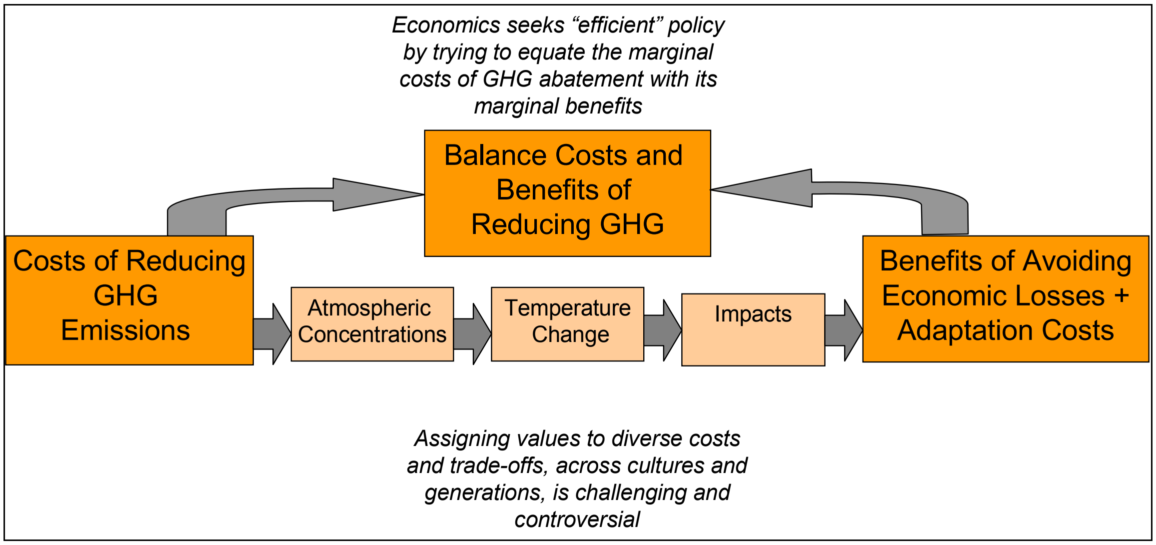
Intuitively, many people only take actions when they perceive that the benefits of the action exceed its costs, though the important benefits and costs may be qualitative, not monetary.[23] For decisions of public policy, many economists and business stakeholders advocate that formal assessment of the costs and benefits of a proposed policy (or policy alternatives) should be performed and that the only options selected should be those wherein the benefits exceed the costs. This preference is predicated on the principle that policies should seek to be *efficient,* making best use of private and public resources available. Indeed, in 1981, President Ronald Reagan issued Executive Order 12291 (46 FR 13193 3 CFR, 1981).[24] E.O. 12291 requires that regulatory objectives seek to the maximize net benefits to society, although some legislative authorities direct other considerations to be paramount (e.g., protecting the most vulnerable populations).

[22] There are additional economic decision frameworks that may be useful for climate change questions, including Value at Risk, which aims to maximize income subject to explicit limits on tolerable risks of the decision agent. Though VaR and others are not discussed in this paper, they may merit further development, especially as tools for managing risks in the context of persistent uncertainties.

[23] For example, a consumer may purchase an automobile that costs more and has higher fuel efficiency than others, though the "payback" may seem long compared to other market opportunities. The consumer may be responding to such perceived benefits as contributing to oil independence, reducing air pollution, trying the latest technology, or other factors that typically are not quantified.

[24] http://www.archives.gov/federal-register/codification/executive-order/12291.html.

**Figure 3. An Economics-Centric Approach to Policy**




**Source:** CRS.

**Note:** This is a simplified depiction of a complex approach, and many variations exist.

There are limitations of formal cost-benefit analysis (CBA), however, and particularly as applied to climate change policy-making. First is the consideration that CBA addresses efficiency, but typically not other policy considerations, such as "fairness" (although some economists are testing methods to address some equity issues). Additionally, problems to applying CBA to climate change have been established by a variety of researchers:[25]

1. Climate change decisions will be made (or not made) by many disparate people and organizations, public and private, in the context of multiple goals, constraints, and secondary effects; the sum of their decisions (and their costs and benefits) would necessarily differ from the options and valuations considered in a cost-benefit analysis.
2. Estimates of costs and of benefits may be unreliable. Several studies following completion of projects or after implementation of policy decisions have shown that prospective estimates may be very inaccurate.[26] Decisions based on inaccurate estimates may be inefficient. Some researchers have found that

[25] See, among other critiques: Morgan, M. Granger, Milind Kandlikar, James Risbey, and Hadi Dowlatabadi. "Why Conventional Tools for Policy Analysis Are Often Inadequate for Problems of Global Change." *Climatic Change* 41, no. 3 (March 1, 1999): 271-281-281; or Adler, Matthew D., and Eric A. Posner. "Rethinking Cost-Benefit Analysis." *The Yale Law Journal* 109, no. 2 (November 1, 1999): 165-247. One ongoing debate among analysts is whether CBA is neutral or whether it has an anti-regulation bias. A useful distinction may be made between criticisms of problems inherent to CBA versus those in the methods and ways CBA has been applied.

[26] Harrington, W., R. D Morgenstern, and P. Nelson. "On the accuracy of regulatory cost estimates." *Journal of Policy Analysis and Management* 19, no. 2 (2000): 297–322; Sherrington, Chris, and Dominic Moran. "The accuracy of regulatory cost estimates: a study of the London congestion charging scheme." European Environment 17, no. 2 (March 1, 2007): 106-123; Flyvbjerg, Bent, Mette Skamris Holm, and Soren Buhl. "Underestimating Costs in Public Works Projects: Error or Lie?" (n.d.). http://flyvbjerg.plan.aau.dk/JAPAASPUBLISHED.pdf; or Thompson, Kimberly M, Maria Segui□Gomez, and John D Graham. "Validating Benefit and Cost Estimates: The Case of Airbag Regulation." *Risk Analysis* 22, no. 4 (August 1, 2002): 803-811. As a general matter, there are few analyses of the accuracy of ex ante economic analyses of regulations or other public decisions.

retrospective evaluations of actual costs or benefits may reveal them to be very different, at least in some cases, than pre-decision projections.

3. CBA methods assume that a policy decision is "marginal," that it can be made in clearly ordered increments from some baseline level, and that the choice can be isolated from significant changes in the structure and output of the entire economy.[27] However, some analysts contend that human-induced climate change is a "non-marginal" problem: decisions to address it or not would alter the structure, the path of growth, and even the existence of some economies.[28] At least one study has shown that applying marginal analysis to non-marginal policy questions can produce both quantitatively and qualitatively "wrong" decisions.[29]
4. The outcomes of CBA for choices having long-term effects can be strongly determined by the choice of "discount rates" to reflect the "time value of money"—that is, the observation that people typically would prefer to get a given amount of money today rather than a year from now. Respected economists disagree over what the appropriate discount rate should be for climate change decisions, and even whether discounting should be used at all when choices affect unborn generations. This discounting controversy remains unresolved despite decades of discourse.[30]
5. CBA, at least as practiced, typically uses single point estimates whereas many values important in climate change analysis are uncertain—sometimes widely uncertain. Few, if any, researchers have conducted analyses in ways that adequately reflect the distributions of uncertainties and the interactions of uncertain variables in their analyses.
6. Moreover, the "average" values used frequently assume that people are neutral to risks (they equally weight higher versus lower risks), while empirical data indicate that most people seem to be "risk averse"[31] (i.e., they would make lower-

[27] Three ways in which the choice of the United States to abate GHG emissions may considered non- marginal are that (1) U.S. choices are not independent of the choices that other countries may make; and (2) the underlying reference baseline is projected to shift in unpredictable ways depending on the policy choices of the United States and other countries/emitters, and (3) the changes affected by climate change policy decisions could be very large, so that prices (set by markets at the margin of supply and demand) may not be a good representation of non-marginal values. For example, if a shift of more than a couple percent from the baselines were to occur in incomes or consumption (e.g., the existence of biodiversity), then the values derived used in the baseline conditions would no longer be valid to use with the changed baseline. To make this example more specific, the value estimated for the willingness to pay of people to save, say, one species given current biodiversity, might be very different from the value per species that same person might have if the choice were to save 3000 species. While improved physical and economic models could help address this analytical problem, with non-marginal changes there would be only weak empirical evidence to support the valuations used in the models.

[28] See, for example, Prest, A. R., and R. Turvey. "Cost-Benefit Analysis: A Survey." The Economic Journal 75, no. 300 (December 1, 1965): 683-735, or more recently, Dietz, Simon, and Cameron Hepburn. "On non-marginal cost-benefit analysis." Centre for Climate Change Economics and Policy, 2010. http://74.125.127.132/scholar?q=cache:7nOfPnry1B4J:scholar.google.com/&hl=en&as_sdt=0,9.

[29] Dietz, Simon, op. cit.

[30] See, for example, Oates, Wallace E. *The RFF Reader in Environmental and Resource Policy*. Washington DC: Resources for the Future, 2006.

[31] Tom, Sabrina M., Craig R. Fox, Christopher Trepel, and Russell A. Poldrack. "The Neural Basis of Loss Aversion in Decision-Making Under Risk." Science 315, no. 5811 (January 26, 2007): 515-518. Interestingly, recent research indicates that many people will accept higher risk to avoid ambiguity. Rustichini, Aldo. "Emotion and Reason in Making Decisions." *Science* 310, no. 5754 (December 9, 2005): 1624 -1625. Neutral economic assumptions do not (continued...)

risk choices even in instances where their expected payoffs on average would be greater with the higher-risk choice). Arguably, differences among people in their aversions to particular *kinds* of risks in climate change policy choices—whether more attuned to risks of energy cost increases or to employment, or whether more to health and ecological stability—make it more difficult to build consensus on policy.

7. Some critics suggest that CBA does not support an appropriate decision rule. CBA assumes a "Kaldor-Hicks" rule—that the optimal public decision should make everyone *in aggregate* better off, even if those who are made worse off are not compensated by those made better off. Some economists have pointed out theoretical problems in applying the Kaldor-Hicks rule, for example, that it can result in inconsistent decisions. In addition, one economist notes that "social decision-making necessarily is about weighing up gains and losses and deciding on the relative importance of different individuals' gains and losses." CBA typically does not assist in making those trade-offs. Proponents point out that CBA provides one type of information—not that it is the only and exclusive criterion for public policy decisions.

Economic analyses would be, at best, incomplete and likely biased because of the current state of information and methods. Many values that should be included in a rigorous CBA are unknown, and even unimagined at this stage of understanding. The direction of bias most often is posited to undercount benefits of mitigation policies, though there are reasons that omissions could overstate climate damages as well (e.g., by missing low-cost adaptations that people might make). Despite these challenges, formal CBA arguably provides one of the most complete *frameworks* for organizing and presenting a vast array of incommensurate impacts for decision-makers. However, CBA is unlikely in the near term to yield a simple or objective "answer" on optimal policy for decision-makers.

## Hedging or Insurance Policies

An alternative economic approach is "hedging" or insurance, by adopting policies that would reduce the risks of losses, without certainty of what those risks are.[32] This approach can be similar to buying homeowners' insurance even though the likelihood of fire or other losses is unknown. In this approach, policy-makers might enact some low-cost measures or measures that serve other policy goals. (Sometimes these are called "no regrets" measures.) If long-term restructuring of the energy economy might be needed in the future, hedging policies might initiate measures in that direction (such as research support for some new technologies) while further information on risks evolves. Hedging as a strategy does not provide objective guidance on the "right" level or kinds of measures. In some senses, "clean energy" development may be a primary hedging strategy, proposed by some Members of Congress.

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reflect these kinds of preferences against risk and uncertainty.

[32] See, for example, Yohe, Gary, Natasha Andronova, and Michael Schlesinger. "To Hedge or Not Against an Uncertain Climate Future?" *Science* 306, no. 5695 (October 15, 2004): 416 -417.

### Cost-Effectiveness and Other Concepts

Economics offers additional approaches, such as estimating the most efficient policy design once the objective has been established (cost-effectiveness analysis). In other words, if policy-makers agree on a policy goal, such as a limit on GHG emissions, cost-effectiveness analysis is one means to evaluate alternative policy designs to achieve the goal in the least costly way. Conversely, cost-effectiveness analysis may seek the policy design with greatest effectiveness (e.g., the lowest level of GHG concentration stabilization, or greatest risk reduction comparing GHG mitigation and adaptation to climate) for a given cost.

A broader critique of using economics to recommend policies, and in favor of "muddling through" (next section), questions several of the fundamental assumptions of most current economic analysis:

> [T]here is a change occurring in formal theorizing in which the holy trinity—rationality, greed, and equilibrium—is being abandoned as required aspects of any model, and being replaced with a slightly broader trinity—purposeful behavior, enlightened self interest and sustainability.[33]

In essence, CBA grew from the "economics of control." It assumed that "infinitely bright economists with full knowledge of the system" could optimize the economy. More contemporary examination of the quality of information (frequently poor) and seemingly "irrational" behavior evidenced by peoples' actions has led some economists to "search for understanding a system in which the blueprints are missing, nonexistent, or so far beyond our analytic capabilities that we might as well forget about them."[34]

## Incrementalism,"Muddling Through," and Adaptive Strategies

Political scientist Charles Lindblom argued that neither drastic policy change nor carefully planned giant steps are usually possible in policy-making. Rather, only "small or incremental steps—no more than muddling—is ordinarily possible."[35] He argued that "No person, committee, or research team, even with all the resources of modern electronic computation, can complete the analysis of a complex problem. Too many interacting values are at stake, too many possible alternatives, too many consequences to be traced through an uncertain future—the best we can do is achieve partial analysis."[36] In other words, particularly in cases where decision-makers cannot agree on the objective of policy, the best that policies can achieve is making agreed incremental policy changes with ad hoc adjustments as conditions evolve and agreements arise.

As a variant of "muddling through," some experts advocate an *adaptive* approach to climate change decision-making (both public and private). An adaptive approach entails setting an initial policy, then monitoring and evaluating progress toward the stated goal, and making adjustments

[33] Colander, David. "Muddling Through and Policy Analysis." Keynote Address presented at the New Zealand Economic Association, June 2003. http://sandcat.middlebury.edu/econ/repec/mdl/ancoec/0317.pdf.

[34] Ibid. p. 8.

[35] Lindblom, Charles E. "Still Muddling, Not Yet Through." *Public Administration Review* 39, no. 6 (November 1, 1979): 517-526.

[36] Ibid.

as knowledge is gained and new opportunities become available. Two proponents of adaptive strategies argue:

> [C]limate change presents a problem of decision-making under conditions of deep uncertainty. We begin with the premise that while we know a great deal about the potential threat of climate change and the actions we might take to prevent it, we cannot now, nor are we likely for the foreseeable future [to], answer the most basic questions, such as is climate change a serious problem and how much would it cost to prevent it? We argue that in the face of this uncertainty, we should seek robust strategies. Robust strategies are ones that will work reasonably well no matter what the future holds.... [R]obust strategies for climate change are possible by means of adaptive-decision strategies, that is, strategies that evolve over time in response to observations of changes in the climate and economic systems. Viewing climate policy as an adaptive process provides an important reconfiguration of the climate-change policy problem.[37]

Several concerns about adaptive approaches may be raised. First, while an adaptive approach may achieve overall efficiencies compared to less flexible strategies, the efficiencies come at a cost of lessened certainty for investors that a policy will remain fixed (e.g., for investment on long-lived infrastructure). This can raise the risks of certain investments and add to their costs.

Second, some people conclude that abating climate change would require radical technological change, and perhaps changes in social and economic structures, which cannot be achieved with incremental changes. Experts point to “path dependence” of economic structures and technological evolution, in which initial conditions set a trajectory or “path” that becomes increasingly difficult to modify as investments build on one another. “Muddling through” follows that path dependence, almost by definition. Others propose that successfully addressing climate change requires “transformational change,” a change in state that is not merely an extension of the past.

Also, pursuing adaptive strategies, Lempert and Schlesinger have argued that “the real measure of ... success” should not be near-term GHG reductions, but “rather the new potential for large-scale emissions reductions society has created for the years ahead.”[38] Though this point may be valid, it may be, alternatively, that expanding the potential for emissions reductions requires incentives to shift from a “business-as-usual” path that may not be provided by incrementalism. Transformational change frequently alters power relationships, and may be obstructed by a human tendency to ignore or reject information that does not conform with one’s existing beliefs or prior decisions.[39] This leaves open the question of whether muddling through would serve to maintain the status quo or to serve the “creative destruction” that “incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.”[40]

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[37] Lempert, Robert J., and Michael Schlesinger. “Adaptive Strategies for Climate Change.” In *Innovative Energy Strategies for $CO_2$ Stabilization*, 48-85. Cambridge, UK: Cambridge University Press, 2002.

[38] Ibid.

[39] See, for example, Jonas, Eva, Stefan Schulz-Hardt, Dieter Frey, and Norman Thelen. “Confirmation bias in sequential information search after preliminary decisions: An expansion of dissonance theoretical research on selective exposure to information.” *Journal of Personality and Social Psychology* 80, no. 4 (2001): 557-571.

[40] Joseph Schumpeter, in *Capitalism, Socialism, and Democracy* (1942), as quoted in W. Michael Cox and Richard Alm, “Creative Destruction” *The Concise Encyclopedia of Economics*. The authors interpret:

> Herein lies the paradox of progress. A society cannot reap the rewards of creative destruction

(continued...)

# The Policy Tool Box

Public and political interest in addressing climate change has cycled up and down over the past three decades. Although no comprehensive or cohesive strategy exists at the federal level, many existing programs and measures (including tax incentives)—and uncertainty about what future science and policy will bring—create a context that influences private and governmental decision-making. Some in the public and 112th Congress may seek to eliminate climate change-related programs and policies, while others may seek to modify, reorganize, or enhance them.

A variety of generic policy tools may be in use already or be potentially available to address climate change concerns. This section is intended to introduce the rationales, designs, and applicability of options, to assist Members' deliberations. The order of the following policy tools is not intended to represent any order of priority:

- regulatory, including market-based, tools to reduce GHGs;
- 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 may be in use now. Many of these tools are seen as complementary, and proponents often contend that results can be achieved more efficiently with a carefully matched combination of policy tools than by wielding any one alone.[41]

## Regulatory and Market Tools to Reduce Greenhouse Gases

Most experts believe that the most economically efficient way to reduce GHG emissions is to put a price on emissions that reflects the costs (or risks) of those emissions to others. Putting a price

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> without accepting that some individuals might be worse off, not just in the short term, but perhaps forever. At the same time, attempts to soften the harsher aspects of creative destruction by trying to preserve jobs or protect industries will lead to stagnation and decline, short-circuiting the march of progress. Schumpeter's enduring term reminds us that capitalism's pain and gain are inextricably linked. The process of creating new industries does not go forward without sweeping away the preexisting order.

[41] See, for example, Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. "The Environment and Directed Technical Change." National Bureau of Economic Research Working Paper Series No. 15451 (October 2009). The modeling in this paper indicates that, among alternative policy designs, "optimal" policy results with *both* carbon pricing and research subsidies; or, Goulder, Lawrence H., and Ian W. H. Parry. "Instrument Choice in Environmental Policy." *Review of Environmental Economics and Policy* 2, no. 2 (July 1, 2008): 152 -174. See also, Fischer, Carolyn, and Richard G. Newell. "Environmental and technology policies for climate mitigation." Journal of Environmental Economics and Management 55, no. 2. *Journal of Environmental Economics and Management* (2008): 142-162.

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 often 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." These may be applied for sectors as a whole, or varying with individual source permits. Practice has sometimes successfully included "technology-forcing" regulation, as well, that sets future performance standards well beyond contemporaneously achievable levels.

Many regulatory controls have been effective through decades of experience,[42] though studies contend that the compliance costs might be reduced if strategies give greater priority to cost-effectiveness and flexibility. Even when U.S. 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 compliance for each individual source. Also, regulations can be difficult to adjust as circumstances evolve. 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.

## Market Mechanisms

An approach that utilizes aspects of commodity markets can achieve, in some cases, emission reductions similar to a source-by-source regulatory approach but at lower overall cost.[44] Though none to reduce GHG emissions have been proposed in the 112$^{th}$ Congress, several bills introduced in the 111$^{th}$ Congress proposed such "market mechanisms" because, for some sources, they can increase the efficiency of regulation by allowing the least costly reductions first.

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

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

[42] See, for example, Freeman III, A. Myrick. "Environmental Policy since Earth Day I: What Have We Gained?" *The Journal of Economic Perspectives* 16, no. 1 (January 1, 2002): 125-146.

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

[44] It may be worth exercising caution, however, regarding the actual performance of real programs versus the theoretical gains analyzed by scholars in hypothetical markets. As economist Robert Hahn has pointed out, "a competitive market actually must exist for the results to hold true. Perhaps more importantly, the results assume that it is possible easily monitor and enforce a system of permits or taxes....the capacity to monitor and enforce can dramatically affect the choice of instruments." in Hahn, Robert W. "Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders." *The Journal of Economic Perspectives* 3, no. 2 (April 1, 1989): 95-114.

Both emission fees and cap-and-trade systems potentially generate revenues—potentially in the hundreds of billions of dollars annually.

Another important difference between cap-and-trade and other policy tools is that it can separate *who pays* for emissions reductions from *where the reductions occur*, as discussed below. This can allow the program design to accomplish both efficiency and equity objectives simultaneously.

### *GHG Fees or "Carbon Taxes"*

Fees could 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 takes action 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 (such as availability of accurate information on response options), and it would not guarantee an overall level of effectiveness for the program.

In the context of possible, broader tax reform in the 112th Congress, some experts might argue in favor of shifting existing taxes from "goods" to "bads"[45] like pollution, since taxes raise prices and tend to decrease demand for the taxed product or service. A number of studies have examined the implications of replacing existing taxes by GHG taxes: though not conclusive, several studies suggest that such a tax shift, depending on its structure, could have positive or negative impacts on economic growth and/or employment.[46] (The actual results would depend on the particular size and structure of a tax shift.) One concern about pollution taxes is that they would tend to be regressive; another is that to the degree that carbon fees are effective in reducing the emissions, they also reduce the revenue base.

### *"Cap and Trade"*

One type of market mechanism begins with regulations on emission sources to reduce their emissions, but then may allow flexibility in *who* makes the emission reduction, *when* the reductions are made, and/or *where* the emission reductions occur (outside of the regulated sources, or even internationally).

In a cap-and-trade program, the regulator sets an overall *cap* on emissions. It must allocate responsibility for achieving the cap to individual sources, frequently termed "allowances" to emit. These may be allocated by giving away allowances and/or selling them at prices at fixed rates or

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[45] Taxes on goods or services that have adverse effects on people beyond the buyers and sellers ("negative externalities") are called Pigouvian taxes. This economic approach is a basis for taxes on, among other items, sales of tobacco products.

[46] See, for example, Aldy, Joseph E., Eduardo Ley, and Ian W. H. Parry. "A Tax-Based Approach to Slowing Global Climate Change." SSRN eLibrary (July 15, 2008) pp. 9-10; or, Nordhaus, William D. "To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming." *Review of Environmental Economics and Policy* 1, no. 1 (January 1, 2007): 26-44.

set by auctions (discussed in a later section). The allocation mechanism essentially establishes who pays or potentially benefits from the cap-and-trade system.

In a cap-and-trade program, the *trade* component allows entities to sell their unneeded emission "allowances," while emission sources that emit more than their allocation of allowances may comply by reducing their emissions and/or buying additional allowances.[47] Emissions trading establishes a market, creating incentives to reduce emissions below required levels in order to sell the extra allowances to sources who may have higher costs of control. "Cap-and-trade is *the* free market based approach to complex multilateral problems like climate change," say proponents.[48]

Cap-and-trade programs allow flexibility in *who* makes the required emission reductions. While the allocation of allowances determines who pays to reduce emissions, trading allows the regulated sources to pay for reductions elsewhere at lower cost. Thus, cap-and-trade can address both efficiency and equity considerations.

Within cap-and-trade systems are two additional types of flexibility:

- Emission reduction 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 GHGs could be reduced reliably at lower cost in other countries, could help reduce costs of complying with any 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,[49] 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. The first decision is what the emissions limit or performance standards may be across categories of GHG sources. Certain types of sources, by sector or size, may be excluded from GHG reduction

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

[48] Spencer Banzhaf "The Case for Cap-and-Trade" PERC in *The Touch Questions for Free Market Environmentalism*, Reports for Free Market Environmentalism Vol. 29: 2 (Summer 2011).

[49] Ibid.

requirements, such as in EPA's "tailoring rule," which proposes not to require GHG permits for sources that emit less than 25,000 tons of CO2 annually.[50] Frequently, this step is among the most controversial in establishing control policy. (Alternatively, the policy-makers may not set a particular limit or standard, but require all regulated sources to buy emissions permits.) Typically, at the end of a compliance period (e.g., a year), a source must turn in to the regulating authority a number of allowances at least equal to the tons emitted in that period.

The second decision is how emissions sources will get their emission allowances. The regulator may give away or sell permits to cover all or some of each source's emissions. In many systems, these permits are called "allowances" and one allowance equals a permit to emit one ton of a pollutant. In a cap-and-trade system, allowances can be

- given away (e.g., "grandfathered" to existing GHG sources, or given to non-source entities[51]),
- 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 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 past 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 GHGs turns out to be more difficult 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

[50] See EPA, Fact Sheet—Proposed Rule: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, at http://www.epa.gov/NSR/fs20090930action.html.

[51] In other words, emission allowances can be given to entities that are not sources of emissions. Recipients may hold, sell, or retire these allowances.

regulatory authority could release additional allowances into the market through an auction, or sell them 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' caps). It also would reduce incentives for technological innovation by limiting the price rise that could occur, limiting the profit potential that could stimulate some investors to finance technological research. Some researchers note that the positive potential effects on technology innovation resulting from price volatility is one reason policy-makers might favor emissions caps over emission fees.[52]

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 sets 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 Emission Fees 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., production-based rebates to energy-intensive sources; 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. Providing public information about climate change risks would likely induce some voluntary action—an approach

[52] Weber, Thomas A., and Karsten Neuhoff. "Carbon markets and technological innovation." Journal of Environmental Economics and Management 60, no. 2 (September 2010): 115-132.

used to promote anticipatory adaptation, for example. Information about government programs, including advanced notice of regulatory requirements, can help decision-makers to make an efficient transition to changing circumstances. Product labeling and "seals of approval" are additional informational tools used privately and by governments to facilitate efficient markets. Accurate information about risks can allow investors to make appropriate decisions.[53] Some private initiatives, such as the Ceres Investor Network on Climate Risks,[54] seek and disseminate information, including through corporate shareholder resolutions, about investment risks and opportunities associated with climate change.

Additionally, technical assistance programs—like several existing federal voluntary programs, such as the Climate Leaders or Energy Star programs[55]—can help consumers and businesses to make economical 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 GHGs, 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. Some programs, however, may result in private savings that far exceed their federal budgetary costs (which are broadly spread across taxpayers). On the other hand, the governmental expenditures per unit of emissions reduction achieved may be much higher than regulatory programs, where more costs are borne by emissions sources.

Perceived investment 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 emission reductions from projected levels would require extraordinary changes in how energy is used and supplied over time. Moreover, the cost to reduce GHG emissions would depend critically on development and deployment of improved technologies. Multiple studies conclude that "markets are unlikely to provide proper incentives for the development of clean technologies, absent public policy."[56] Public policies clearly have led to major technological advances in other fields (e.g., developing nuclear energy, putting humans on the moon, developing advanced weapons). Still, the quantitative link between policy tools and resulting technological advance is unpredictable.

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[53] Konar, Shameek, and Mark A. Cohen. "Information As Regulation: The Effect of Community Right to Know Laws on Toxic Emissions." *Journal of Environmental Economics and Management* 32, no. 1 (January 1997): 109-124.

[54] http://www.ceres.org/investor-network.

[55] 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://www.energystar.gov/.

[56] A review of research is provided in Popp, David, Richard G. Newell, and Adam B. Jaffe. "Energy, the Environment, and Technological Change." National Bureau of Economic Research Working Paper Series No. 14832 (April 2009).

Often, policies to stimulate technological change are described as "demand-pull," or "supply-push." A third type of policy aims to improve market function, to lubricate the interface between buyers and suppliers. Specific measures in these three categories are described below.

**Demand-Pull:** Policy tools can act on the *demand* for new technologies. Some types of policy tools act primarily to stimulate demand for new technologies:

- "Technology-forcing" regulations[57] have effectively stimulated demand for better (and more cost-effective) technologies in the past. "Technology-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."[58] Many economists prefer price incentives to stimulate technological change, because they decentralize decision-making to consumers and suppliers, and are arguably more cost-effective. On the other hand, price incentives may not succeed in inducing transformative or radical change from existing technologies because of the lack of certainty regarding prices over the long period required for developing and commercializing new technologies. At least one study found that, in some circumstances, technology mandates may be more effective than direct financial incentives.[59]
- Renewable or clean energy quotas have been enacted in many states, requiring electricity producers to generate a specified share of power with defined renewable energy or other (i.e., nuclear, hydroelectric) technologies. These kinds of quotas create demand for designated classes of technologies that may not otherwise be commercially preferred by investors (e.g., because of perceived risks or extra costs). The Clean Energy Standard (CES) is an example of demand-side, technology-forcing incentive. This option has been proposed by the Obama Administration,[60] as well as by Senators Jeff Bingaman and Lisa Murkowski.[61] A CES has been enacted in Indiana.[62]
- Tax incentives and consumer rebates 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.

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[57] "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.

[58] 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.

[59] Johnstone, Nick and Ivan Hascic, "Environmental Policy Design and the Fragmentation of Markets for Innovation" unpublished (2008).

[60] Climatewire, Evan Lehmann Of. "Obama to Focus on Clean Energy, Daring Republicans to Call It 'Froufrou.'" The *New York Times*, March 30, 2011, sec. Business Day / Energy & Environment. http://www.nytimes.com/cwire/2011/03/30/30climatewire-obama-to-focus-on-clean-energy-daring-republ-45993.html.

[61] U.S. Senate Committee on Energy and Natural Resources, http://energy.senate.gov/public/index.cfm?FuseAction=IssueItems.View&IssueItem_ID=7b61e406-3e17-4927-b3f4-d909394d46de.

[62] North American Windpower, "Mitch Daniels Signs Clean Energy Standard Bill," http://www.nawindpower.com/naw/e107_plugins/content/content.php?content.7849.

**Supply-Push:** 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 are 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 GHGs than more conventional technologies.
- "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.

**Supply-Demand Interface:** Some policy instruments focus on lubricating the connections between suppliers and users of technologies;[63] sometimes these are called *market facilitation*. They may reduce the "transaction costs" of deploying new technologies in commercial markets. Programs to improve the interface between suppliers and users (e.g., the "Energy Star" programs of the Environmental Protection Agency and the Department of Energy) became a new emphasis since the late 1980s and early 1990s. The Energy Star website claims savings in the utility bills of consumers assisted by the program of nearly $18 billion in 2010.[64]

Such programs may improve the information available on technologies and markets, make it more accessible, give it independent "third party" evaluations, improving technical capacity to choose and install technologies, and many others. More specific examples include trade conferences and missions, internet-based technology databases, publication of research including reviews of applications, "stamps of approval," etc. Most of these measures are employed already in private markets (i.e., marketing by suppliers), especially by larger firms. However, there are niches in markets where government-supported actions may improve the supply-demand interface in markets and speed deployment of new technologies as well as make technology developers

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[63] For example, see Taylor, Margaret R. "Beyond Technology-Push and Demand-Pull: Lessons from California's Solar Policy." SSRN eLibrary (July 31, 2008).

[64] Energy Star, http://www.energystar.gov/index.cfm?c=about.ab_index.

better aware of potential users needs and interests. Experts have noted the ability of supply-demand interface measures to improve market efficiency, as well as their limits in reducing emissions in lieu of stronger incentives.

## Options to Ease the Economic Transition

The U.S. economy currently depends primarily on fossil fuels, especially for electricity generation and transportation. Without factoring in the environmental, energy security, and other "external" costs, the United States has optimized its infrastructure to use the relatively inexpensive fossil fuels. A transition to alternatives or to low-emission technologies, if faster than the natural rate of capital turnover, could incur 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;[65]
- 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 and consumers 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
- 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,[66] 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;

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[65] 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.

[66] The WTO discusses the relationship between the multilateral trading system and climate change at http://www.wto.org/english/tratop_e/envir_e/climate_intro_e.htm.

- in the process of crafting domestic policies, negotiating with potentially affected WTO Members to seek 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; and
- 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

Because GHG emissions from virtually all countries add to global atmospheric concentrations, the effectiveness of policies to address climate change will depend on the collaboration of all major countries, especially the largest emitters. Some of the large emitters, such as the nations of the European Union, already have committed to reducing their GHG emissions below year 1990 levels and have proposed further reductions beyond the Kyoto Protocol's current commitment period that ends in 2012. The United States, China and other large developing country emitters have offered GHG targets, but are not obligated to reduce their GHG, and the position of Russia beyond 2012 remains a question. A country, if it wished to promote global GHG emission reductions, could exercise a number of relevant policy tools, unilaterally or in cooperation (including legal treaties) with other nations:

- 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; and
- 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

Computer modeling suggests that, even if GHG emissions were stopped today, historical emissions would lead to another $1^oC$ ($1.8^oF$) of warming by 2050.[67] Interest has grown in recent years in improving understanding of the potential impacts of climate variability and change, and in stimulating effective adaptation to minimize future losses and take advantage of opportunities. Policy tools to promote efficient adaptation could include, among other options:

[67] This is roughly the same amount of global average warming that has occurred over the past century.

- research to improve characterization of future climate change,[68] natural variability, and the potential implications for different sectors and ecosystems;
- public information, both broad and targeted to specific populations, including access to robust characterization of future climate conditions and associated risks;[69]
- 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.); and
- 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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[68] 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.

[69] The Obama Administration has moved to establish a Climate Service within the National Oceanic and Atmospheric Administration (NOAA), comparable to the National Weather Service but providing access to climate information on longer time horizons—seasonally, inter-annually, or over years to decades. A variety of proposals in the 111th Congress would have established a National Climate Service, with varying authorities, within NOAA or across agencies but none were passed. In the President's budget proposal for FY2012, NOAA has proposed a budget-neutral reorganization to consolidate operations in a Climate Service. At least one appropriations proposal would prohibit any funds for implementation of Climate Services, and other Members have expressed skepticism of the proposal.