



Limiting the Magnitude of Future Climate Change

Meeting internationally discussed targets for limiting atmospheric greenhouse gas concentrations and associated increases in global average temperatures will require a major departure from business as usual in how the world uses and produces energy. This report recommends a U.S. policy goal stated in terms of a budget for cumulative greenhouse gas emissions over the period 2012-2050. With only so much to “spend” during this period, the nation should act now to: (1) take advantage of key near-term opportunities to limit greenhouse gas emissions (e.g., through energy efficiency and low carbon energy sources), and to create new and better emission reduction opportunities for the longer term (e.g., invest in research and development); (2) create a national policy framework within which actors at all levels can work toward a common goal; and (3) develop policy mechanisms durable enough to persist for decades but flexible enough to adapt to new information and understanding.

Climate change, driven by the increasing concentration of greenhouse gases in the atmosphere, poses serious, wide-ranging threats to human societies and natural ecosystems around the world. The largest overall source of greenhouse gas emissions is the burning of fossil fuels. The global atmospheric concentration of CO₂, the dominant greenhouse gas of concern, is increasing by roughly two parts per million per year; and the United States is currently the second-largest contributor to global CO₂ emissions (behind China).

Increasing U.S. emissions are driven by a growing national economy and a growing population. Even with expected improvements in energy efficiency, a business-as-usual pathway means that U.S. emissions will continue increasing. Greenhouse gases are currently emitted without any sort of penalty. With no financial incentives or regulatory pressure, the nation will continue to rely upon and “lock in” carbon-intensive technologies and systems.

This report, part of the *America's Climate Choices* suite of studies requested by Congress, focuses on strategies to contribute to the global effort of limiting future climate change by reducing U.S. greenhouse gas emissions (and



SOURCE: NASA's Earth Observatory

enhancing greenhouse gas “sinks,” such as forests). The report identifies strategies that appear to be feasible now or in the near-term, as well as strategies that may play an important role in the longer-term.

Setting a Greenhouse Gas Budget

Many important efforts to limit greenhouse gases are underway by state- and local-level leaders, individuals and households, business and industry, and community groups across the United States. The nation lacks, however, a framework of national goals and policies to help coordinate and expand the efforts of all these crucial actors. Establishing

a credible national emissions reductions policy will require setting a goal that can be measured. This report suggests that the overarching national goal be framed in terms of a quantitative limit on domestic greenhouse gas emissions over a specified time period—in other words, an emissions budget.

Because of the scientific uncertainties involved in identifying a safe level of global greenhouse gas emissions, and because of the political/ethical judgments involved in determining an appropriate U.S. share of global emissions, the report does not recommend a specific budget. The report does, however, use recent modeling studies (from the Energy Modeling Forum, <http://emf.stanford.edu>) to suggest a ‘representative’ domestic emissions budget in the range of 170 to 200 gigatons of CO₂-equivalent¹ for the period 2012 through 2050. This corresponds roughly to a reduction of emissions from 1990 levels by 80 to 50 percent, respectively—a major departure from business as usual emission trends (see Figure 1). At the current rate of U.S. emissions (roughly 7 Gt CO₂-eq per year), the proposed budget would be “spent” well before 2050.

Opportunities for Reducing Emissions

Based on analyses of both the Energy Modeling Forum studies and the National Research Council’s *America’s Energy Future* studies (AEF, which estimated the technical potential for expanding deployment of key energy technologies), the report concludes that meeting the representative emission budget goals is technically possible but very difficult. Within the electric power and transportation sectors, essentially all available options (e.g., for energy efficiency, for low-carbon electricity production, for low-carbon fuels) will need to be deployed at levels near the maximum extent of what AEF estimates is technically possible. These technical potential estimates, however, are based on optimistic assumptions about each technology’s cost, performance, and social acceptance. Thus there is also a need to help assure that new and improved technological options become available, through strong support of research and development efforts.

¹ A common practice is to compare and aggregate emissions among different GHGs by using global warming potentials (GWPs). Emissions are converted to a CO₂ equivalent (CO₂-eq) basis using GWPs as published by the Intergovernmental Panel on Climate Change. GWPs used here and elsewhere are calculated over a 100-year period, and vary due to the gases’ ability to trap heat and their atmospheric lifetime, compared to an equivalent mass of CO₂.

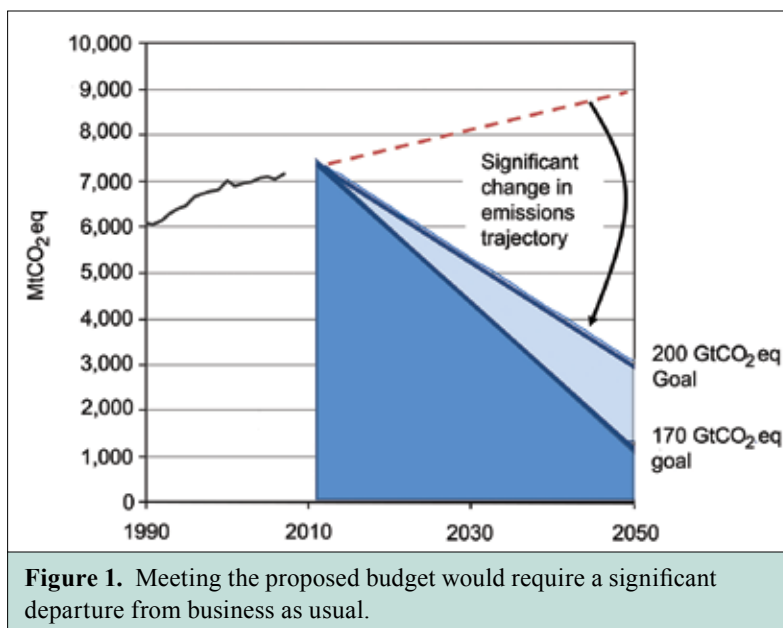
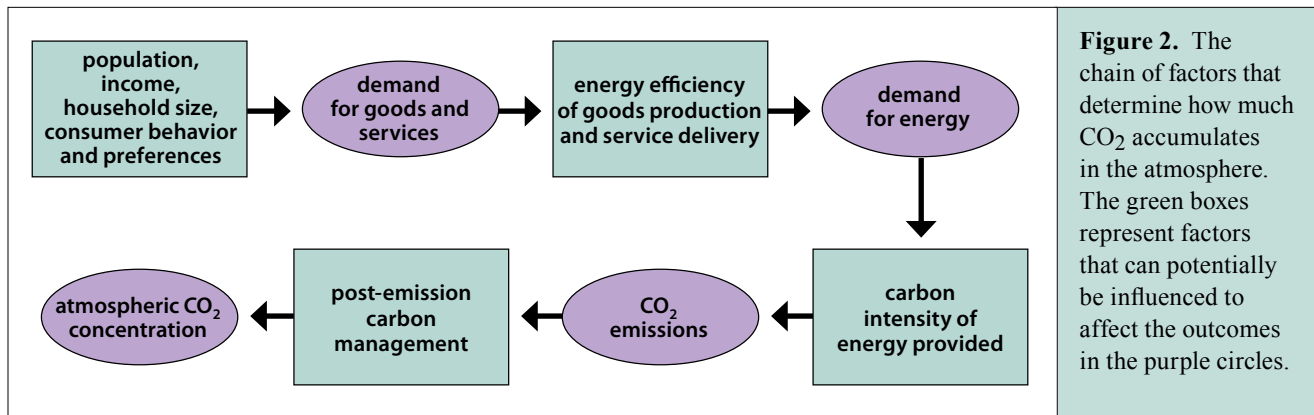


Figure 1. Meeting the proposed budget would require a significant departure from business as usual.

These analyses of potential emission budget goals, and the degree of action required to meet such goals, underlie the report’s conclusion that national-scale response efforts are urgently needed. Such response efforts may encompass the following key opportunities to reduce atmospheric concentrations of CO₂ (see Figure 2):

- **Reduce underlying demand for goods and services that require energy** (e.g., expand education and incentive programs to influence consumer behavior and preferences; curtail sprawling development patterns that further our dependence on petroleum).
- **Improve the efficiency with which energy is used** (e.g., use more efficient methods for insulating, heating, cooling, and lighting of buildings; upgrade industrial equipment and processes to be more energy efficient; encourage the purchase of efficient home appliances and personal vehicles).
- **Expand the use of low- and zero-carbon energy sources** (e.g., switch from coal and oil to natural gas, expand the use nuclear power and renewable energy sources such as solar, wind, geothermal, and biomass; capture and sequester CO₂ from power plants and factories).
- **Capture and sequester CO₂ directly from the atmosphere** (e.g., manage forests and soils to enhance carbon uptake; develop mechanical methods to “scrub” CO₂ directly from ambient air).

Some of the emission reduction opportunities listed above require more time and investment to



develop to the point of deployment, and some will likely have marginal overall impacts. The report thus focuses its policy recommendations on aggressive pursuit of a few key “near-term, high-leverage” opportunities. The report also discusses an array of opportunities that exist to control non-CO₂ greenhouse gases (such as methane, nitrous oxide, long-lived fluorinated gases, and certain short-lived air pollutant species), which may be particularly important as near-term strategies to employ while longer-term CO₂ reduction efforts take shape.

Recommendations

The report concludes that there is an urgent need for U.S. action to reduce greenhouse gas emissions. In response to this need for action, the following core strategies for U.S. policy makers are recommended:

1. **Adopt an economy-wide carbon pricing system.** A system that places a price on greenhouse gas emissions (through cap-and-trade, taxes, or some hybrid of the two) creates incentives for emission reduction efforts and markets for low-emission technologies. Evidence suggests that economic efficiency is best served by avoiding free emission allowances (or exemptions in a tax system) and by having a pricing system that is economy-wide rather than limited to particular sectors.
2. **Complement the carbon pricing system.** Because political realities may inhibit an optimally designed carbon pricing system, and because some emission sources may be relatively insensitive to pricing signals, major emission reductions will also require a portfolio of complementary policies aimed at ensuring rapid progress in efforts to:
 - realize the full potential of energy efficiency and low-emission energy sources in the

electric sector (e.g., renewables) and the transportation sector (e.g., low-carbon fuels).

- advance full-scale demonstration efforts to establish the technical and economic feasibility of carbon capture and storage and new-generation nuclear technologies;
 - accelerate the retirement or retrofit of emission-intensive infrastructure.
3. **Create new technology choices by investing heavily in research and crafting policies to stimulate innovation.** U.S. policies to facilitate technological innovation need to be strengthened on a number of fronts. This includes efforts to significantly increase both government and private-sector funding for energy R&D, establish and expand markets for low-greenhouse gas technologies and more rapidly bring new technologies to commercial scale, foster workforce development and training, and improve understanding of how social and behavioral dynamics interact with technology.
 4. **Consider potential equity implications when designing and implementing climate change limiting policies, with special attention to disadvantaged populations.** Some low-income/disadvantaged groups are likely to suffer disproportionately from adverse impacts of climate change, and may also be adversely affected by policies to limit climate change. It will be important to monitor, and to consider options for minimizing, adverse impacts upon these groups (e.g., by providing relief from higher energy prices to low-income households and by actively engaging representatives of poor and minority communities in policy planning efforts). Major changes to our nation’s energy system will inevitably lead to job gains in some sectors and regions, and losses in others. Policy

makers could help smooth this transition through additional, targeted support for educational, training, and retraining programs.

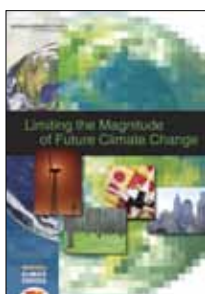
- 5. Establish the United States as a leader to stimulate other countries to adopt greenhouse gas emissions reduction targets.** U.S. emissions reductions alone are not sufficient for limiting future climate change; but what the United States does about its own emissions can have a major impact on how other countries act. It will likely be necessary for U.S. international engagement on climate change to continue to operate at multiple levels (United Nations Framework Convention on Climate Change; bilateral/multilateral agreements; sectoral-based agreements). Of particular value are science and technology initiatives aimed at helping developing countries limit emissions while advancing other sustainable development goals.
- 6. Enable flexibility and experimentation with emission reduction policies at regional, state, and local levels.** Considerable state and local-level action to reduce emissions is already underway, and offers a valuable laboratory for

policy experimentation and learning. In some instances, it may be appropriate for state/local efforts to be preempted by new federal programs, but this must be balanced against the need to allow for flexibility and innovation. Care should be taken to avoid punishing states that have taken early action to limit emissions and to ensure that states and localities have sufficient resources to implement and enforce mandated national programs.

- 7. Design policies that balance durability and consistency with flexibility and capacity for modification as we learn from experience.** Policies for limiting climate change must remain durable for decades. Durability is enhanced if key constituencies benefit from the policies and therefore have a vested interest in maintaining them. At the same time, policies must be sufficiently flexible to allow for evolution in response to new developments (e.g., in climate change science, in socioeconomic trends, in technological innovation, in our understanding of climate policy impacts). It will be an ongoing challenge to find a balance between these goals of durability and flexibility.

America's Climate Choices is a congressionally requested suite of studies from the National Research Council designed to inform and guide the nation's response to climate change. Experts representing various levels of government, the private sector, nongovernmental organizations, and research and academic institutions were selected to provide advice in peer-reviewed reports on limiting the magnitude of climate change, adapting to the impacts of climate change, advancing the science of climate change, and informing effective decisions related to climate change.

Panel on Limiting the Magnitude of Future Climate Change: **Robert W. Fri** (*Chair*), Resources for the Future; **Marilyn A. Brown** (*Vice Chair*), Georgia Institute of Technology; **Doug Arent**, National Renewable Energy Laboratory; **Ann Carlson**, University of California, Los Angeles; **Majora Carter**, Majora Carter Group, LLC; **Leon Clarke**, Pacific Northwest National Laboratory; **Francisco de la Chesnaye**, Electric Power Research Institute, Inc.; **George C. Eads**, CRA Charles River Associates; **Genevieve Giuliano**, University of Southern California; **Andrew J. Hoffman**, University of Michigan; **Robert O. Keohane**, Princeton University; **Loren Lutzenhiser**, Portland State University; **Bruce McCarl**, Texas A&M University—College Station; **Mack McFarland**, DuPont Fluoroproducts; **Mary D. Nichols**, California Air Resources Board; **Edward S. Rubin**, Carnegie Mellon University; **Thomas H. Tietenberg**, Colby College (Ret.); **James A. Trainham, III**, Sundrop Fuels Inc.; **Laurie Geller** (*Study Director*), National Research Council.



The National Academies appointed the above panel of experts to address the specific task, sponsored by the National Oceanic and Atmospheric Administration. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.



For more information, contact the Board on Atmospheric Sciences and Climate at (202) 334-3426 or visit <http://nationalacademies.org/basc> or America's Climate Choices at americasclimatechoices.org. Copies of *Limiting the Magnitude of Future Climate Change* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.

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