REBALANCING THE CARBON CYCLE

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND RESOURCES

OF THE

COMMITTEE ON
GOVERNMENT REFORM

HOUSE OF REPRESENTATIVES

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REBALANCING THE CARBON CYCLE

WEDNESDAY, SEPTEMBER 27, 2006

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND RESOURCES,
COMMITTEE ON GOVERNMENT REFORM,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:05 p.m., in room 2154, Rayburn House Office Building, Hon. Darrell Issa (chairman of the subcommittee) presiding.

Present: Representatives Issa, and Watson.

Staff present: Larry Brady, staff director; Lori Gavaghan, legislative clerk; Tom Alexander, counsel; Dave Solan, Ph.D., and Ray Robbins, professional staff members; Joe Thompson, GAO detailee; Alexandra Teitz, minority counsel; Shaun Garrison, minority professional staff member; and Jean Gosa, minority assistant clerk.

Mr. ISSA. Good afternoon. The ranking member will be here shortly and will give her opening statement when she arrives, and at that point we will also have a quorum. However, according to our rules, we can begin. She is on her way.

We can begin now, which means we can get past my painful opening statement and on to yours.

The administration's release of the U.S. Climate Change Technology Program's strategic plan on September 21st of this year and the Government Reform Committee hearing on technology research titled "Do We Need a 'Manhattan Project' for the Environment?" are just two very recent examples of how climate change is being addressed by the Federal Government and this Congress. Notwithstanding thousands of studies and the politicization of this issue on both sides of the aisle, the central problem is a simple one: humans, and our advanced societies emit more carbon dioxide into the atmosphere than can be processed by natural systems. The question that we must answer, then, is how to best address/solve this imbalance in the flow of carbon between the Earth, atmosphere, and oceans.

From my point of view, this is an engineering problem with two basic solutions: we can emit less carbon dioxide by burning less fossil fuels; and we can, during this interim, capture and store excess carbon that results from burning carbon fuels. I have become a strong believer that on the first part of the equation we have an absolute mandate to restore and increase our nuclear power industry as a major part of the solution to the imbalance of the carbon cycle, and this is why I held a hearing last week about the progress by the Department of Energy on Next Generation nuclear plants.

Current plans to construct new nuclear plants are not enough, first of all, because they are Generation III or Generation III+. It is important that Next Generation nuclear plants be designed, studied, prototyped, and completed because of the tremendous potential for zero emission electricity and, most of all, the production of hydrogen for transportation and use by the industrial sector. Together, electricity and transportation alone account for about 69 percent of U.S. carbon dioxide emissions.

This hearing will explore Federal funding, scientific research, and technology development related to the carbon cycle and discuss what we do and do not know about the carbon cycle and the strengths and weaknesses of different technologies to reduce carbon emissions.

Today, on our first panel, the Government Accountability Office will detail Federal funding for climate change science, technology, and emission reduction programs. Officials from the U.S. Climate Change Science Program and U.S. Climate Change Technology Program will discuss Federal science and technology programs related to the carbon cycle.

Our second panel includes carbon cycle experts from Oak Ridge National Laboratory, Harvard University, and the Natural Resources Defense Council, who will discuss what we do or do not know about the carbon cycle, the potential significance of changes in the carbon cycle, and the strengths and weaknesses of different technologies—and I repeat, the strengths and weaknesses of these different technologies—to reduce carbon emissions.

Today we welcome on our first panel of witnesses Mr. John B. Stephenson, Government Accountability Office; Dr. Roger C. Dahlman, Climate Change Science Program; and Mr. Stephen D. Eule, Climate Change Technology Program.

I would also like to introduce at this time and swear in, since we are all here, the second panel: Dr. Gregg Marland, of the Oak Ridge National Laboratory; Dr. Steven C. Wofsy of Harvard University; and Dr. Daniel Lashof of the Natural Resources Defense Council.

I look forward to your testimony, and I ask unanimous consent, since we do have a reporting quorum here now, that the briefing memo prepared by the subcommittee staff be inserted into the record, as well as all relevant materials.

[The prepared statement of Hon. Darrell E. Issa follows:]

COMMITTEE ON GOVERNMENT REFORM
SUBCOMMITTEE ON ENERGY AND RESOURCES

OPENING STATEMENT OF
CHAIRMAN DARRELL ISSA

Oversight Hearing:

"Rebalancing the Carbon Cycle"

September 27, 2006

The Administration's release of the U.S. Climate Change Technology Program's strategic plan on September 21, 2006 and the Government Reform Committee hearing on technology research titled "Do We Need a 'Manhattan Project" for the Environment?" are just two very recent examples of how climate change is being addressed by the federal government and Congress. Notwithstanding thousands of studies and politicization of the issue on both sides of the aisle, the central problem is a simple one. Humans emit more carbon dioxide into the atmosphere than can be processed by natural systems. The question that we must answer, then, is how best to address this imbalance in the flow of carbon between the earth, atmosphere, and oceans.

From my point of view, this is an engineering problem with two basic solutions. We can (1) emit less carbon dioxide by burning less fossil fuels, and (2) capture and store carbon dioxide produced by burning fossil fuels. I have come to strongly believe that nuclear power is a major part of the solution to the unbalanced carbon cycle, and this is why I held a hearing last week about the progress of the Department of Energy's Next Generation Nuclear Plant. Current plans to construct new nuclear plants are not enough. It is important that the Next Gen nuclear plant is completed because of its tremendous potential for zero-emission electricity and the production of hydrogen for the transportation and industrial sectors. Together, electricity and transportation account for about 69 percent of U.S. carbon dioxide emissions.

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Our second panel includes carbon cycle experts from Oak Ridge National Laboratory, Harvard University, and the Natural Resources Defense Council who will discuss what we do and do not know about the carbon cycle, the potential significance of changes in the carbon cycle, and the strengths and weaknesses of different technologies to reduce carbon emissions.

Today we welcome:

Panel 1

- **Mr. John B. Stephenson**
  Director, Natural Resources and Environment, Government Accountability Office
- **Dr. Roger C. Dahlman**
  Co-Chair, Interagency Carbon Cycle Working Group, Climate Change Science Program
- **Mr. Stephen D. Eule**
  Director, U.S. Climate Change Technology Program

Panel 2

- **Dr. Gregg Marland**
  Ecosystems Science Group, Environmental Sciences Division, Oak Ridge National Laboratory
- **Dr. Steven C. Wofsy**
  Abbott Lawrence Rotch Professor of Atmospheric and Environmental Chemistry, Harvard University
- **Dr. Daniel A. Lashof**
  Science Director, Climate Center, Natural Resources Defense Council

COMMITTEE ON GOVERNMENT REFORM

Subcommittee on Energy and Resources

DARRELL ISSA, CHAIRMAN

Oversight Hearing:

Rebalancing the Carbon Cycle

September 27, 2006, 2:00 pm
Rayburn House Office Building
Room 2154

BRIEFING MEMORANDUM

Summary

In 2004, the United States emitted about 5.7 billion more tons of carbon dioxide than could be processed by natural systems, such as trees, soils, and oceans. As a result, concentrations of carbon dioxide in the atmosphere are rising, potentially increasing the risk of climate change. The carbon cycle, or the flow of carbon between the atmosphere, land, oceans, and plants, could be rebalanced by (1) emitting less carbon dioxide by burning less fossil fuels, and (2) capturing and storing carbon dioxide produced by burning fossil fuels. A diverse range of approaches are necessary to rebalance the carbon cycle, including improved energy efficiency and the production of more electricity with nuclear power and renewable resources.

Background

The United States emitted 6.6 billion tons of carbon dioxide in 2004, primarily due to the combustion of fossil fuels, including coal, oil, and natural gas for electricity production, industrial processes, and transportation.[1] Electricity production was responsible for about 38 percent of carbon dioxide emissions in 2004. Land use changes, such as increases in the amount of forest productivity, removed about 860 million tons of carbon dioxide from the atmosphere through natural processes.[2] As a result, in 2004, the United States emitted about 5.7 billion more tons of carbon dioxide than natural systems could absorb, affecting the delicately balanced carbon cycle that flows between the land, atmosphere, and oceans, and increasing the risk of potential changes to the climate system. According to the United States Climate Change Science Program, over the past two

[1] Environmental Protection Agency, *The U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2004*, (Washington DC, April 15, 2006).

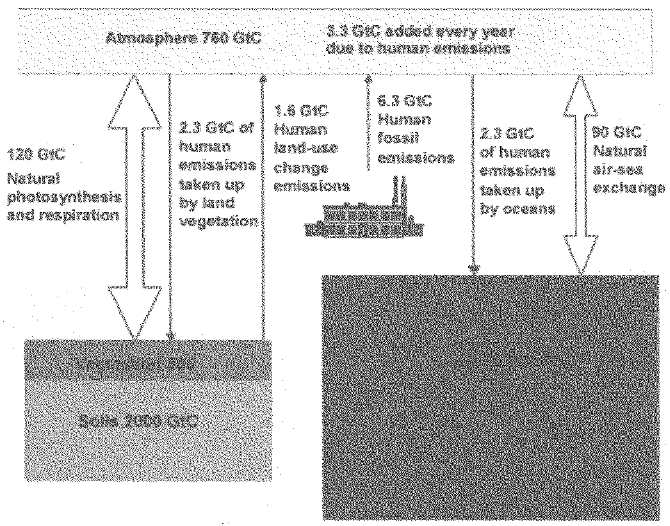
[2] EPA estimates do not include emissions sources without reliable estimation methods or emissions sources, such as volcanic eruptions and natural forest fires and sequestration activities, like the uptake of carbon dioxide by oceans, that are not a direct result of or influenced by human activities.

centuries, fossil-fuel emissions, land-use change, and other human activities increased atmospheric carbon dioxide by 30 percent to concentrations unprecedented over the past 420,000 years.[3] Other countries are also contributing to the increased concentration of carbon dioxide in the atmosphere. According to the Energy Information Administration, the United States accounted for 21.7 percent of the world's carbon dioxide emissions from the consumption and flaring of fossil fuels in 2004.[4]

The Carbon Cycle

The carbon cycle consists of flows, or "fluxes" of carbon between storage reservoirs, or "sinks" including the atmosphere, oceans, and plants. For example, if a tree dies in a forest, the carbon stored in the tree is released through decomposition into the atmosphere. Some of the carbon released by the tree may be used by other vegetation as an input for photosynthetic growth, wind up in the ocean or soils through natural processes, or remain in the atmosphere. Figure 1 illustrates a simplified version of the global carbon cycle and the annual carbon fluxes between carbon sinks, including the impact of human-caused emissions from burning fossil fuels and land use changes.

Figure 1: Simplified Global Carbon Cycle Including Human-Caused Emissions



Large arrows represent natural, annual carbon fluxes. Small arrows represent human-induced, annual carbon fluxes. All numbers are in billion metric tons (Gigatons) of carbon (GtC). Numbers next to arrows represent annual carbon fluxes (GtC/yr). Numbers in boxes represent size of carbon reservoirs (GtC).

Source: Environmental Protection Agency, http://www.epa.gov/sequestration/ccyle.html, based on IPCC SRLULUCF 2000 and IPCC TAR WGI 2001

[3] U.S. Climate Change Science Program, *Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2006*, (Washington DC, October 2005)
[4] http://www.eia.doe.gov/pub/international/iealf/tableh1co2.xls

Strategies to Rebalance the Carbon Cycle

The carbon cycle could be rebalanced by (1) emitting less carbon dioxide by burning less fossil fuels, and (2) capturing and storing carbon dioxide produced by burning fossil fuels.[5] Any single technology or method is unlikely to address the entire carbon imbalance by itself. A diverse set of approaches would provide greater flexibility to respond to new information or technological advances.

Reducing Carbon Dioxide Emissions

The United States can reduce carbon dioxide emissions from electricity generation by switching to less carbon-intensive fuels, such as nuclear power and renewable resources, or through energy efficiency activities to reduce the demand for electricity. Nuclear power and renewables, such as wind and solar power, have proven track records and emit no carbon dioxide. The combustion of natural gas and biomass, such as switchgrass, to produce electricity is also less carbon-intensive than fossil fuels. To the extent that such low-carbon alternatives replace fossil fuel generation, they may help reduce the imbalance in the carbon cycle. Potential drawbacks of nuclear power include the lack of nuclear waste storage or reprocessing capacity and high construction costs. Some weaknesses of renewable resources are that they produce intermittently and are often sited far from populated areas and therefore require significant investments in electricity transmission infrastructure. Increased energy efficiency could also reduce the demand for electricity and decrease the associated carbon dioxide emissions.

Carbon Sequestration

There are two types of carbon sequestration, including (1) human engineered technologies, such as capturing and then piping carbon dioxide from coal power plants into geologic rock formations, and (2) natural carbon sinks, such as forests and soil.

Human-engineered carbon capture and sequestration projects, such as injecting carbon dioxide into geological formations or the deep ocean, offer significant opportunities to remove carbon dioxide from the atmosphere. Although not widely practiced to date, geological sequestration appears feasible based on experience in the oil and natural gas industries. The basic approach is to inject carbon dioxide into underground rock formations and then permanently store the gas. The possibility of sequestering carbon dioxide in the deep ocean is also being studied and employed in limited situations. In this case, carbon dioxide emissions would be captured and then pumped deep in the ocean.

The benefits of engineered carbon capture and sequestration projects are that they would complement existing and proposed fossil fuel power plants, and that carbon dioxide would likely be trapped for thousands of years in the case of geological sequestration, or hundreds of years for deep ocean sequestration. Key weaknesses of such projects are that certain technologies for capturing the carbon dioxide emitted by burning fossil fuels are still in the developmental stage or are very costly. Further, employing these technologies decreases the efficiency of power plants because they require significant amounts of

[5] Carbon storage is commonly referred to as carbon sequestration.

energy to capture carbon dioxide from the emissions stream. Other weaknesses of geological sequestration include the lack of experience with such projects, the need to perpetually monitor sequestration sites, the lack of methods to monitor and repair leaks, the lack of a legal framework and regulatory structure, and the need to develop pipelines and other infrastructure to transport carbon dioxide from the source to the sequestration site. Despite recent studies suggesting great carbon storage potential, the weaknesses of deep ocean sequestration include the unknown impact on sea life, among other factors.

Natural carbon sinks sequester carbon dioxide already in the atmosphere. For example, plants remove carbon dioxide from the atmosphere as an input for photosynthesis and store it in plant matter, such as tree trunks. If plants that sequester large amounts of carbon (like certain species of trees) replaced plants that do not sequester large amounts of carbon (such as some crops), they could remove carbon dioxide from the atmosphere for a period of time, potentially hundreds of years. The key benefit of this approach is that it relies on natural processes. The drawbacks of natural sequestration are that the carbon is only trapped temporarily, and that it requires a large amount of land. For example, the U.S. would have to replace over half of the country's 968 million acres of farmland with very fast-growing trees by the end of 2006 in order to sequester 5.7 billion tons of carbon dioxide annually by 2020.[6] Even if all of this farmland could support such forests, other uses of such land may be more economically efficient and environmental or land-use changes could disrupt the productivity of such projects. Figure 2 below illustrates carbon sequestration options and policy considerations.

Figure 2: Carbon Dioxide Sequestration Options

Property	Terrestrial biosphere	Deep ocean	Geological reservoirs
CO_2 sequestered or stored	Stock changes can be monitored over time.	Injected carbon can be measured.	Injected carbon can be measured.
Ownership	Stocks will have a discrete location and can be associated with an identifiable owner.	Stocks will be mobile and may reside in international waters.	Stocks may reside in reservoirs that cross national or property boundaries and differ from surface boundaries.
Management decisions	Storage will be subject to continuing decisions about land-use priorities.	Once injected there are no further human decisions about maintenance once injection has taken place.	Once injection has taken place, human decisions about continued storage involve minimal maintenance, unless storage interferes with resource recovery.
Monitoring	Changes in stocks can be monitored.	Changes in stocks will be modelled.	Release of CO_2 can be detected by physical monitoring.
Expected retention time	Decades, depending on management decisions.	Centuries, depending on depth and location of injection.	Essentially permanent, barring physical disruption of the reservoir.
Physical leakage	Losses might occur due to disturbance, climate change, or land-use decisions.	Losses will assuredly occur as an eventual consequence of marine circulation and equilibration with the atmosphere.	Losses are unlikely except in the case of disruption of the reservoir or the existence of initially undetected leakage pathways.
Liability	A discrete land-owner can be identified with the stock of sequestered carbon.	Multiple parties may contribute to the same stock of stored CO_2 and the CO_2 may reside in international waters.	Multiple parties may contribute to the same stock of stored CO_2 that may lie under multiple countries.

Source: Intergovernmental Panel on Climate Change, *Carbon Dioxide Capture and Storage: Summary for Policymakers and Technical Summary*, (September 2005)

[6]This committee staff calculation is based upon the total acres of farmland in the U.S. in 2002 as reported in the 2002 Census of Agriculture by the National Agriculture Statistics Service, and the *Sequestration from Forestry Excel Workbook* and *Guidance for Reporting Sequestration from Forestry Activities* published by the Energy Information Administration (see http://www.eia.doe.gov/oiaf/1605/techassist.html).

Conclusion

Increasing the amount of electricity generated by nuclear power and renewable resources in combination with energy efficiency efforts appears preferable on a number of levels to other strategies. First, it is simpler to emit less carbon dioxide in the first place than to capture, transport, and store the gas after the fact. Although promising, the added complexity of carbon sequestration invites uncertainty and an increased risk of failure. Second, in contrast to the proven track record of nuclear and renewable technologies, significant uncertainties remain about the cost and viability of human-engineered carbon sequestration activities. For example, in 2004, the U.S. Climate Change Science Program stated that:

> "Enhancing carbon sequestration is of current interest as a near-term policy option to slow the rise in atmospheric CO2 and provide more time to develop a wider range of viable mitigation and adaptation options. However, uncertainties remain about how much additional carbon storage can be achieved, the efficacy and longevity of carbon sequestration approaches, whether they will lead to unintended environmental consequences, and just how vulnerable or resilient the global carbon cycle is to such manipulations." [7]

Third, the amount of land necessary to sequester significant amounts of carbon dioxide in forests and other natural systems is not feasible from a land management standpoint. For example, the U.S. would have to replace over half of the country's 968 million acres of farmland with very fast-growing trees by the end of 2006 in order to sequester 5.7 billion tons of carbon dioxide annually by 2020.[8] Even if all of this farmland could support such forests, it is very likely that other uses of the land are more economically efficient. Again, while a diverse range of approaches are necessary to fully rebalance the carbon cycle, reducing emissions by emphasizing nuclear power and renewable resources in conjunction with energy efficiency efforts makes the most sense because these technologies are more proven and reliable than other alternatives and they directly address the problem by emitting zero carbon dioxide.

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[7] U.S. Climate Change Science Program, *Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Years 2004 and 2005*, (Washington DC, July 2004)

[8] This committee staff calculation is based upon the total acres of farmland in the U.S. in 2002 as reported in the 2002 Census of Agriculture by the National Agriculture Statistics Service of the United States Department of Agriculture, and the *Sequestration from Forestry Excel Workbook* and *Guidance for Reporting Sequestration from Forestry Activities* published by the Energy Information Administration of the Department of Energy (see http://www.eia.doe.gov/oiaf/1605/techassist.html).

Issues That Will Be Addressed By This Hearing

Panel 1 - What is the Federal Government Doing to Rebalance the Carbon Cycle?

- What is the federal government doing to learn about the carbon cycle?
- What is the federal government doing to reduce anthropogenic carbon emissions?

Panel 2 - Carbon Cycle Science

- What do and don't we know about the carbon cycle?
- How is the carbon cycle changing in the United States, and why?
- What is the potential significance of these changes?

Both Panel 1 and Panel 2

- What are the strengths and weaknesses of different technologies to reduce carbon emissions?
- How do federal government programs address what is and is not known about the carbon cycle?

Witnesses

Panel 1 - What is the Federal Government Doing to Rebalance the Carbon Cycle?

- **Mr. John B. Stephenson**
  Director, Natural Resources and Environment, Government Accountability Office
- **Dr. Roger C. Dahlman**
  Co-Chair, Interagency Carbon Cycle Working Group, Climate Change Science Program
- **Mr. Stephen D. Eule**
  Director, U.S. Climate Change Technology Program

Panel 2 - Carbon Cycle Science

- **Dr. Gregg Marland**
  Ecosystems Science Group, Environmental Sciences Division, Oak Ridge National Laboratory
- **Dr. Steven C. Wofsy**
  Abbott Lawrence Rotch Professor of Atmospheric and Environmental Chemistry, Harvard University
- **Dr. Daniel A. Lashof**
  Science Director, Climate Center, Natural Resources Defense Council

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COMMITTEE ON GOVERNMENT REFORM

SUBCOMMITTEE ON ENERGY AND RESOURCES

DARRELL ISSA, CHAIRMAN

Will Hold an Oversight Hearing:

Rebalancing the Carbon Cycle

September 27, 2006, 2:00 p.m.
Room 2154 Rayburn House Office Building

WITNESSES

Panel 1 - What is the Federal Government Doing to Rebalance the Carbon Cycle?

Mr. John B. Stephenson
Director, Natural Resources and Environment, Government Accountability Office

Dr. Roger C. Dahlman
Co-Chair, Interagency Carbon Cycle Working Group, Climate Change Science Program

Mr. Stephen D. Eule
Director, U.S. Climate Change Technology Program

Panel 2 - Carbon Cycle Science

Dr. Gregg Marland
Ecosystems Science Group, Environmental Sciences Division, Oak Ridge National Laboratory

o **Dr. Steven C. Wofsy**
Abbott Lawrence Rotch Professor of Atmospheric and Environmental Chemistry, Harvard University

Dr. Daniel A. Lashof
Science Director, Climate Center, Natural Resources Defense Council

Mr. ISSA. And then I am going to deviate from the order just for a moment to give the gentlelady an opportunity to settle in. I ask that all those who will testify or who will provide assistance to those testifying on questions and answers please rise and take the oath, as required by the committee rules.

[Witnesses sworn.]

Mr. ISSA. The record will show that all answered in the affirmative.

And with that, I take great pleasure in yielding to the gentlelady from California, Ms. Watson, for her opening remarks.

Ms. WATSON. Mr. Chairman, thank you for convening today's hearing, and I especially want to commend you on your timeliness on addressing an issue that can have a long lasting impact on our Nation. This hearing addresses the issues that the public needs to know regarding the science of the carbon cycle. With the threat of global warming on the rise, Congress needs to pay attention, deep attention, to this issue.

Carbon serves as one of the most essential elements on Earth and is the principal building block for organic compounds. The flow of carbon throughout the atmosphere is one of the most complex and important global cycles. Unfortunately, this vital element and its cycles are out of balance. As a result, carbon dioxide levels in the atmosphere are higher than they have been for 650,000 years, and are still on the rise. Human activities are releasing carbon dioxide into the atmosphere at a rapid pace, causing the atmosphere to trap heat and thereby rapidly warming our planet. This ongoing environmental problem must be addressed.

I understand that witnesses today will discuss the administration's response to global warming and discuss the research and technologies that could help reduce greenhouse emission gases and new international initiatives for research and technology. These projects are very important because greenhouse gas emissions are on the rise every day. In fact, it is estimated that actual emissions will rise by an additional 14 percent, which is almost the projected rate of business-as-usual emissions increase.

There is overwhelming evidence of the urgency of the threat of global warming. The administration needs to take immediate action to protect our Nation. In the year 2001, the President stated that carbon dioxide is not a pollutant while questioning the reality of global warming. The President also withdrew the United States from the Kyoto Protocol, which is an international agreement to limit the emissions of global warming pollution. These actions would seem to indicate that the President does not consider this to be a serious issue.

Mr. Chairman, the time is now for us to put global warming at the forefront of our agenda. Complacency now will only necessitate more drastic and, hence, more expensive reductions in the future. So I look forward to the testimony from our witnesses today, and I hope that we will be able to take this threat of global warming very seriously, because inadequate preparation can have a drastic impact on the environmental safety of the American people.

So I yield back and I thank you very much, Mr. Chairman.

[The prepared statement of Hon. Diane E. Watson follows:]

Opening Statement
Congresswoman Diane E. Watson
Ranking Member
Government Reform Subcommittee on Energy and Resources
Hearing: "The Next Generation Nuclear Plant and Hydrogen Production: A Critical Status Report"
September 20th, 2006

Mr. Chairman, thank you for convening today's hearing to discuss a very critical project that can play a major role in shaping the future of America's energy use and production. All of us are aware of the importance of nuclear energy and I hope that our witnesses today will update us on the progress of the Next Generation Nuclear Plant (NGNP) project and tell us if the goals in completing the project are being met.

There are several concerns as to whether or not this project is on track to meet its 2021 deadline for completion. In a recent GAO study, it has come to the committee's attention that there are several technological challenges in completing the NGNP and

whether the technologies developed will meet the needs of the private sector. GAO also found that the project's initial research and development results indicate that the likelihood is slim that the project will be able to stay on schedule, considering the amount of research and development that still needs to be done. This is a problem!

This committee's job is to conduct oversight on federal spending and we must ensure that all projects, including this one, are conducted in an expeditious and profitable manner that benefits the American taxpayer. The public should be secure in knowing that we do meet deadlines in the federal government and when we don't, we have a viable explanation as to why or why not a deadline was not met. Every April 15th, taxpayers are required to file their taxes or they will face a penalty unless they explain why they need an extension. Shouldn't that same accountability be held on the government when conducting business?

Mr. Chairman, I again want to thank you for your leadership in bringing this issue before this subcommittee. I am confident that our discussion today will yield us some definite answers on the progress of the Next Generation Nuclear Plant. I hope that the findings of this GAO report will be of benefit to all of the researchers and scientists involved to make this endeavor a success.

I yield back.

Mr. ISSA. I thank the gentlelady.

As you can see, there is no shortage of a belief that dealing with the excess carbon emitted into the atmosphere is important on this committee. On a bipartisan basis we will continue to address it in this and the next Congress, regardless of conflicts among some about the impact of global warming.

And, with that, I would like to recognize Mr. Stephenson for his opening remarks.

STATEMENTS OF JOHN B. STEPHENSON, DIRECTOR, NATURAL RESOURCES AND ENVIRONMENT, GOVERNMENT ACCOUNTABILITY OFFICE; DR. ROGER C. DAHLMAN, CO-CHAIR, INTERAGENCY CARBON CYCLE WORKING GROUP, CLIMATE CHANGE SCIENCE PROGRAM; AND STEPHEN D. EULE, DIRECTOR, U.S. CLIMATE CHANGE TECHNOLOGY PROGRAM

STATEMENT OF JOHN B. STEPHENSON

Mr. STEPHENSON. Thank you, Mr. Chairman. We are here today to discuss two GAO reports relevant to today's hearing. One report deals with the billions of dollars the Federal Government annually spends on research and other activities, and the other report deals with two voluntary programs that are key components of the administration's efforts to reduce emissions of carbon dioxide and other greenhouses gases.

First, our report on climate spending showed that 14 Federal agencies have provided billions of dollars for climate change activities. OMB, at the direction of Congress, annually reports on expenditures for these activities in four broad categories: one, science, which includes research to better understand climate change; two, technology, which includes the development and deployment of technologies to reduce greenhouse gas emissions or increase energy efficiencies; three, international assistance, which helps developing countries to address climate change; and, four, tax expenditures, which are Federal income tax provisions that grant preferential tax treatment to encourage emission reduction, such as credits for purchasing clean fuel burning vehicles.

In analyzing overall Federal climate change funding, we found that OMB reported that climate change funding more than doubled, from $2.4 billion in 1993 to $5.1 billion in 2004, with almost all of this increase in real or inflation-adjusted dollars occurring in technology. However, it was difficult for us to determine if this was a real or a definitional increase because of numerous changes in reporting format from year to year without adequate explanation. We found that in some cases new accounts were added and the definitions of existing accounts expanded to include more activities.

For example, a $152 million NASA research program to reduce emissions in aircraft was included for the first time in 2003. In addition, we found that over 50 percent of the increase in technology funding was the result of the Department of Eenergy expanding the definition of two accounts to include over $500 million in nuclear research programs, programs that this administration considers part of climate change but that the previous administration did not.

We made several recommendations to improve the clarity and usefulness of these climate change spending reports that OMB agreed with and plans to incorporate in future reports. Nevertheless, these reports are based on individual agency spending priorities merely rolled up into a single report by OMB.

While we have not formally reviewed either the Climate Change Science Program or the just released Climate Change Technology Program, we think that if these programs are to be successful, it will be important to clearly articulate the relationship between the Government's $5 billion investment portfolio and the goals of both programs. Moreover, we think a funding mechanism will need to be established to ensure that individual agency investment decisions reflect these goals and priorities.

For our other report we examined two voluntary programs announced by the President in February 2002 aimed at securing private sector agreements to voluntarily reduce greenhouse gas emissions: EPA's Climate Leaders Program and DOE's Climate VISION Program. At the time of our report, 74 companies and 15 trade groups were participating in one program or the other. In general, participants are expected to set emission reduction goals, measure and track emissions, and annually report progress against goals.

At the time of our study, about half of the participants had established goals, but few had begun to measure and track emissions or annually report progress. In addition, it will be difficult for EPA and DOE to determine the success of these programs in terms of emission reductions because of overlap with other programs and the difficulty in accounting for reductions that would have occurred anyway because of rising energy prices or other factors.

We concluded that EPA and DOE needed to do more to encourage progress under both programs by, among other things, developing a system for tracking participants' progress in completing key steps associated with the program and establishing a formal policy for actions to be taken if participants are not progressing as expected.

Both DOE and EPA agreed with our recommendations, but we have not yet done any followup work to determine the extent to which they have been implemented.

Mr. Chairman, that concludes a summary of my prepared statement. I would be happy to answer questions.

[The prepared statement of Mr. Stephenson follows:]

United States Government Accountability Office

GAO

Testimony
Before the Subcommittee on Energy and Resources, Committee on Government Reform, House of Representatives

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CLIMATE CHANGE

Federal Agencies Should Do More to Make Funding Reports Clearer and Encourage Progress on Two Voluntary Programs

Statement of John B. Stephenson, Director
Natural Resources and Environment

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GAO-06-1126T

September 27, 2006

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Highlights

Highlights of GAO-06-1126T, testimony before the Subcommittee on Energy and Resources, Committee on Government Reform, House of Representatives

CLIMATE CHANGE

Federal Agencies Could Do More to Make Funding Reports Clearer and Encourage Progress on Two Voluntary Programs

Why GAO Did This Study

The Office of Management and Budget (OMB) reports on federal funding for climate research and to develop technologies to reduce greenhouse gas emissions, among other things. The Climate Change Science Program (CCSP), which coordinates many agencies' activities, also reports on science funding. The Environmental Protection Agency's (EPA's) Climate Leaders and the Department of Energy's (DOE's) Climate VISION programs aim to reduce such emissions through voluntary industry efforts.

This testimony is based on GAO's August 2005 report *Climate Change: Federal Reports on Climate Change Funding Should Be Clearer and More Complete* (GAO-05-461) and its April 2006 report *Climate Change: EPA and DOE Should Do More to Encourage Progress Under Two Voluntary Programs* (GAO-06-97), which addressed (1) reported changes in federal climate change funding and (2) the status and progress of two federal voluntary climate programs.

What GAO Recommends

GAO recommended actions to improve OMB's and CCSP's reporting. GAO recommended that both EPA and DOE develop written policies on what to do about participants not meeting program expectations. All four agencies appear to have taken steps to implement our recommendations, but we have not fully reviewed the extent to which they have done so.

www.gao.gov/cgi-bin/getrpt?GAO-06-1126T.

To view the full product, including the scope and methodology, click on the link above. For more information, contact John Stephenson at (202) 512-3841 or StephensonJ@gao.gov.

What GAO Found

Federal funding for climate change, as reported by OMB, increased from $2.35 billion in 1993 to $5.09 billion in 2004 (117 percent), or from $3.28 billion to $5.09 billion (55 percent) after adjusting for inflation. OMB reports show that, during this period, funding increased for technology, science, and–before adjusting for inflation–international assistance. CCSP, which reports only science funding, generally presented totals that were consistent with OMB's, but provided more detail. However, changes in reporting methods used by both OMB and CCSP limit the comparability of funding data over time, and therefore it was unclear whether total funding actually increased as reported. Furthermore, we were unable to compare changes in the fourth category (climate-related tax expenditures), because from 1993 to 2004 OMB reported estimates for proposed but not existing tax expenditures. With regard to individual agencies' funding, OMB reported that 12 of the 14 agencies receiving funding for climate change programs in 2004 received more funding in that year than they had in 1993, but it is unclear whether funding changed as OMB reported because of unexplained changes in what was defined as climate change funding. Reported funding for DOE, the agency with the most reported climate-related funding in 2004, increased from $963 million to $2.52 billion (162 percent), or from $1.34 billion to $2.52 billion (88 percent) after adjusting for inflation. DOE and the National Aeronautics and Space Administration accounted for 81 percent of the reported increase in funding from 1993 through 2004. However, because agency funding totals are composed of individual accounts, changes in the reports' contents, such as the unexplained addition of accounts to the technology category, limit the comparability of agencies' funding data over time, making it difficult to determine if these are real or definitional increases.

EPA and DOE expected participants in their voluntary climate programs to complete several program steps within general time frames, but participants' progress in completing those steps within the time frames was mixed. Furthermore, DOE did not have a system for tracking groups' progress in completing program steps, and neither DOE nor EPA had a written policy specifying the consequences for participants not proceeding as expected. In addition, EPA and DOE had both estimated the share of total U.S. greenhouse gas emissions attributable to participants in their respective programs and were working through an interagency process to quantify emissions reductions attributable to their programs. However, determining reductions attributable to each program will be challenging because of the overlap between these programs and other voluntary programs and because it is difficult to determine how much of a participant's emissions reductions can be attributed to its participation in the program, since the participant's emissions in the absence of the program cannot be known.

Mr. Chairman and Members of the Subcommittee:

I am pleased to participate in the Subcommittee's hearing and to discuss some of our recent work on federal climate change funding and voluntary programs.

Increases in the earth's average temperature that have already occurred over the last 100 years, combined with additional future increases projected by a consensus of scientists, have the potential to dramatically change life on earth. For example, changes in the frequency and intensity of rainfall, both possible effects of climate change, could affect human health, agriculture, forests, and water supplies in certain locations. Effects on planetary biodiversity are projected to be even more pronounced. The Congress and the president have supported research to improve scientific understanding of the climate system and to develop new technologies to reduce greenhouse gas emissions. They have also created various federal programs to help reduce such emissions. These programs are largely voluntary and encourage private and public sector entities to adopt goals for reducing emissions.

My remarks today are based on our August 2005[1] report on federal climate change funding from 1993 through 2004 and our April 2006[2] report on voluntary programs that encourage industry participants to set greenhouse gas emissions reduction goals.[3] I will focus on (1) how total funding, funding by category, and funding by agency as reported by the Office of Management and Budget (OMB) and the Climate Change Science Program (CCSP) changed and the extent to which such funding data are comparable over time, and (2) the expectations for, and progress being made by, participants in two federal voluntary programs–the Environmental Protection Agency's (EPA's) Climate Leaders and the Department of Energy's (DOE's) Climate VISION–and these agencies'

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[1]U.S. Government Accountability Office, ***Climate Change: Federal Reports on Climate Change Funding Should be Clearer and More Complete.*** GAO-05-461 (Washington, D.C.: August 25, 2005).

[2]U.S. Government Accountability Office, ***Climate Change: EPA and DOE Should Do More to Encourage Progress Under Two Voluntary Programs.*** GAO-06-97 (Washington, D.C.: April 25, 2006).

[3]For the sake of consistency, we describe both Climate Leaders and Climate VISION participants' targets as goals, even though DOE describes Climate VISION participants' targets as commitments.

estimates of the programs' current coverage (the share of U.S. emissions that participants contribute to total U.S. emissions) and impact (emissions reduced).

To determine how federal climate change funding by category—science, technology, international assistance, and tax expenditures–and agency changed, we analyzed data from annual OMB and CCSP reports as well as congressional testimony. To determine the extent to which the data on climate change funding were comparable over time, we analyzed and compared the contents of the reports and interviewed responsible officials. The term "funding" in this testimony reflects discretionary budget authority, or the authority provided in law to incur financial obligations that will result in outlays, as reported by OMB and CCSP in their reports.[4] Unless otherwise stated, we report funding in nominal terms (not adjusted for inflation), and all years refer to fiscal years.[5] To evaluate the EPA and DOE voluntary programs, we reviewed and analyzed EPA and DOE documents and met with these agencies' officials. Most of the information in the report, except where otherwise noted, reflects the status of the two programs as of November 2005. As of September 20, 2006, an additional 18 firms had joined Climate Leaders. To assess the reliability of EPA, DOE, and other data, we spoke with agency officials about data quality control procedures and reviewed relevant documentation. We determined that the data were sufficiently reliable for the purposes of our reports. We performed our work on the federal funding report between July 2004 and August 2005 and on the voluntary programs report between June 2004 and March 2006 in accordance with generally accepted government auditing standards.

In summary, we found that:

[4]An OMB official stated that there is no mandatory budget authority for climate change programs.

[5]When we adjusted for inflation, we used a fiscal year price index that we calculated based on a calendar year price index published by the Department of Commerce's Bureau of Economic Analysis. Unless otherwise specified, figures represent actual funding (not estimates), with the exception of 1993, 1994, and 2004, where we present estimated funding reported by CCSP because actual data are not available. For the purposes of this testimony, the term "agency" includes executive departments and agencies, and we use the term "account" to describe the budget accounts, line items, programs, and activities presented in OMB and CCSP reports. Throughout this testimony, we characterize all climate change science reports from 1993 through 2004 as CCSP reports, even though CCSP has been in existence only since 2002, and reports prior to 2002 were published by a predecessor organization. Totals and percentages may not add due to rounding.

- As reported by OMB, federal funding for climate change increased from $2.35 billion in 1993 to $5.09 billion in 2004 (117 percent), or from $3.28 billion to $5.09 billion (55 percent) after adjusting for inflation. During this period, federal funding increased for science, technology, and before adjusting for inflation, international assistance, according to OMB reports. CCSP, which reports only science funding, provided more detail, but generally presented totals that were consistent with OMB's. However, changes in methods used by both OMB and CCSP to report funding data made it difficult to compare the data over time, and therefore, to determine whether total funding actually increased as reported. We were unable to compare changes in the fourth category (climate-related tax expenditures), because from 1993 to 2004 OMB did not report estimates for existing tax expenditures. For individual agencies, OMB reported that 12 of the 14 agencies that received funding for climate change programs in 2004 received more funding in that year than they had in 1993. However, unexplained changes in what was defined as climate change funding made it difficult to determine whether funding changed to the extent that OMB reported. Funding for the Department of Energy (DOE), the agency with the most reported climate-related funding in 2004, increased from $963 million to $2.52 billion (162 percent), or from $1.34 billion to $2.52 billion (88 percent) after adjusting for inflation. DOE and the National Aeronautics and Space Administration (NASA) accounted for 81 percent of the reported increase in funding from 1993 through 2004. However, because agency funding totals are composed of individual accounts, changes in the reports' contents, such as the unexplained addition of accounts to the technology category, make it difficult to compare funding data over time. This, in turn, makes it difficult to determine if these are real or definitional increases.

- EPA and DOE expected the participants in their voluntary climate change programs to complete several program steps within general time frames, but participants' progress in completing those steps within the time frames varied. Moreover, DOE did not have a system to track the participants' progress in completing the required steps, and neither DOE nor EPA had a written policy specifying what actions would be taken to address participants' not proceeding as expected. In addition, EPA and DOE had both estimated the share of total U.S.

greenhouse gas emissions that could be attributed to the participants in their programs and were working through an interagency process to quantify emissions reductions attributable to their programs. However, determining reductions attributable to each program will be challenging because these programs overlap with other voluntary programs and because it is difficult to determine how much of a participant's emissions reductions can be attributed to its participation in the program, versus what they would have done anyway in the absence of the program.

With regard to reporting of federal climate change funding, we recommended that OMB and CCSP use the same format for presenting data from year-to-year, explain changes in report content or format when they are introduced, and provide and maintain a crosswalk comparing new and old report structures when changes in report format are introduced. We also recommended that OMB include data on existing climate-related tax expenditures in future reports.

Regarding the voluntary programs, we recommended that DOE develop a system for tracking participants' progress in completing key steps associated with its Climate VISION Program, and that both EPA and DOE develop written policies establishing the actions the agencies will take if participants are not completing program steps on time.

All four agencies appear to have taken steps to implement our recommendations, but we have not comprehensively reviewed the extent to which they have done so.

Background

In 1990, the Congress enacted the Global Change Research Act.[6] This act, among other things, required the administration to (1) prepare and at least every 3 years revise and submit to the Congress a national global change research plan, including an estimate of federal funding for global change research activities to be conducted under the plan; (2)

[6]Pub. L. No. 101-606, 104 Stat. 3096 (1990) (partially terminated pursuant to the Federal Reports Elimination and Sunset Act of 1995, Pub. L. No. 104-66, § 3003 (1995)).

in each annual budget submission to the Congress, identify the items in each agency's budget that are elements of the United States Global Change Research Program (USGCRP), an interagency long-term climate change science research program; and (3) report annually on climate change "expenditures required" for the USGCRP.[7]

In response to the requirements of the 1990 act, the administration reported annually from 1990 through 2004 on funding for climate change science.[8] From 1990 through 2001, the reports presented detailed science funding data for the USGCRP. Federal climate change science programs were reorganized in 2001 and 2002. In 2001, the Climate Change Research Initiative (CCRI) was created to coordinate short-term climate change research focused on reducing scientific uncertainty, and in 2002, CCSP was created to coordinate and integrate USGCRP and CCRI activities. CCSP is a collaborative interagency program designed to improve the government wide management of climate science and research.

With respect to federal research, OMB, in annual reports and testimony before the Congress, reported climate change funding for 1993 through 2004 using four categories:

- **Technology**, which includes the research, development, and deployment of technologies and processes to reduce greenhouse gas emissions or increase energy efficiency. Funding for this category focuses on programs for energy conservation, renewable energy, and related efforts.

- **Science**, which includes research and monitoring to better understand climate change, such as measuring changes in forest cover and land use.

- **International assistance**, which helps developing countries address climate change by, for example, providing funds for energy efficiency programs.

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[7]The annual reporting requirement for climate change expenditures was terminated effective May 15, 2000. The reporting requirement had called for "(A) the amounts spent during the fiscal year most recently ended; (B) the amounts expected to be spent during the current fiscal year; and (C) the amounts requested for the fiscal year for which the budget is being submitted."

[8]To maintain consistency with OMB data, which are available from 1993 to 2004, we reviewed reported science funding from 1993 to 2004.

- **Tax expenditures** related to climate change, which are federal income tax provisions that grant preferential tax treatment to encourage emission reductions by, for example, providing tax incentives to promote the use of renewable energy.[9]

Over the same time period, the administration also has reported annually on funding specifically for climate change science. CCSP is currently responsible for preparing these climate change science reports, which duplicate to some extent data provided by OMB in the science category.

In 1992, the United States ratified the United Nations Framework Convention on Climate Change, which has as its objective the stabilization of greenhouse gas concentrations in the earth's atmosphere but does not impose specific goals or timetables for limiting emissions. In response, federal agencies developed a plan for reducing greenhouse gas emissions, primarily through voluntary efforts by companies, state and local governments, and other organizations. Since that time, federal agencies have sponsored voluntary programs that encourage private and public sector entities to curb their greenhouse gas emissions by providing technical assistance, education, research, and information sharing. The administration has promoted such voluntary programs, along with other measures, as an alternative to mandatory emissions reductions.

In February 2002, the president announced a Global Climate Change Initiative to reduce the rate of increase in greenhouse gas emissions in the United States. Specifically, he established the goal of reducing the emissions intensity of the United States by 18 percent between 2002 and 2012. Emissions intensity is a ratio calculated by dividing emissions in a given year by economic output for that year. In support of this goal, the president announced two new voluntary programs aimed at securing private sector agreements to voluntarily reduce greenhouse gas emissions or emissions intensity.

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[9]The revenue losses resulting from provisions of federal tax laws may, in effect, be viewed as expenditures channeled through the tax system. The Congressional Budget and Impoundment Control Act of 1974, as amended, requires that the budget include the level of tax expenditures under existing law. Like the annual lists of tax expenditures prepared by the Department of the Treasury, this testimony considers only tax expenditures related to individual and corporate income taxes and does not address excise taxes.

- *Climate Leaders,* an Environmental Protection Agency (EPA)-sponsored government-industry partnership established in February 2002, works with firms[10] to develop long-term climate change strategies. According to EPA officials, as of November 2005, 74 firms were participating in the program.

- *Climate VISION* (Voluntary Innovative Sector Initiatives: Opportunities Now), introduced in February 2003 and coordinated by the Department of Energy (DOE) in cooperation with EPA and other federal agencies, works with trade groups[11] to develop strategies to reduce their members' greenhouse gas emissions intensity. Most industries participating in the program are represented by a single trade group. As of November 2005, 14 industry sectors and the Business Roundtable–an association of chief executive officers representing diverse sectors of the economy–were participating in the program. According to DOE, the trade groups participating in Climate VISION typically have high energy requirements.

The Extent of Changes in Federal Climate Change Funding Are Difficult to Determine

OMB reports indicated that federal funding on climate change increased from $2.35 billion in 1993 to $5.09 billion in 2004, or from $3.28 billion to $5.09 billion after adjusting for inflation, and that funding increased in three of the four categories between 1993 and 2004. However, changes in reporting methods limit the comparability of funding data over time, making it unclear whether total funding actually increased as reported. OMB reports also indicated that 12 of the 14 federal agencies receiving funding for climate change programs in 2004 received more funding in that year than they had in 1993, but again, unexplained modifications in the reports' contents limit the comparability of agencies' funding data, making it difficult to determine whether funding increased as OMB reported.

[10]For the sake of brevity, we refer to all participants in the Climate Leaders programs as firms, even though one of them, the National Renewable Energy Laboratory, is a federal research laboratory.

[11]We refer to all Climate VISION participants as trade groups, even though one participant, the Tennessee Valley Authority, is a utility.

Reported Federal Climate Change Funding Increased for Three of the Four Funding Categories, but Data May Not Be Comparable Over Time

We found that federal funding for climate change, as reported by OMB, increased from $2.35 billion in 1993 to $5.09 billion in 2004 (117 percent), or from $3.28 billion to $5.09 billion (55 percent) after adjusting for inflation, and reported funding increased for three of the four categories between 1993 and 2004. However, changes in reporting methods limit the comparability of funding data over time, and therefore it was unclear whether total funding actually increased as OMB reported. We were unable to compare changes in the fourth category–climate-related tax expenditures–because OMB reported estimates for proposed but not existing tax expenditures from 1993 to 2004. Specifically, for 1993 through 2004, we found the following:

- **Technology** funding, as reported by OMB, increased from $845 million to $2.87 billion (240 percent), or from $1.18 billion to $2.87 billion (143 percent) in inflation-adjusted dollars. The share of total climate change funding devoted to technology increased from 36 percent to 56 percent. However, we identified several ways that technology funding presented in OMB's more recent reports may not be comparable to previously reported technology funding. For example, OMB added accounts to the technology category that were not reported before or were presented in different categories and did not explain whether these accounts reflected the creation of new programs or a decision to count existing programs for the first time. OMB also expanded the definitions of some accounts to include more activities without clarifying how the definitions were changed. Furthermore, OMB reports include a wide range of federal climate-related programs and activities, some of which–such as scientific research on global environmental change–are explicitly climate change programs, whereas others–such as technology initiatives promoting emissions reduction or encouraging energy conservation–are not solely for climate change purposes.

- **Science** funding increased from $1.31 billion to $1.98 billion (51 percent), according to both OMB and CCSP, or from $1.82 billion to $1.98 billion (9 percent) in inflation-adjusted dollars. However, science's share of total climate change funding decreased from 56 percent to 39 percent. OMB and CCSP generally presented consistent climate change science funding totals from 1993 through 2004. CCSP reports also presented more detailed data, but these data were difficult to compare over the entire period because CCSP periodically introduced new categorization methods without explaining how the new methods related to the ones they replaced. Specifically, over the period CCSP used seven different methods to present detailed science funding data, making it impossible to develop consistent funding trends for the entire timeframe.

- **International assistance** funding reported by OMB increased from $201 million to $252 million (25 percent), but decreased from $280 million to $252 million (10 percent) in inflation-adjusted dollars. Moreover, its share of total climate change funding decreased from 9 percent to 5 percent. International assistance funding reported by OMB was generally comparable over time, although several new accounts were added without explanation.

- **Tax expenditures** were not fully reported by OMB for any year, even though climate-related tax expenditures amounted to hundreds of millions of dollars in forgone federal revenue in fiscal year 2004. Although not required to do so, OMB reported *proposed* climate-related tax expenditures. However, OMB did not report revenue loss estimates for *existing* climate change-related tax expenditures. Whereas OMB reported no funding for existing climate change-related tax expenditures in 2004, the federal budget for that year listed four tax expenditures related to climate change, including estimated revenue losses of $330 million for incentives to develop certain renewable energy sources.

Table 1 shows federal climate change funding by category between 1993 and 2004.

Table 1: Reported Federal Climate Change Funding by Category, Selected Years

Discretionary budget authority in millions of dollars

Category	1993	1997	2001	2004
Technology	$845	$1,056	$1,675	$2,868
Science	1,306	1,656	1,728	1,976
International assistance	201	164	218	252
Tax expenditures	[a]	[a]	[a]	[a]
Total	**$2,352**	**$2,876**	**$3,603**	**$5,090**

Source: GAO analysis of OMB data.

[a]OMB did not report revenue loss estimates for existing climate-related tax expenditures for this year.

Table 2 shows funding data for the seven largest technology accounts, which accounted for 92 percent of technology funding in 2004.

Table 2: Reported Technology Funding for Selected Accounts and Years

Discretionary budget authority in millions of dollars

Agency	Account	1993	1997	2001	2004
Department of Energy	Energy Conservation	$346	$414	$810	$868
	Energy Supply -- Fossil Energy Research and Development (R&D)	250	201	292	455
	Energy Supply --Renewable Energy	249	244	370	352
	Science (Fusion, Sequestration, and Hydrogen) [a]	[b]	[b]	35	333
	Energy Supply – Nuclear [c]	[b]	[b]	39	309
National Aeronautics and Space Administration	Exploration, Science, and Aeronautics	[b]	[b]	[b]	227
Environmental Protection Agency	Environmental Programs and Management	[b]	70	96	89
Other		[b]	127	33	235
Total		**$845**	**$1,056**	**$1,675**	**$2,868**

Source: GAO analysis of OMB data.

[a]Sequestration can be defined as the capture and isolation of gases that otherwise could contribute to global climate change.

[b]OMB did not report a value in the technology category for this account for this year.

[c]For 2001 Energy Supply -- Nuclear funding, we counted the Nuclear Energy Research Initiative and Energy Supply -- Nuclear budget accounts as presented by OMB. OMB did not separately present these accounts for 2004, and included funding for the Nuclear Energy Research Initiative within the Energy Supply--Nuclear account.

OMB and CCSP officials told us that time constraints and other factors contributed to changes in report structure and content over time. For example, OMB officials said that the short timeline for completing the report required by the Congress (within 45 days of submitting the upcoming fiscal year's budget for the three most recent reports) limited OMB's ability to analyze data submitted by agencies. OMB and CCSP officials also noted that each report was prepared in response to a one-time requirement and that they were not directed to use the same report format over time or to explain differences in methodology from one report to another. The director of CCSP told us that changes to climate change science reports, such as the creation and deletion of different categorization methods, were made because CCSP was changing towards a goals-oriented budget, and categorization methods changed as the program evolved. The director also said that future reports will explicitly present budget data as it was reported in prior reports to retain continuity, even if new methods are introduced. Regarding tax expenditures, OMB officials said that they consistently included in the reports those proposed tax expenditures where a key purpose was specifically to reduce greenhouse gas emissions. They also stated that they had not included existing tax expenditures that may reduce greenhouse gas emissions but that were enacted for other purposes, and that the Congress had not provided any guidance to suggest that additional tax expenditure data should be included in the annual reports.

Reported Funding For Most Agencies Increased, but Unexplained Changes in Report Content Limit the Comparability of Data Over Time

OMB reported that 12 of the 14 agencies receiving funding for climate change programs in 2004 received more funding in that year than they had in 1993. However, it is unclear whether funding changed as OMB reported because of, among other things, unexplained changes in what was defined as climate change funding. Reported funding for the Department of Energy (DOE), the agency with the most reported climate-related funding in 2004, increased from $963 million to $2.52 billion (162 percent), or from $1.34 billion to $2.52 billion (88 percent) after adjusting for inflation. DOE and NASA accounted for 81 percent of the reported increase in funding from 1993 through 2004. However, because agency funding totals are composed of individual accounts, changes in the reports' contents, such as the unexplained addition of accounts to the technology category, limit the comparability of agencies' funding data over time, making it difficult to determine if these are real or definitional increases. OMB stated that it consistently reported funding data for the 3 years presented in each of its reports and that there had been no requirement to use a consistent format from one report to the next or to explain differences in methodology from one report to another.

We recommended that OMB and CCSP use the same format for presenting data from year-to-year, explain changes in report content or format when they are introduced, and provide and maintain a crosswalk comparing new and old report structures when changes in report format are introduced. We also recommended that OMB include data on existing climate-related tax expenditures in future reports. OMB agreed with the recommendations relating to report content and format and said it was studying the other recommendations. CCSP agreed with all of our recommendations. Both agencies appear to have taken actions in response to our recommendations, but we have not comprehensively reviewed the extent to which they may have done so.

Voluntary Programs Have Shown Mixed Progress

EPA and DOE expect participants in their respective programs to complete a number of actions within certain timeframes. However, participants' progress toward completing those actions was mixed, and neither agency had a written policy for dealing with this situation. EPA estimated that the first fifty Climate Leaders participants accounted for at least 8 percent of U.S. emissions on average for the years 2000 through 2003, and DOE estimated that Climate VISION participants account for over 40 percent of U.S. greenhouse gas emissions; both agencies believe these to be conservative estimates. While EPA and DOE are participating in an interagency process to estimate the impact of their programs on emissions, we found that accurately attributing specific emissions reductions to either program would be difficult.

Some Climate Leaders and Climate VISION Participants Have Not Completed Program Steps as Soon as Expected, and Neither Agency Had a Written Policy For Dealing with Such Participants

EPA and DOE expect participants in their voluntary emissions reduction programs to complete a number of actions; however, participants' progress toward completing those actions, as well as the agencies' efforts to track accomplishments, varied. For example, within about 1 year of joining the program, EPA expects firms to enter into discussions with the agency to establish an emissions reduction goal and to complete these negotiations, generally within another year. As of November 2005, 38 of the 74 firms had established goals, while most of the other 36 firms, including 13 that joined in 2002, were still working to establish goals; most of the remaining firms had joined the program recently and had not yet established goals. EPA officials told us that they were developing a system for tracking firms' progress in accomplishing the key steps associated with participating in the program, but were still in the process of obtaining and validating data from participants. While EPA officials told us that they would be willing to remove participants from the program if they were not progressing as expected, they had not specified the conditions under which they would do so. DOE asks that trade groups participating in its Climate VISION program develop a work plan for measuring and reporting emissions information within about 1 year after joining the program and report their emissions levels. As of November 2005, 11 of the 15 participating trade groups had completed their work plans and 5 groups had reported on emissions. As of November 2005, DOE officials said that the agency did not have a system for tracking how long each group takes to complete its work plan and report emissions data. Furthermore, while DOE officials said that the agency would remove groups from the program if they did not seem to be taking sufficient action, DOE had not yet established specific deadlines for reporting emissions. Because DOE did not have a system for tracking how long participants take to complete key program steps–and neither DOE nor EPA had established written policies for taking action against participants not progressing as expected–it will be difficult for them to ensure that all participants are meeting program expectations.

We recommended that DOE develop a system for tracking participants' progress in completing key steps associated with its Climate VISION Program, and that both EPA and DOE develop written policies establishing the actions the agencies will take if participants are not completing program steps on time. DOE and EPA appear to have taken steps to implement our recommendation regarding a written policy, but we have not conducted a comprehensive review to determine the extent to which the recommendations have been implemented.

Participants in Both Programs Have Set Quantitative Emissions-Related Goals

The specific types of emission reduction goals being established by Climate Leaders firms and Climate VISION groups varied. Of the 38 firms participating in Climate Leaders that had established emission reduction goals as of November 2005, 19 had committed to reduce their total greenhouse gas emissions, 18 had committed to reduce their emissions intensity (emissions per unit of output), and 1 firm had committed to reduce both its total emissions and its emissions intensity. Furthermore, firms' goals differed in their geographic scope and the time period they covered. For example, Cinergy Corporation pledged to reduce its total U.S. domestic greenhouse gas emissions by 5 percent from 2000 to 2010, while Pfizer, Inc., pledged to reduce its worldwide emissions by 35 percent per dollar of revenue from 2000 to 2007. Table 3 presents information on the 38 firms' goals.

Table 3: Climate Leaders Goals as of November 2005

Company	Metric used and percent to be reduced			Geographic scope of goal		Time period covered
	Emissions	Emissions intensity	Metric for measuring emissions intensity	United States	Global	
3M	30			x		2002-07
Advanced Micro Devices, Inc.		40	Manufacturing index		x	2002-07
American Electric Power	4			x		2001-06
Ball Corporation		16	Production index	x		2002-12
Bank of America Corporation	9			x		2004-09
Baxter International Inc.		16	Unit of production value	x		2000-05
Calpine		4	Megawatt hour	x		2003-08
Caterpillar		20	Dollar of revenue		x	2002-10
Cinergy Corporation	5			x		2000-10
The Collins Companies	18			x		2000-10
Eastman Kodak Company	10				x	2002-08
Exelon Corporation	8			x		2001-08
First Environment, Inc.	Net 0[a]			x		by 2008
FPL Group, Inc.		18	Kilowatt hour	x		2001-08
Frito-Lay, Inc.		14	Pound of production	x		2002-10
GAP, Inc.		11	Square foot	x		2003-08
General Electric	1				x	2004-12
General Motors Corporation	10			x[b]		2000-05
Green Mountain Energy Co.	Net 0[a]			x		2005-09
Hasbro, Inc.	30			x		2000-07
Holcim (U.S.) Inc.		12	Ton of cement	x		2000-08
IBM Corporation[c]	10	4	Energy use		x	Average annual reduction 2000-05
Interface, Inc.		15	Unit of production	x		2001-10
International Paper	15			x		2000-10
Johnson & Johnson	14			x		2001-10
Marriott International, Inc.		6	Available room	x		2004-10
Melaver, Inc.	Net 0[a]			x		2006-09
Miller Brewing Company		18	Barrel of production	x		2001-06
National Renewable Energy Lab.		10	Square foot	x		2000-05
Pfizer, Inc.		35	Dollar of revenue		x	2000-07
PSEG		18	Kilowatt hour	x		2000-08
Roche Group US Affiliates	10			x		2001-08
SC Johnson		23	Pound of product	x		2000-05
Staples, Inc.	7			x		2001-10
St. Lawrence Cement		15	Ton of product		x	2000-10
Sun Microsystems	20			x		2002-12
United Technologies Corporation		16	Dollar of revenue		x	2001-06
Xerox Corporation	10				x	2002-12

Source: GAO analysis of EPA data.

[a]Net zero means that the company will substitute emissions it produces by some other activity such that no new, additional emissions are produced. Green Mountain Energy, for example, is substituting emissions from fossil fuel-based energy, such as coal or gas, with the purchase of renewable energy that produces few greenhouse gas emissions relative to fossil fuels.

[b]General Motors pledged to reduce total greenhouse gas emissions from its North American facilities.

[c]IBM pledged to achieve a reduction in its average annual carbon dioxide emissions equivalent to 4 percent of the emissions associated with the company's worldwide energy use. IBM also pledged to reduce its perfluorocarbon emissions from its semiconductor manufacturing processes by 10 percent from 2000 to 2005.

In contrast to EPA's program, 14 of the 15 trade groups participating in DOE's Climate VISION established an emissions-related goal in collaboration with DOE or another federal agency upon joining the program. (The remaining group, the Business Roundtable, did not establish a quantitative emissions goal because of the diversity of its membership). According to a DOE official, participants need not establish new goals as a condition of joining the program. Nine of the 14 groups had set goals to improve their emissions intensity, 2 groups had established a goal of reducing emissions of specific greenhouse gases, 2 groups had set goals to improve energy efficiency, and 1 group had established a goal of both reducing its total emissions and improving its energy efficiency. For example, the American Forest & Paper Association pledged to reduce emissions intensity by 12 percent between 2002 and 2012, while the American Iron and Steel Institute agreed to a 10-percent, sector wide increase in energy efficiency by 2012. Some of these groups stated that their goals would be difficult to achieve, however, without reciprocal federal actions, such as tax incentives or regulatory relief. Table 4 presents information on Climate VISION industry groups' goals.

Table 4. Climate VISION Trade Groups' Goals as of November 2005

Industry/ participant	Type of goal: Reduce emissions	Type of goal: Reduce emissions intensity	Type of goal: Improve energy efficiency	Goal metric	Start and end dates
Aluminum • Aluminum Association		53%		Combined direct carbon emissions intensity based on PFC reductions and reduced anode carbon consumption	1990-2010
Automobiles • Alliance of Automobile Manufacturers		10%		Carbon dioxide emissions per vehicle produced	2002-12
Cement • Portland Cement Association		10%		Carbon dioxide emissions per ton of cementitious product produced or sold	1990-2020
Chemicals • American Chemistry Council		18%[a]		Greenhouse gas emissions intensity[b]	1990-2012
Electric power • American Public Power Association • Edison Electric Institute • Electric Power Supply Association • Large Public Power Council • National Rural Electric Cooperative Association • Nuclear Energy Institute • Tennessee Valley Authority		The equivalent of 3 to 5%		Ratio of carbon equivalent emissions to generation in megawatt hours	2002-02 to 2010-12
Forest products • American Forest & Paper Assn.		12%		Greenhouse gas intensity	2000-12
Iron and steel • American Iron and Steel Institute			10%	Millions of British thermal units per ton of steel produced	2002-12
Lime • National Lime Association		8%		Fuel used per ton of lime produced	2002-12
Magnesium • International Magnesium Assn.	100%			Sulfur hexafluoride emissions	by 2010[c]
Minerals • Industrial Minerals Association North America		4.2%		Greenhouse gas emissions from fuel combustion	2002-12
Mining • National Mining Association			10%	Energy efficiency	2002-12
	25 MMTCE			Methane emissions in million metric tons carbon dioxide equivalent/year	2002-12[d]
	2 MMTCE			Million metric tons of carbon equivalent	2002-15[e]
Oil and gas • American Petroleum Institute			10%	Energy efficiency	2002-12
Railroads • American Association of Railroads		18%		Transportation-related greenhouse gas emissions intensity adjusted for traffic levels in ton miles	2002-12
Semiconductors • Semiconductor Industry Assn.	10%			PFC emissions in million metric tons of carbon equivalent	1995–2010

Sources: Climate VISION web site.

[a]According to the American Chemistry Council (ACC), the U.S. chemistry industry reduced its greenhouse gas intensity by 12 percent from 1990 to 2000, with projections to 2002.
[b]ACC measures its greenhouse gas emissions intensity using a special index that is particularly suited for an industry with a diverse product base. The index measures changes in the physical quantity of production, and where these data are unavailable, the index is based on changes in electricity consumption and production worker hours.
[c]The International Magnesium Association committed to eliminate all SF_6 emissions by 2010 and did not define a baseline year because of the nature of its goal.
[d]The National Mining Association committed to maintain annual methane emissions reductions achieved since 1990.
[e]The National Mining Association committed to maximize efforts to reduce annual carbon reductions projected as a result of the partnership with DOE. These projections are 600,000 metric tons of carbon equivalent by 2010 and 2 million metric tons by 2015.

Both Agencies Had Estimated Their Programs' Coverage and Were Working to Estimate Their Impact, But It Will Be Difficult to Attribute Specific Emissions Reductions From These Programs

EPA and DOE both estimated the share of total U.S. greenhouse gas emissions attributable to participants in their respective programs and were working to develop an estimate of the programs' impacts. EPA estimated that Climate Leaders participants accounted for at least 8 percent of U.S. emissions. According to EPA, this was a conservative estimate, because it was based solely on emissions from the program's first 50 participants. DOE estimated that Climate VISION participants accounted for over 40 percent of U.S. greenhouse gas emissions and noted that this was a conservative estimate. Both agencies were participating in an interagency process to estimate the effect of their programs on reducing emissions, which was expected to be completed in 2006. However, preparing accurate estimates of these programs' impacts will be difficult. First, there is considerable overlap between these two programs and other voluntary programs. For example, 60 of the 74 Climate Leaders participants also participated in one or more other EPA programs, and 3 of the 14 Climate VISION participants with quantitative goals also participated in EPA voluntary programs. Such overlap makes it difficult to determine the effects that are attributable to a given program. Second, it will be difficult to determine how much of a firm's or trade group's emissions reductions can be attributed to its participation in the program because the level of a participant's emissions in the absence of the program is unknown. For example, higher energy prices or changes in business operations could lead to emissions reductions, making it difficult to distinguish reductions attributable to participation in the program versus other causes.

Conclusions

In conclusion, we found that the lack of consistency and clarity in OMB's and CCSP's reports made it difficult to identify trends in federal climate change funding. A better understanding of these expenditures is needed before it is possible to assess CCSP's and other federal agencies' progress towards their climate change goals. We therefore made a total of seven recommendations to OMB and three to CCSP to clarify how they present climate change funding information. OMB agreed with most of our recommendations and CCSP agreed with all of our recommendations. Both agencies appear to have taken steps to implement our recommendations, but we have not comprehensively reviewed the extent to which they have done so.

We found that opportunities remain to improve the progress of both voluntary programs, since some industry participants in both programs appeared not to be progressing at the rate expected by the agencies. We also found that it will be difficult for the agencies to estimate the emissions reductions attributable to their programs, due to overlaps between organizations participating in more than one voluntary program and to the fact that it was difficult to know how much of a participant's emissions reductions were a direct result of the program or other factors, such as higher energy prices, which generally lead to lower emissions. Therefore, we recommended that DOE develop a system for tracking participants' progress in completing key steps associated with the program, and that both EPA and DOE develop written policies that establish the actions the agencies will take if participants are not completing program steps on time. EPA did not comment on our recommendation; DOE stated that it agreed with our recommendation regarding a tracking system and would consider our recommendation regarding establishing a written policy. We have not fully reviewed the extent to which the recommendations have been implemented.

Mr. Chairman, this concludes my prepared statement. I would be pleased to respond to any questions you or other Members of the Committee may have.

Contact and Staff Acknowledgements:

For further information regarding this testimony, please contact me at (202) 512-3841 or stephensonj@gao.gov. John Healey, Anne K. Johnson, and Vincent P. Price made key contributions to this testimony. John Delicath, Karen Keegan, and Charles Egan also made important contributions.

(360768)

Mr. ISSA. Thank you, Mr. Stephenson.

And I now ask unanimous consent that all statements be placed in the record, along with any other submissions from any of the panelists.

Without objection, so ordered.

Dr. Dahlman.

STATEMENT OF DR. ROGER C. DAHLMAN

Dr. DAHLMAN. Mr. Chairman and members of the subcommittee, thank you very much for the opportunity to appear before you today and to report on the Federal Carbon Cycle Research Program. This research is an element of the Climate Change Science Program and it is coordinated by one of its working groups, the Carbon Cycle Interagency Working Group. I am co-chair of that working group. Mr. Ed Sheffner, who is seated in the second row behind me, is the other co-chair. He is from the National Aeronautics and Space Administration and I am from the Department of Energy.

As I breeze through my statement today, I will cite references to relevant pages of the written testimony so that everyone can perhaps follow along with more detail.

My testimony focuses on the interagency program that implements the carbon cycle research element of the Climate Change Science Program strategic plan. There is a reference to the strategic plan in the testimony. This strategic plan guides the research of the interagency carbon cycle program and we follow it very closely.

The science panel of this hearing will point out that not all CO_2 emissions remain in the atmosphere and there is a large net exchange of CO_2 between the atmosphere and oceans and land. The net exchange of carbon from the atmosphere into the ocean and land on a global scale involves a large number of processes and properties, and, accordingly, the U.S. Government supports an aggressive multi-and inter-agency research program to better understand the quantities and uncertainties of the fluxes, properties, processes, and numerous components of the carbon cycle.

The research results are providing new knowledge about contemporary changes in carbon sinks and the results are important for projecting future atmospheric CO_2 change and the influence on climate. The program is also developing tools for measuring and modeling changes in carbon sinks, and it provides a scientific foundation to support greenhouse gas management strategies.

The Carbon Cycle Research Program is described in the strategic plan and there are six questions that guide the research. These six questions are on page 3 of the testimony. Briefly, the first question focuses on North American carbon sources, sinks, and processes. The North American Carbon Program, and Dr. Wofsy's testimony provide snapshots of some of the scientific results from this program. The second question focuses on ocean carbon sources and sinks.

Currently, these are two high priority activities of the integrated Carbon Cycle Research Program. The next two questions address the management of carbon sources and sinks at different scales. The fifth question addresses the science needed for future projections of atmospheric CO_2, and the last question deals with scientific research needed for managing components of the carbon cycle.

I want to emphasize that these questions have been carefully defined, extensively reviewed, and vetted with the carbon cycle science community. They have been discussed with stakeholders and are the key guideposts for implementing the integrated research program.

Briefly, the Carbon Cycle Interagency Working Group [CCIWG] is a cooperative venture and it coordinates and integrates the research across agencies. It has responsibility for coordinating solicitations and reviews of research proposals for implementing targeted research and for providing an interface with the scientific community and for updating assessments of research needs and priorities. It also identifies new interagency research activities.

On page 5 of the testimony there is a list of 10 Federal agencies and departments that participate in this Interagency Working Group.

I want to briefly mention a number of activities that are carried out by this Interagency Program. These are not all-inclusive, but are representative of the kind of work that this cross-agency program supports.

The first item, of course, is the coordination of the carbon cycle research on page 5 of the testimony. The CCIWG coordinates research among its participating agencies, leverages efforts and avoids duplication, and enhances the overall scientific findings and products. The coordination builds on unique agency capabilities and resources. For example, I want to cite a combination of AmeriFlux observations from a program supported by DOE, NASA's GLOBALVIEW observations of carbon dioxide in the atmosphere, including platform observation and instrumentation; and NASA's observation capability from space. The integration of all of those activities led to a better understanding and quantification of the terrestrial carbon parameters.

I mentioned the North American Carbon Program, which is explained in a little bit more detail on page 6 of the testimony. This is a priority research program whose goals are to quantify the magnitudes and distributions of carbon sources and sinks for North America and adjacent oceans, to understand the processes controlling the sources and sink dynamics, to introduce consistent analyses of North American carbon budget, and explain regional and sectoral values of year-to-year variability.

Another priority program noted on page 7 of the testimony is the Ocean Carbon and Climate Change [OCCC] Program. This effort is addressing how much atmospheric carbon dioxide is taken up by oceans at the present time and how climate change may affect the future behavior of the ocean carbon sink. The NACP and the OCCC Programs are synergistic and converge to address the dynamics of coastal oceans adjacent to North America and its land-sea margins.

Another activity involves the Climate Change Science Program Synthesis and Assessment Product 2.2. It is noted on page 7 of the testimony. The Carbon Cycle Interagency Working Group sponsors this assessment on the State of the Carbon Cycle Report. It is under review now and is scheduled for release in March 2007.

Mr. ISSA. Excellent, Doctor. The remainder will be placed in the record, if that is all right with you.

Dr. DAHLMAN. OK. Thank you very much.

Mr. ISSA. Thank you.

[The prepared statement of Mr. Dahlman follows:]

TESTIMONY OF

DR. ROGER DAHLMAN

PROGRAM MANAGER

CLIMATE CHANGE RESEARCH DIVISION
OFFICE OF BIOLOGICAL AND ENVIRONMENTAL RESEARCH
OFFICE OF SCIENCE
U.S. DEPARTMENT OF ENERGY

BEFORE THE

SUBCOMMITTEE ON ENERGY AND RESOURCES
GOVERNMENT REFORM COMMITTEE

U.S. HOUSE OF REPRESENTATIVES

ON THE SUBJECT OF
"REBALANCING THE CARBON CYCLE"

SEPTEMBER 27, 2006

Introduction

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today and report on the Federal Carbon Cycle Research Program. This research is an important element of the Climate Change Science Program (CCSP), and is coordinated by one of its working groups, the Carbon Cycle Interagency Working Group. I am co-chair of that working group; Mr Ed Sheffner of the National Aeronautics and Space Administration (NASA) is the other co-chair, and I gratefully acknowledge his significant contributions to this testimony.

My testimony focuses on scientific scope of the Inter-Agency program implementing the Carbon Cycle research element of the CCSP Strategic Plan. The U.S. Carbon Cycle Research Program is embedded in the U.S. Climate Change Research Program. It implements research related to an important CCSP goal, "to improve quantification of the forces bringing about changes in the Earth's climate and related systems." Atmospheric CO_2 is considered a primary forcing agent of future climate; accordingly, CO_2 and carbon cycle research is a high priority of the CCSP.

We know from long-term measurements that the concentration of atmospheric CO_2 is increasing, currently at the rate of about 1.8 ppm per year. Much of the increase is attributed to CO_2 emissions from fossil fuel combustion, as reported by members of the Science Panel at this hearing. It is also recognized that not all the CO_2 emissions remain in the atmosphere because there is a large net exchange of CO_2 from the atmosphere into the ocean and land. This net exchange of carbon from the atmosphere into the ocean and land on a global scale involves a large number of processes and properties, where some are known qualitatively. An aggressive, multi- and inter-agency research program, the

U.S. Carbon Cycle Carbon Program, is employed by the U.S. Government to better understand quantities and uncertainties of fluxes, properties and processes of numerous components of the carbon cycle. Much of the research focuses on quantifying rates and magnitudes of CO_2 exchanges between the atmosphere and ocean and the atmosphere and land, and on improving estimates of terrestrial and oceanic carbon sources and sinks. Carbon cycle research programs sponsored by Agencies of this Program seek to understand the processes that currently remove more than half of fossil fuel emissions from the atmosphere before they can affect the climate. It is crucial to know whether these processes will continue to operate and whether there is anything that we can do to increase their efficiency. Without reliable practical knowledge of the sinks, we can't hope to project the impact of future CO_2 emissions. This basic research is needed to address one of the most significant sources of uncertainty in projections of future climate. Results are providing knowledge of contemporary changes in carbon sinks which, when combined with other information, provides the basis for projecting future atmospheric CO_2 change and its influence on climate. The Program is also developing tools for measuring and prognostic modeling of changes in carbon sinks, and it provides the scientific foundation to support future greenhouse gas management strategies.

The U.S. Government Carbon Cycle Program for implementing research is described in chapter seven of the CCSP Strategic Plan (http://www.climatescience.gov/Library/stratplan2003/) . Key scientific questions that guide the Government's implementation of an integrated Carbon Cycle Program are:

- "What are the magnitudes and distributions of North American carbon sources and sinks on seasonal to centennial time scales, and what are the processes controlling their dynamics?"

- "What are the magnitudes and distributions of ocean carbon sources and sinks on seasonal to centennial time scales, and what are the processes controlling their dynamics?"
- "What are the effects on carbon sources and sinks of past, present, and future land-use change and resource management practices at local, regional, and global scales?"
- "How do global terrestrial, oceanic, and atmospheric carbon sources and sinks change on seasonal to centennial timescales, and how can this knowledge be integrated to quantify and explain annual global carbon budgets?"
- "What will be the future atmospheric concentrations of carbon dioxide, methane, and other carbon-containing greenhouse gases, and how will terrestrial and marine carbon sources and sinks change in the future?"
- "How will the Earth system, and its different components, respond to various options for managing carbon in the environment, and what scientific information is needed for evaluating these options?"

These questions have been carefully defined, extensively reviewed and vetted with the carbon cycle science community, and discussed with stakeholders. They are key reference points used by the Carbon Cycle Interagency Working Group (CCIWG) in carrying out carbon cycle science research in the United States.

The CCIWG is one of nine natural sciences and cross-cutting working groups that coordinate and integrate CCSP's research elements within and across agencies. The CCIWG has responsibility for coordinating solicitations and reviews of research proposals (when appropriate); for implementing targeted research; for providing an interface with the scientific community; for updating assessments of research needs and priorities; and for identifying new Inter-Agency research activities. The CCIWG provides up-to-date information to both government and non-government users, it annually communicates results and accomplishments in the "Our Changing Planet" report to Congress, and it is sponsoring the development of a Synthesis and Assessment Product (SAP, see below).

The Interagency Working Group is comprised of 10 participating federal agencies and departments, which support and execute U.S. carbon cycle science research:

- Department of Agriculture (USDA):
    - Agricultural Research Service (ARS)
    - Cooperative State Research, Education and Extension Service (CSREES)
    - Forest Service (FS)
    - Natural Resources Conservation Service (NRCS)
- Department of Commerce (DOC):
    - National Oceanic and Atmospheric Administration (NOAA)
- Department of Energy (DOE): Climate Change Research Division (CCRD)
- Environmental Protection Agency (EPA)
- Department of Interior (DOI): United States Geological Survey (USGS)
- National Aeronautics and Space Administration (NASA): Earth Science Division (ESD)
- National Science Foundation (NSF)

The CCIWG is currently co-chaired by members from the DOE and NASA, and has proved to be a very effective means for achieving management and coordination goals. Selected activities of the CCIWG include:

- Coordinating carbon cycle science research across multiple agencies, including enhancement of global and national carbon observational systems and networks;
- Implementing the North American Carbon Program (NACP);
- Implementing Ocean Carbon and Climate Change (OCCC) Program;
- Completing the Synthesis and Assessment Product 2.2 of the CCSP;
- Promoting the development of coupled carbon cycle-climate and -Earth system models;
- Providing scientific information for carbon sequestration; and
- Promoting joint research with Canada and Mexico on the North American carbon cycle.

Coordination of carbon cycle science: The CCIWG coordinates research among its participating agencies to leverage efforts and avoid duplication, while enhancing overall scientific findings and products. Coordination builds on unique agency capabilities and resources: for example, the AmeriFlux observational network of CO_2 fluxes between atmosphere and terrestrial biosphere led by DOE; NOAA's GLOBALVIEW CO_2 monitoring network (including airborne platforms and instrumentation); and NASA's capabilities in land, ocean and atmospheric observations from space. These observations are linked with models and other tools to gain a more complete understanding of changes in the carbon cycle, including improved quantification of terrestrial and oceanic carbon sources and sinks. Combined with research sponsored by the CCIWG participants on carbon cycle processes and fluxes (that include joint solicitations of research proposals by two or more participating agencies), the Carbon Cycle Science Program is leading to new clarity and insights into the carbon cycle at the local and regional levels. This new knowledge also enhances the ability to "scale up" carbon source and sink information to the Continental U.S. and North America, and provides foundations for global carbon cycle analysis.

North American Carbon Program (NACP): NACP is a priority research Program under the CCIWG which addresses key scientific questions noted above. The NACP goals are to quantify the magnitudes and distributions of carbon sources and sinks for North America and adjacent oceans; to understand the processes controlling source and sink dynamics; and to produce consistent analyses of North America's carbon budget that explain regional and sectoral values and year-to-year variability. The NACP is committed to understanding and quantifying the uncertainties related to the buildup of carbon dioxide, methane, and carbon monoxide in the atmosphere. Outcomes of the research are also expected to quantify more precisely parameters such as the fraction of fossil fuel carbon that is taken up by North America's ecosystems and adjacent oceans.

Ocean Carbon and Climate Change (OCCC) Program: The OCCC Program, another priority effort being implemented by the CCIWG, also addresses key scientific questions of carbon cycle research. OCCC goals are aimed at determining how much atmospheric carbon dioxide is being taken up by the ocean at the present time and how climate change will affect the future behavior of the oceanic carbon sink. The NACP and OCCC Program are synergistic, converging in addressing carbon dynamics in the coastal oceans adjacent to North America and at its land-sea margins, where changes in the terrestrial system greatly influence carbon processes in the coastal ocean. Coordinated NACP-OCCC research also quantifies carbon properties of coastal zones that influence atmospheric CO_2 concentration and trends over the continent.

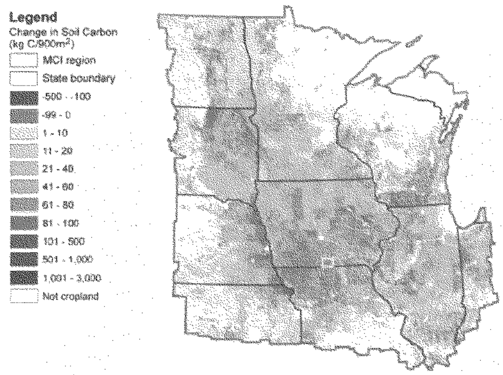
Synthesis and Assessment Product 2.2: The CCIWG is sponsoring the development of the Synthesis and Assessment Product (SAP) 2.2 of the CCSP. That assessment, "The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle," is available for public review, and is on schedule for final release in March 2007. SAP 2.2 will provide an initial estimate of the state-of-the-knowledge of the North American carbon budget in a format useful to decision makers, and it will provide the best currently available scientific information on carbon cycle properties in format and language useful for those making decisions regarding carbon management and policy. Every stage of the report, including the prospectus, selection of authors, and review of the draft, has been publicly vetted, including responses to public comments. The process for SAP 2.2 has been open and very transparent, and it has fostered important interactions with stakeholder communities—i.e., environmental, industry, and public interest organizations—and with individuals who may be concerned or affected by findings of the assessment. The range of stakeholder interactions has enhanced the value of the assessment for a broad spectrum of users, ensuring transparency of both process and product and relevance of the report to decision makers. Throughout the process, valuable stakeholder input has been obtained through workshops where scientists interact with representatives of stakeholder communities; a final workshop, which will include a review of the draft report, is scheduled for October 10, 2006.

Modeling and Integration: Observations of carbon reservoirs, exchange, and transport from NACP and OCCC are currently being evaluated and assimilated in coupled terrestrial-ocean-atmospheric and Earth System models. These models describe, simulate, and evaluate the spatial, seasonal, and inter-annual variations in carbon cycling, highlighting effects of atmospheric and climate variations. In addition, regional and global analyses of terrestrial and oceanic carbon sources and sinks are derived from remotely-sensed data. Observations of atmospheric CO_2 concentrations are assimilated with other emissions and flux data, and with the aid of mesoscale transport and global circulation models, these integrated approaches also identify locations of carbon sources and sinks. Integration of carbon cycle and climate system knowledge is implemented through joint activities of CCSP research elements such as Carbon Cycle, Climate Variability and Change, and Water Cycle research elements. Coordination of CCIWG research with these research elements supports coupled carbon cycle-climate modeling, including the use of high performance supercomputing resources to develop and run Earth system models.

Carbon Sequestration: The carbon dioxide concentration in the atmosphere can be influenced by reducing emissions of carbon compounds like carbon dioxide and methane, by increasing the amount of carbon removed from the atmosphere through natural terrestrial and oceanic uptake mechanisms, and by specific carbon management approaches. In the near term, carbon sequestration may help reduce the rate of increase in the concentration of greenhouse gases in the atmosphere and, over longer terms, carbon sequestration is expected to contribute to a suite of carbon management strategies. The CCIWG is already using knowledge from its NACP and OCCC Program investigations to address the key carbon management questions noted above. One example illustrates research related to the Mid-Continent Intensive of the NACP, where a provisional soil carbon sequestration map has been produced from a project awarded by the joint "Carbon Cycle Science" solicitation in 2004 (Fig 1). In another example, USDA operates the Greenhouse Gas Reduction Program through a Agricultural Carbon Enhancement network (GRACEnet) at 30 locations around the country to measure and predict carbon sequestration and greenhouse gas emissions across a range of agricultural systems, soils and climate zones. There are a number of other studies, like DOE's "Carbon Sequestration in Terrestrial Ecosystems (CSiTE) project, use knowledge of "natural" carbon cycle processes gained through earlier research to enhance terrestrial carbon sequestration. Mr. Eule's testimony this afternoon provides additional examples of carbon sequestration activities of the Climate Change Technology Program (CCTP).

Fig 1: T. West, ORNL, Information on carbon storage and emissions from soil is essential to understand the potential of agricultural systems to sequester carbon.

Cumulative change in soil carbon from 1991-2000 caused by changes in tillage intensity and crop rotations.



Research with Canada and Mexico on the North American carbon cycle: Joint research is being planned as a part of the Administration's Climate Change Bilateral Agreements with Canada and Mexico. The United States, Canada, and Mexico are engaged in planning coordinated North American carbon cycle research at the full continental scale. Representatives of governments and scientific communities of the respective countries have agreed to work together, and further coordination as well as scientific meetings are planned for early in 2007. Meeting participants will develop scope, scientific collaborations, and Inter-governmental interactions for a joint Carbon Program of North America.

Resources: Total federal investment in carbon cycle science is $118M for FY 06. The table below shows the budget breakdown by agency of the CCSP Carbon Cycle Program's scientific research.

U.S. Carbon Cycle Research Budget Fiscal Year 2006	
(Discretionary Budget Authority)	
Agency	**$Millions**
USDA	16.4
DOC/NOAA	16.4
DOE	16.6
DOI/USGS	4.4
NASA	40.7
NSF	23.2
SI	0.3
Total	**118.0**

Budget information is extracted from Tables 4 and 5, pages 7 and 8 of FY2006 Budget Tables, "Our Changing Planet. The U.S. Climate Change Science Program for Fiscal Year 2006. A Report by the Climate Change Science Program and The Subcommittee on Global Change Research. A Supplement to the President's Fiscal Year 2006 Budget" (http://www.usgcrp.gov/usgcrp/Library/ocp2006/default.htm)

Summary: Changes in the carbon reservoirs and processes on land and in oceans are currently the leading sources of uncertainty in the projection of climate change in the 21st century. About half of the CO_2 emitted to the atmosphere by fossil fuel sources is taken up by a combination of land and ocean sinks; and inter-annual variability in carbon exchange within the atmosphere is dominated by terrestrial ecosystems. Atmospheric increase of CO_2 is estimated to contribute 60%-70% of the calculated greenhouse gas forcing of the climate system. Future forcing of climate will depend significantly on the rate of natural and anthropogenic CO_2 and CH_4 increases in the atmosphere, which in turn are modulated by strength and longevity of terrestrial and oceanic sources and sinks. These properties of the carbon cycle have considerable uncertainty, which are being addressed as a priority of the U.S. Carbon Cycle Research Program.

Mr. ISSA. Mr. Eule.

STATEMENT OF STEPHEN D. EULE

Mr. EULE. Mr. Chairman and members of the subcommittee, thank you for the opportunity to appear before you today.

The administration believes the most effective way to meet the challenge of climate change is through an agenda that promotes economic growth, provides energy security, reduces pollution, and mitigates greenhouse gas emissions. To meet these goals, the administration has established a comprehensive approach, major elements of which include policies and measures to slow the growth of greenhouse gas emissions, advancing climate change science—and you heard quite a bit about that from Dr. Dahlman—accelerating technology development, and promoting international collaboration.

Since fiscal year 2001, the Federal Government has devoted nearly $29 billion to climate change programs. In 2002, President Bush set an ambitious but achievable goal to reduce the Nation's greenhouse gas intensity by 18 percent by 2012. To this end, the administration has implemented about 60 Federal programs, including voluntary programs, incentives, and mandates. Examples include Climate VISION, a program that works in partnership with 15 energy-intensive industry sectors represented by trade groups to reduce the greenhouse gas intensity of their operation. EPA's Climate Leaders and SmartWay Transport Partnership programs work with individual companies to achieve emissions reductions. USDA is using its conservation programs to provide incentives to increase terrestrial carbon sequestration, and the Department of Transportation has implemented a new fuel economy standard for light trucks and SUVs.

The Energy Policy Act of 2005 also includes tax incentives and credits, $1.6 billion in fiscal year 2007 alone, for a range of clean energy technologies, and it mandates 15 new appliance efficiency standards and a 7.5 billion gallon renewable fuel requirement by 2012.

Recent data suggests that we are well on our way toward meeting the President's intensity goal. While acting to slow the growth of greenhouse gas emissions in the near term, the United States is laying a strong technological foundation.

The Climate Change Technology Program, or CCTP, is designed to coordinate and prioritize the Federal Government's investment in climate related technology, which was nearly $3 billion in fiscal year 2006. CCTP's principal aim is to accelerate the development and lower the cost of advanced technologies that reduce, avoid, or sequester greenhouse gases. Last week, CCTP released its strategic plan, which revolves around six goals: reducing emissions from energy use and infrastructure, reducing emissions from energy supply, capturing and sequestering carbon dioxide, reducing emissions of non-carbon dioxide greenhouse gases, measuring and monitoring emissions, and bolstering contributions of basic science.

Transportation and power generation are two obvious areas of research under this framework. The President has proposed about $1.7 billion over 5 years for his Hydrogen Fuel Initiative and FreedomCAR Program to develop hydrogen technologies. A transition to hydrogen over the next few decades could transform the Nation's energy system and increase our energy security by making better use of diverse domestic energy resources for hydrogen production.

In his 2006 State of the Union Address, President Bush outlined plans for an Advanced Energy Initiative. AEI is designed to take advantage of technologies that, with a small push, could play a big role in reducing the use of foreign energy sources and lowering pollutant and CO_2 emissions. AEI includes significantly greater investments in solar and wind power, better battery and fuel cell technologies for pollution-free cars, cellulosic biorefining, near zero emission coal, and nuclear technologies.

Our research into carbon capture and sequestration recognizes that for the foreseeable future fossil fuels will continue to be a low-cost form of energy. DOE's Sequestration Program is finding ways to capture and store CO_2 produced when these fuels, especially coal, are used. DOE supports a nationwide network of seven carbon sequestration regional partnerships that are working on determining the best approach for sequestration in their regions, as well as regulatory and infrastructure needs. Future Gen is a 10 year, $1 billion government industry collaboration, which now includes the governments of India and South Korea, to build the world's first near zero emissions coal-fired power plant. This project will integrate the latest technologies in carbon sequestration, oxygen and hydrogen separation membranes, turbines, fuel cells, and coal-to-hydrogen gasification.

Looking further into the future, Next Generation nuclear energy and fusion energy systems offer tremendous potential as zero emission energy supply choices. The administration believes that well designed multilateral collaborations can leverage resources and quicken technology development. The International Partnership for the Hydrogen Economy, Carbon Sequestration Leadership Forum, Generation IV International Forum, Methane to Markets, all U.S. initiatives, and the International Thermonuclear Experimental Reactor [ITER] Fusion Project provide vehicles for international collaboration to advance these technologies.

The new Global Nuclear Energy Partnership seeks to develop a worldwide consensus on approaches to expanding safe use of zero emission nuclear power. Through the Asia-Pacific Partnership, the United States is working with Australia, China, India, Japan, and South Korea to accelerate the uptake of clean technologies in this rapidly growing region of the world.

These and other technologies we are developing today could 1 day revolutionize energy systems and put us on the path to ensuring access to clean, affordable energy, while dramatically reducing greenhouse gas emissions.

That concludes my statement. I would be happy to answer any questions you may have.

[The prepared statement of Mr. Eule follows:]

TESTIMONY OF
STEPHEN D. EULE
DIRECTOR, CLIMATE CHANGE TECHNOLOGY PROGRAM
U.S. DEPARTMENT OF ENERGY

BEFORE THE
SUBCOMMITTEE ON ENERGY AND RESOURCES
COMMITTEE ON GOVERNMENT REFORM
U.S. HOUSE OF REPRESENTATIVES

HEARING ON
"REBALANCING THE CARBON CYCLE"

SEPTEMBER 27, 2006

INTRODUCTION

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the Climate Change Technology Program (CCTP). I would like to begin my testimony by providing a brief overview of the Administration's approach to climate change, which provides the context in which CCTP operates.

As a party to the United Nations Framework Convention on Climate Change (UNFCCC), the United States shares with many countries its ultimate objective: stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. In February 2002, President Bush reaffirmed the Administration's commitment to this long-term goal of the Framework Convention.

There is a growing recognition that climate change cannot be dealt with effectively in isolation. Rather, it needs to be addressed as part of an integrated agenda that promotes economic growth, provides energy security, reduces pollution, and also mitigates greenhouse gas emissions. In July 2005, the G8 leaders, meeting in Gleneagles, Scotland, agreed to a plan of action that interlinked climate change objectives with these other important considerations.

Meeting these complementary objectives will require a sustained, long-term commitment by all nations over many generations. To this end, the President has established a robust and flexible climate change policy that harnesses the power of markets and technological innovation, maintains economic growth, and encourages global participation.

Major elements of this approach include: (1) implementing near-term policies and measures to slow the growth in greenhouse gas emissions; (2) advancing climate change science; (3) accelerating technology development and commercialization; and (4) promoting international collaboration.

For fiscal years 2001 to 2006, the Federal Government will have devoted nearly $29 billion to science, technology, international assistance, and incentive programs that support climate change objectives, more than any other nation. The President's fiscal year 2007 budget calls for $6.5 billion for climate-related activities.

NEAR-TERM POLICIES AND MEASURES

In 2002, President Bush set an ambitious but achievable national goal to reduce the greenhouse gas intensity—that is, emissions per unit of economic output—of the U.S. economy by 18 percent by 2012. At the time, the Administration estimated that achieving this commitment would avoid an additional 106 million metric tons of carbon-equivalent emissions in 2012 compared to the Energy Information Administration's (EIA) *Annual Energy Outlook 2002* business-as-usual base case projection, and would result in cumulative savings of more than 500 million metric tons of carbon-equivalent emissions over the decade.

To this end, the Administration is now implementing numerous programs—including partnerships, consumer information campaigns, incentives, and mandatory regulations—that are directed at developing and deploying cleaner, more efficient energy technologies, conservation, biological sequestration, geological sequestration and adaptation. For example, the Department of Energy's (DOE) Climate VISION program, which was announced in February 2003 by President Bush, is a public-partnership program established to contribute to the President's emission intensity reduction goal. Fourteen major industrial sectors and the Business Roundtable have committed to work with four agencies (Departments of Energy, Transportation, and Agriculture, and the Environmental Protection Agency) to reduce greenhouse gas emissions in the next decade. Participating industries include electric utilities; petroleum refiners and natural gas producers; automobile, iron and steel, aluminum, chemical, and magnesium manufacturers forest and paper producers; railroads; and the cement, mining, industrial minerals, lime, and semiconductor industries.

The Environmental Protection Agency's Climate Leaders and SmartWay Transport Partnership programs also work in voluntary partnership with specific commitments by industry to verifiably reduce emissions. The Department of Agriculture is using its conservation programs to provide substantial incentives to increase carbon sequestration in soils and trees, and to reduce methane and nitrous oxide emissions, two additional and potent greenhouse gases, from crop and animal agricultural systems. The Department of Transportation (DOT) has implemented a new fuel economy standard for light trucks, including sport utility vehicles, that is projected to result in significant reductions in CO_2 emissions over the life of the affected vehicles. DOT has also submitted an Administration proposal to Congress for authority to reform the setting and calculation of fuel economy standards for passenger automobiles.

In terms of financial incentives, new tax rules on expensing and dividends are helping to promote substantial new capital investment, including purchases of cleaner, more efficient equipment and facilities. The Energy Policy Act of 2005 provides for approximately $1.6 billion in tax credits and incentives in fiscal year 2007 to accelerate the market penetration of clean, efficient technologies. For example, the Act also provides tax credits of up to $3,400 for the most highly fuel efficient vehicles such as hybrids and those using clean diesel. It also establishes 15 new appliance efficiency mandates and a 7.5 billion gallon renewable fuel requirement by 2012.

We expect these efforts will contribute to meeting the President's 18 percent, 10-year intensity goal, which represents an average annual rate of improvement of about 1.96 percent. Data from EIA suggest steady progress. Since 2002, EIA reports annual improvements in greenhouse gas emissions intensity of 1.6 percent and 2.1 percent in 2003 and 2004, respectively. Further, a June 2006 EIA preliminary "flash estimate" estimate of energy-related CO_2 emissions—which account for about four fifths of total greenhouse gas emissions—shows an improvement in CO_2 emissions intensity of 3.3 percent in 2005. Although we are only a few years into the effort, the Nation appears on track to meet the President's goal.

While acting to slow the growth of greenhouse gas emissions in the near term, the United States is laying a strong scientific and technological foundation to reduce uncertainties, clarify risks and benefits, and develop realistic mitigation options through better integration and management of its climate change related scientific and technological activities. In February 2002, President Bush announced the creation of a cabinet-level Committee on Climate Change Science and Technology Integration, co-chaired by the Secretaries of Commerce and Energy. Two multi-agency programs were established to coordinate Federal activities in climate change scientific research and advance the President's vision under his National Climate Change Technology Initiative (NCCTI). These are the U.S. Climate Change Science Program (CCSP), led by the Department of Commerce, and CCTP, led by DOE.

CLIMATE CHANGE SCIENCE PROGRAM[1]

CCSP is an interagency research planning and coordinating entity charged with investigating natural and human-induced changes in the Earth's global environmental system; monitoring, understanding, and predicting global change; and providing a sound scientific basis for national and international decision-making. CCSP combines the near-term focus of the Administration's Climate Change Research Initiative—including a focus on advancing the understanding of aerosols and carbon sources and sinks and improvements in climate modeling—with the breadth of the long-term research elements of the U.S. Global Change Research Program.

In July 2003, CCSP released its *Strategic Plan* for guiding climate research. The plan is organized around five goals: (1) improving our knowledge of climate history, variability, and change; (2) improving our ability to quantify factors that affect climate; (3) reducing uncertainty in climate projections; (4) improving our understanding of the sensitivity and adaptability of ecosystems and human systems to climate change; and (5) exploring options to manage risks associated with climate variability and change. CCSP is now in the process of implementing its 10-year *Plan*. The President's fiscal year 2007 budget request includes $1.715 billion for climate change science. The knowledge gained through CCSP will be invaluable in helping CCTP plan for needed technology development.

[1] See: http://www.climatescience.gov.

CLIMATE CHANGE TECHNOLOGY PROGRAM[2]

To address the challenges of energy security, economic development, and climate change, there is need for a visionary, long-term perspective. The International Energy Agency estimates there are about two billion people who lack modern energy services. Many countries are focusing efforts on providing power to their citizens. Although projections vary considerably, a tripling of energy demand by 2100 is certainly not an unreasonable expectation. When one considers further that energy-related CO_2 emissions account for about four fifths of all greenhouse gas emissions, the scale of the challenge becomes apparent. Most anthropogenic greenhouse gases emitted over the course of the 21st century will come from equipment and infrastructure not yet built, a circumstance that poses significant opportunities to reduce or eliminate these emissions.

As we look to the future, providing the energy necessary to power economic growth and development while at the same time reducing greenhouse gas emissions is going to require cost-effective transformational technologies that can fundamentally alter the way we produce and use energy. Given the huge capital investment in existing energy systems, the desired transformation of the global energy system may take many decades. A robust research effort undertaken today can make new, competitive technologies available sooner rather than later and accelerate modernization of capital stock.

Other greenhouse gases from non-energy related sources—methane, nitrous oxides, sulfur hexafluoride, and fluorocarbons, among others—also pose a concern. They have higher warming potentials than CO_2. In aggregate, these gases present a large opportunity to reduce global radiative forcing and, in many cases, the technical strategies to reduce their emissions are straightforward and tractable. Finding ways to mitigate these other greenhouse gases is an important part of CCTP's technology strategy.

The United States is leading the development of many advanced technology options that have the potential to reduce, avoid, or sequester greenhouse gas emissions. CCTP was created in 2002, and subsequently authorized in Title XVI of the Energy Policy Act of 2005, to coordinate and prioritize the Federal Government's investment in climate-related technology and to further the President's National Climate Change Technology Initiative (NCCTI). The fiscal year 2007 Budget includes nearly $3 billion for CCTP-related activities.

CCTP's principal aim is to accelerate the development and reduce the cost of new and advanced technologies with the potential to reduce, avoid, or sequester greenhouse gas emissions. It does this by providing strategic direction for the CCTP-related elements of the overall Federal technology portfolio. It also facilitates the coordinated planning, programming, budgeting, and implementation of the technology development and deployment aspects of U.S. climate change strategy. CCTP also is assessing different technology options and their potential contributions to reducing greenhouse gas emissions over the short, medium, and long term to help inform budget decisions and priorities.

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[2] See: http://www.climatetechnology.gov.

CCTP's strategic vision has six complementary goals: (1) reducing emissions from energy use and infrastructure; (2) reducing emissions from energy supply; (3) capturing and sequestering CO_2; (4) reducing emissions of non-CO_2 greenhouse gases; (5) measuring and monitoring emissions; and (6) bolstering the contributions of basic science.

Ten Federal agencies support a broad portfolio of activities within this framework. Participating Federal agencies in CCTP include the Departments of Energy, Agriculture, Commerce, Defense, Health and Human Services, Interior, State, and Transportation, as well as the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation.

Many CCTP activities build on existing work, but the Administration also has expanded and realigned some activities and launched new initiatives in key technology areas to support the CCTP's goals. The President's NCCTI includes 12 discrete activities that could advance technologies to avoid, reduce, or capture and store greenhouse gas emissions on a large scale. The Administration's budget proposal for fiscal year 2007 included $306 million for these NCCTI priorities.

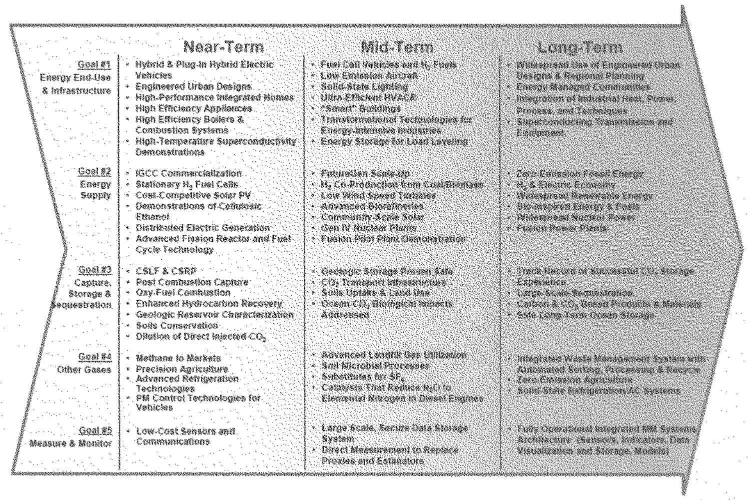
CCTP anticipates that a progression of advanced technologies will be available and enter the marketplace in the near, mid, and long terms. Figure 1 provides a schematic roadmap for the technologies being pursued under CCTP. Readers wishing a fuller explanation of the technology research described below should consult CCTP's *Research and Current Activities* and *Technology Options for the Near and Long Term* reports, both of which are available on the CCTP web page. Short descriptions of each of the NCCTI priorities are also available on the CCTP web page.

ENERGY USE AND INFRASTRUCTURE: Improving energy efficiency and reducing greenhouse gas emissions intensity in transportation, buildings, and industrial processes can contribute greatly to overall greenhouse gas emission reductions. In addition, improving the electricity transmission and distribution "grid" infrastructure can reduce greenhouse gas emissions by making power generation more efficient or by providing greater grid access for wind and solar power.

Key research activities include FreedomCAR (Cooperative Automotive Research)[3] program, a cost-shared government-industry partnership that is pursuing fuel cell and other advanced automotive technologies. Advanced heavy-duty vehicles technologies, zero-energy homes and commercial buildings, solid-state lighting, and superconducting wires that virtually eliminate electricity transmission losses are other areas of research that could yield significant emissions reductions.

[3] See: http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/index.html.

FIGURE 1. CCTP ROADMAP FOR CLIMATE CHANGE TECHNOLOGY DEVELOPMENT



ENERGY SUPPLY: Fossil fuels, which emit CO_2 when burned, remain the world's energy supply of choice. A transition to a low-carbon energy future would, therefore, require the availability of cost-competitive low- or zero-carbon energy supply options. When combined with alternative energy carriers—such as electricity and hydrogen—these options could offer the prospect of considerable reductions in greenhouse gas emissions.

Renewable energy includes a range of different technologies that can play an important role in reducing greenhouse gas emissions. The United States invests considerable resources in wind, solar photovoltaics, and biomass technologies. We have made much progress in price competitiveness of many of these technologies, but there still is a need to reduce their manufacturing, operating, and maintenance costs. For example, new biotechnology breakthroughs offer the potential for extensive domestic production of cellulosic ethanol and other biofuels by both improving feedstocks and increasing the efficiency of conversion processes. In August, DOE's Office of Science issued a Funding Opportunity Announcement for up to $250 million over five years for the establishment and operation of two new bioenergy research centers to advance the science needed to develop these new technologies, which could decrease greatly the greenhouse gas emissions from liquid transportation fuels.[4]

There will be a continuing need for portable, storable energy carriers for heat, power, and transportation. Hydrogen is an excellent energy carrier, produces no emissions when used in a

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[4] See: http://genomicsgtl.energy.gov/centers/index.shtml.

fuel cell, and can be produced from diverse sources, including renewables, nuclear, and fossil fuels (which in the latter case could be combined with carbon capture). President Bush's $1.2 billion Hydrogen Fuel Initiative[5] is exploring these production options as well as the infrastructure needed to store and deliver hydrogen economically and safely. It is expected that the research being performed under the program will make possible a commercialization decision by industry in 2015 and possible market introduction of hydrogen fuel-cell vehicles by 2020.

The United States has vast reserves of coal, and about half of its electricity is generated from this fuel. Advanced fossil-based power and fuels, therefore, is an area of special interest. The FutureGen[6] project is a 10-year, $1 billion government-industry collaboration—which includes India and the Republic of Korea—to build the world's first near-zero atmospheric emissions coal-fired power plant. This project will incorporate the latest technologies in carbon sequestration, oxygen and hydrogen separation membranes, turbines, fuel cells, and coal-to-hydrogen gasification. This research can help coal remain part of a diverse, secure, and environmentally acceptable energy portfolio well into the future.

Concerns over resource availability, energy security, and air quality as well as climate change suggest a larger role for nuclear power as an energy supply choice. The Generation IV Nuclear Energy Systems Initiative[7] is investigating the next-generation reactor and fuel cycle systems that represent a significant leap in economic performance, safety, and proliferation-resistance. While the primary focus for developing a next-generation reactor is on producing electricity in a highly efficient manner, there is also the possibility of coupling a reactor with advanced technology that would allow for the production of hydrogen. These advanced technologies are being developed under the Generation IV Nuclear Energy Systems Initiative and the Nuclear Hydrogen Initiative[8] and could possibly enable the production of hydrogen on a scale to meet transportation needs.

Fusion energy[9] is a way to generate power that, if successfully developed, could be used to produce electricity and possibly hydrogen with zero greenhouse gas or pollutant emissions and no waste in the form of spent nuclear fuel. Fusion has features that make it an attractive option from both an environmental and safety perspective. However, the technical hurdles of fusion energy are very high, and, with a commercialization objective of 2050, its potential impact would be in the second half of the century.

In his 2006 State of the Union Address, President Bush outlined plans for an Advanced Energy Initiative (AEI).[10] AEI aims to accelerate the development of advanced technologies that could change the way American homes, businesses, and automobiles are powered. AEI is designed to take advantage of technologies that with a little push could play a big role in helping to reduce

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[5] See: http://www.eere.energy.gov/hydrogenandfuelcells/presidents_initiative.html.
[6] See: http://fossil.energy.gov/programs/powersystems/futuregen/index.html.
[7] See: http://gen-iv.ne.doe.gov.
[8] See: http://nuclear.gov/hydrogen/hydrogenOV.html.
[9] See: http://www.sc.doe.gov/Program_Offices/fes.htm.
[10] See: http://www.whitehouse.gov/stateoftheunion/2006/energy/index.html.

the Nation's use of foreign sources of energy and its pollution and greenhouse gas emissions. AEI includes greater investments in near-zero atmospheric emissions coal-fired plants, solar and wind power, nuclear energy, better battery and fuel cell technologies for pollution-free cars, and cellulosic biorefining technologies for biofuels production.

CARBON SEQUESTRATION: Carbon capture and sequestration is a central element of CCTP's strategy because for the foreseeable future, fossil fuels will continue to be among the world's most reliable and lowest-cost form of energy. A realistic approach, then, is to find ways to "sequester" the CO_2 produced when these fuels—especially coal—are used. The phrase "carbon sequestration" describes a number of technologies and methods to capture, transport, and store CO_2 or remove it from the atmosphere.

Advanced techniques to capture gaseous CO_2 from energy and industrial facilities and store it permanently in geologic formations are under development. DOE's core Carbon Sequestration Program[11] emphasizes technologies that capture CO_2 from large point sources and store the emissions in geologic formations that potentially could hold vast amounts of CO_2.

Terrestrial sequestration—removing CO_2 from the atmosphere and sequestering it in trees, soils, or other organic materials—has proven to be a low-cost means for long-term carbon storage. The Carbon Sequestration in Terrestrial Ecosystems consortium, supported by DOE's Office of Science, provides research on mechanisms that can enhance terrestrial sequestration of carbon.

In 2003, DOE launched a nationwide network of seven Carbon Sequestration Regional Partnerships[12] that include 40 states, four Canadian Provinces, three Indian Nations, and over 300 organizations. The partnerships' main focus is on determining the best approaches for sequestration in their regions, and they also will examine regulatory and infrastructure needs. Small-scale validation testing of 35 sites involving terrestrial and geologic sequestration technologies began in 2005, and will continue until 2009.

NON-CARBON DIOXIDE GREENHOUSE GASES: A main component of the U.S. strategy is to reduce other greenhouse gases, such as methane, nitrous oxides (N_2O), sulfur hexafluoride (SF_6), and fluorocarbons, among others.

Improvements in methods and technologies to detect and either collect or prevent methane emissions from various sources—such as landfills, coal mines, natural gas pipelines, and oil and gas exploration operations—can prevent this greenhouse gas from escaping to the atmosphere.[13] In agriculture, improved management practices for fertilizer applications and livestock waste can reduce methane and N_2O emissions appreciably.

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and SF_6 are all high global warming potential (High GWP) gases. HFCs and PFCs are used as substitutes for ozone-depleting

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[11] See: http://fossil.energy.gov/programs/sequestration/index.html.

[12] See: http://fossil.energy.gov/programs/sequestration/partnerships/index.html.

[13] Reducing methane emissions may also have a positive benefit in reducing local ozone problems, as methane is an ozone precursor.

chlorofluorocarbons and are used in or emitted during complex manufacturing processes. Advanced methods to reduce the leakage of, reuse, and recycle these chemicals and lower GWP alternatives are being explored.

Programs aimed at reducing particulate matter have led to significant advances in fuel combustion and emission control technologies to reduce U.S. black carbon aerosol emissions. Reducing emissions of black carbon, soot, and other chemical aerosols can have multiple benefits, including better air quality and public health and reduced radiative forcing.

Measuring and Monitoring: To meet future greenhouse gas emissions measurement requirements, a wide array of sensors, measuring platforms, monitoring and inventorying systems, and inference methods are being developed. Many of the baseline measurement, observation, and sensing systems used to advance climate change science are being developed as part of CCSP. CCTP's efforts focus primarily on validating the performance of various climate change technologies, such as in terrestrial and geologic sequestration.

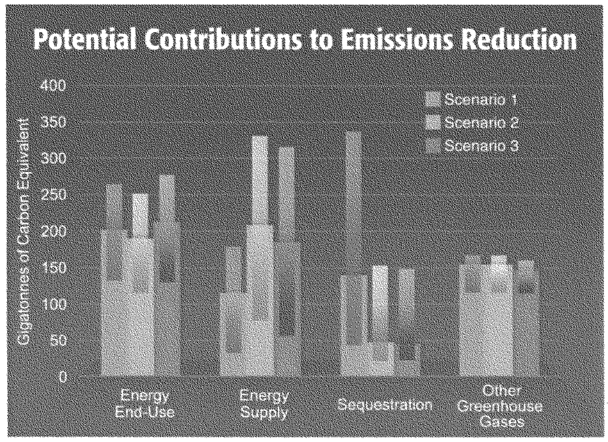
Basic Science: Basic scientific research is a fundamental element of CCTP. Meeting the dual challenges of addressing climate change and meeting growing world energy demand is likely to require discoveries and innovations that can shape the future in often unexpected ways. The CCTP framework aims to strengthen the basic research enterprise through strategic research that supports ongoing or projected research activities and exploratory research involving innovative concepts.

Scenario Analysis: CCTP uses scenario analyses that incorporate various assumptions about the future to clarify the potential role of climate change technologies and to aid in portfolio planning. Scenarios analyses can provide a relative indication of the potential climate change benefits of a particular technology mix compared to others, and it can help determine which classes of technology would most likely provide larger-scale benefits. Figure 2 offers a glimpse of the range of emissions reductions new technologies in energy end use, energy supply, carbon sequestration, and other non-CO_2 greenhouse gases may make possible on a 100-year scale and across a range of uncertainties and constraints.

International Collaborations

The United States believes that well-designed multilateral collaborations focused on achieving practical results can accelerate development and commercialization of new technologies. The U.S. has initiated or joined a number of multilateral technology collaborations in hydrogen, carbon sequestration, nuclear energy, and fusion that address many energy-related concerns (e.g., energy security, climate change, and environmental protection).

FIGURE 2: POTENTIAL CONTRIBUTIONS TO EMISSIONS REDUCTIONS



Potential ranges of greenhouse gas emissions reductions to 2100 by category of activity for three technology scenarios characterized by: viable carbon sequestration (Scenario 1); dramatically expanded nuclear and renewable energy (Scenario 2); and novel and advanced technologies (Scenario 3). Note also the consistently large potential reductions in other greenhouse gas emissions under all three scenarios. A number of common features cut across all three of the advanced technology scenarios: additional gains in energy efficiency beyond the reference case occur; additional technologies for managing non-CO_2 GHGs become available; terrestrial carbon sequestration increases; the full potential of conventional oil and gas is realized; and hydrogen production technology advance (CCTP 2006).

ASIA-PACIFIC PARTNERSHIP ON CLEAN DEVELOPMENT AND CLIMATE[14] (APP): Launched formally in January 2006, APP is a multi-stakeholder partnership working to generate practical and innovative projects promoting clean development and the mitigation of greenhouse gases. The six APP partnering nations—Australia, China, India, Japan, Republic of Korea, and the United States—account for about half of the world's economy, energy use, and greenhouse gas emissions. APP is pursuing public-private partnerships to build local capacity, improve efficiency and reduce greenhouse gas emissions, create new investment opportunities, and remove barriers to the introduction of clean energy technologies in the Asia Pacific region. At the ministerial launch, the APP partners created eight task forces in the following areas: (1) cleaner fossil energy; (2) renewable energy and distributed generation; (3) power generation and transmission; (4) steel; (5) aluminum; (6) cement; (7) coal mining; and (8) buildings and

[14] See: http://www.asiapacificpartnership.org.

appliances. Each Task Force is completing an Action Plan that will serve as blueprint for cooperation and provide a strategic framework for identifying and implementing Partnership activities. The President's fiscal year 2007 budget request includes $52 million to support APP.

INTERNATIONAL PARTNERSHIP FOR THE HYDROGEN ECONOMY (IPHE)[15]**:** In November 2003, representatives from 16 governments gathered in Washington, DC to launch IPHE, a vehicle to coordinate and leverage multinational hydrogen research programs. Moreover, IPHE will develop common recommendations for internationally-recognized standards and safety protocols to speed market penetration of hydrogen technologies. An important aspect of IPHE is maintaining communications with the private sector and other stakeholders to foster public-private collaboration and address the technological, financial, and institutional barriers to hydrogen.

CARBON SEQUESTRATION LEADERSHIP FORUM (CSLF)[16]**:** CSLF is a U.S. initiative that was established at a ministerial meeting held in Washington, DC, in June 2003. CSLF is a multilateral initiative that provides a framework for international collaboration on sequestration technologies. CSLF has as members 22 governments representing both developed and developing countries.

The Forum's main focus is assisting the development of technologies to separate, capture, transport, and store CO_2 safely over the long term, making carbon sequestration technologies broadly available internationally, and addressing wider issues, such as regulation and policy, relating to carbon capture and storage. To date, 17 international research projects have been endorsed by the Forum, five of which involve the United States.

GENERATION IV INTERNATIONAL FORUM (GIF)[17]**:** In July 2001, nine other countries and Euratom joined together under U.S. leadership to charter GIF, a multilateral collaboration to fulfill the objective of the Generation IV Nuclear Energy Systems Initiative. GIF's goal is to develop a fourth generation of advanced, economical, and safe nuclear systems that offer enhanced proliferation-resistance and can be adopted commercially by 2030. Six technologies have been selected as the most promising candidates for future designs, some of which could be commercially ready in the 2020 to 2030 timeframe. The U.S. focus is on the development of a very high temperature reactor capable of producing both electricity and hydrogen. GIF countries are jointly preparing a collaborative research program to develop and demonstrate these projects.

[15] See: http://www.iphe.net. IPHE members include the United States, Australia, Brazil, Canada, China, European Commission, France, Germany, Iceland, India, Italy, Japan, New Zealand, Norway, Republic of Korea, Russian Federation, and United Kingdom.
[16] See: http://www.cslforum.org. CSLF members include the United States, Australia, Brazil, Canada, China, Colombia, Denmark, European Commission, France, Germany, Greece, India, Italy, Japan, Republic of Korea, Mexico, Netherlands, Norway, Russian Federation, Saudi Arabia, South Africa, and United Kingdom.
[17] See: http://gen-iv.ne.doe.gov/GENIVintl-gif.asp. GIF member countries include the United States, Argentina, Brazil, Canada, France, Japan, Republic of Korea, South Africa, Switzerland, and United Kingdom.

ITER[18]**:** In January 2003, President Bush announced that the U.S. was joining the negotiations for the construction and operation of the international fusion experiment called ITER. ITER is a proposed multilateral collaborative project to design and demonstrate a fusion energy production system. If successful, this multi-year, multi-billion dollar project will advance progress toward determining whether fusion technology can produce clean, abundant, commercially available energy by the middle of the century.

GLOBAL NUCLEAR ENERGY PARTNERSHIP (GNEP)[19]**:** GNEP has two major goals: (1) expand carbon-free nuclear energy to meet growing electricity demand worldwide; and (2) promote non-proliferation objectives by providing reliable nuclear fuel services to countries which agree to forgo enrichment and reprocessing. The closed fuel cycle model envisioned by this partnership requires development and deployment of technologies that enable recycling and consumption of long-lived radioactive waste. The GNEP initiative proposes international partnerships to achieve these goals.

METHANE TO MARKETS[20]**:** The Methane to Markets Partnership is another highly practical major element in the series of international technology partnerships advanced by the Administration. Launched in November 2004, the Methane to Markets Partnership focuses on advancing cost effective, near-term methane recovery and use as a clean energy source from coal beds, natural gas facilities, landfills, and agricultural waste management systems. The Partnership will reduce global methane emissions to enhance economic growth, promote energy security, improve the environment, and reduce greenhouse gas emissions. Other benefits include improving mine safety, reducing waste, and improving local air quality.

CLOSING OBSERVATIONS

The United States, in partnership with others, has embarked on an ambitious undertaking to develop new and advanced climate change technologies that have the potential to transform the economic activities that give rise to greenhouse gas emissions. Innovations can be expected to change the ways in which the world produces and uses energy, performs industrial processes, grows crops and livestock, manages carbon dioxide, and uses land. These technologies could both enable and facilitate a gradual shift toward significantly lower global greenhouse gas emissions and provide the energy-related and other services needed to spur and sustain economic growth.

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[18] See: http://www.iter.org. ITER members include the United States, China, EU, India, Japan, Russian Federation, and Republic of Korea.

[19] See: http://www.gnep.energy.gov.

[20] See: http://www.methanetomarkets.org/.

Mr. ISSA. Thank you.

Thank you all for your testimony. We will alternate between myself, the ranking member, and other Members as they arrive.

I would like to just summarize what you all had to say, and I do this with my colleague here at my side, in the friendliest possible way.

For an administration that denied the existence of global warming, that saw no problem whatsoever, according to the opening statements, you certainly have been busy, and I appreciate that. I will now go to the questions, because we are not here to give you credit for all that you have done, although you have done it. We are here to figure out, from an oversight perspective, what more could be done and what part Congress should play in it.

Personally, looking at the United States consuming 25 percent of the world's energy, producing 30 percent or so of the world's GDP, and putting out 22 percent of CO_2 emissions, one would say that, in the abstract, we are doing better than the world as a whole in each of those categories. I am concerned, though, that there is some level of CO_2 in the atmosphere that has to be achieved by the world and we have to be the leader of the world in that.

I have been told that studies show that if we had raised our nuclear electricity production to the same level as France, about 80 percent, that it would have made us Kyoto compliant. This probably would have changed the dynamics that existed in the Senate in which 95+ Senators said they wouldn't vote for Kyoto, thus dooming it.

Mr. Stephenson, what accounts for the greatest increase in climate change funding since 1993?

Mr. STEPHENSON. If you adjust for inflation, technology is almost all of it.

Mr. ISSA. Has that been a good investment?

Mr. STEPHENSON. We haven't analyzed it formally. We think that a two-pronged attack of emission reductions and technology for clean fuel, etc., is the right approach.

Mr. ISSA. In a perfect world, if sequestration cost no energy and we simply captured and stored CO_2, with no downside other than storing a lot of crystals or other forms that would be stable, would you have concerns if we could achieve that?

Mr. STEPHENSON. I am not a scientist, Mr. Chairman, but right now sequestration is not keeping up with emissions, so, in a perfect world, I guess that would be wonderful.

Mr. ISSA. So I will summarize and say we don't live in this perfect world, and we are going to have to do more than we are doing presently in the way of pumping CO_2 into empty oil wells.

Mr. STEPHENSON. Exactly.

Mr. ISSA. I appreciate that.

Mr. Eule, you mentioned the work on fusion. Now, I have an incredibly good staffer here, Joe, and I asked him when he was born, and he told me 1978, which just happens to be when a friend of mine, as a captain, joined my engineer unit. Prior to that he had been a detailee at Lawrence Livermore for 2 years, as a scientist working on a highly funded fusion project.

From a practical standpoint, when we look at the dollars we put into fusion versus the dollars we are putting into Next Generation or high temperature nuclear reactors, wouldn't it be fair to say that we could have many reactors up and running for a fraction of the cost of what we put into fusion that, as of yet, has not yielded any benefits?

Mr. EULE. That is a very difficult question to answer.

Mr. ISSA. That is why we ask them that way.

Mr. EULE. Yes, I know.

Mr. ISSA. The leading question is one of our strong points.

Mr. EULE. Right. I will say that fusion has potentially many benefits. It is a very high risk program, as you know. We are looking, I think, at a commercialization target of around 2050, so it is really something, from the climate change perspective, that probably won't have an impact until the second half of the century.

Having said that, it has attractive environmental safety features. There are no greenhouse gases, you don't have the waste problem, and fuel is readily available, so the potential is so great that I think it behooves us to invest in fusion.

Now, having said that, I think the administration has committed large resources to nuclear power, and I don't have the figures in front of me, but I do know that our funding for nuclear power has increased tremendously over the past few years. So funding for nuclear power is increasing. I hate to think of this as a sort of robbing Peter to pay Paul type of situation because I think they are both valuable technologies and both have a role to play.

Mr. ISSA. Well, I will accept what you have to say because I am not here to cut long-term funding for fusion. I am concerned—and I think this committee, through many hearings during this Congress is concerned—that, in fact, getting to a hydrogen economy is virtually impossible if we cannot use a zero emission source.

In previous hearings—and I think our next panel will deal with it a little bit—we were shown maps of what the world would look like if we tried to get a terawatt of power from wind. As much as I am a proponent of wind, I recognize that we would need wind turbines off every shore, in the middle of Lake Erie, Lake Michigan, Lake Superior, and absolutely all along the Pacific Coast in order to meet just our electric needs, separate from hydrogen. We are not going to get there by wind alone.

Mr. EULE. I think you raise an excellent point. When you think about climate change, there are really two areas you have to think about: transportation and base load power. Nuclear, as a clean and emission-free energy option, is certainly one option we have to consider.

Coal is one of the other emphases of the technology program. The United States, at current reserves and current recovery rates, has over 400 years of coal. From an energy security perspective, that is very valuable. The question is how do we use it in an environmentally friendly manner. One of the objectives of the Future Gen program is to be able to use that resource, use it where it doesn't have an impact on the climate. It would also be virtually pollution free.

I think we have to look at not just nuclear, because coal has to play a role here as well. The trick, of course, is figuring out how to reduce the environmental impact of coal.

Mr. ISSA. You know, I could ask many more questions, but the ranking lady has been very patient, so we will go back and forth.

Ms. Watson.

Ms. WATSON. Thank you so much.

I will address this question to Mr. Eule. Why do you recommend that the Climate Change Technology Program be replaced with Climate Change Technology Initiative for the following years dealing with global warming? Give us the difference between the two. If one is better than the other, why do you deem CCTI more effective?

Mr. EULE. I think you are referring to the NCCTI initiative, the National Climate Change Technology Initiative that was the Presidential——

Ms. WATSON. Yes.

Mr. EULE. Yes. NCCTI is a subset of priority programs that were identified through the Climate Change Technology Program. The Climate Change Technology Program provides the overarching framework. Within that framework we have set some priorities, and those priorities are the NCCTI priorities that you are referring to. There are about a dozen of those and they are listed in Appendix B of the report.

Through our interagency working groups, we have identified a subset of specific activities that we think should get priority treatment, and that is the explanation.

Ms. WATSON. Can you just give us a few of those?

Mr. EULE. Oh, sure. I would be happy to.

Ms. WATSON. The ones that you feel are most important.

Mr. EULE. Well, there are only 12 of them, and they are: hydrogen storage, low wind speed technology, solid state lighting, cellulosic biomass, transportation fuel cell systems, the Nuclear Hydrogen Initiative, the Advanced Fuel Cycle, Advanced Burner Reactor Program, Carbon Sequestration is a big one, IGCC, and in EPA we have the Methane Partnerships Initiative and the Climate Leaders Program. EPA has a lot of expertise in non-carbon dioxide greenhouses gases, so we have a couple of programs that deal with those as well.

That is an overview of the NCCTI programs.

Ms. WATSON. If I may just ask another one, too. Is it true that under the former administration CCTI was less costly than the similar program CCTP under the Bush administration? Why was that one less costly?

Mr. EULE. I am not familiar. If there really is an analog between the CCTP and anything that the Clinton administration had, I am not aware of any.

Ms. WATSON. Well, do you see the CCTI as more effective, considering the lesser amount of money used?

Mr. EULE. We see the NCCTI initiatives as discreet priorities that if they received a little bit more funding could have a big impact on developing certain technologies that could significantly reduce greenhouse gas emissions, avoid those emissions, or sequester those emissions. So, again, it is a subset of priorities that we identified within the program we think deserve special recognition, primarily—especially—during the budget process.

Ms. WATSON. Considering the weaknesses already in the CCTP draft strategic plan that are more than likely to appear in the final draft, why should billions of dollars be invested in a program that already seems to have some failing aspects to it?

Mr. EULE. Well, I would disagree with that characterization. I think we have made an effort. There were shortcomings in the report when the first draft was released for public comment in September. I think we have done a very good job of addressing those concerns. We received about 280 comments on the report, and through the interagency working groups we have done, I think, a pretty good job of examining those comments and changing the report where we thought it was wise to do so.

I think the report that has come out is a much tighter report. In particular, we have laid out some goals of potential emission reductions for certain technologies at certain times when those technologies would have to be ready. So I think we have made an effort to improve the final document, and we think it is one that will aid the administration and we hope future administrations, as they struggle with these issues.

I would note that with any first-of-a-kind document, it is not going to satisfy everyone, but the United States is the only country that I am aware of that has thought these issues through and come up with a strategic plan to deal with them.

Ms. WATSON. Well, just one more question, Mr. Chairman. The interagency working groups are composed of who?

Mr. EULE. We have six of them. They are organized according to each strategic goal in the plan, and include fairly senior level people within the agencies that participate in CCTP. There are 10 agencies, and the Department of Energy leads the working groups on energy supply, energy use, and basic research. EPA leads the working group on non-CO_2 greenhouse gases.

Ms. WATSON. Do you go outside of the agency to bring in——

Mr. EULE. Oh, yes.

Ms. WATSON [continuing]. Technicians, people who have experience, like working with universities and so on?

Mr. EULE. Yes, that is a good question. We do bring in outside experts to review the portfolio. Last year, for example, we held six workshops where we brought in experts from the outside to examine the portfolio, again, according to the strategic goals that we set in the plan. They issued a report, and I think it is available on the Oak Ridge National Lab Web page, and we would be happy to get that for you.

Ms. WATSON. So there would be some opportunity for, not necessarily the general public, but people with expertise to review and maybe to add to your report?

Mr. EULE. We consider this report a living document. We hope it is not going to change too much in the near future, but we see the report as largely the beginning of a dialog not only with the other agencies and governments, but with experts from the outside and the general public, so, yes.

Ms. WATSON. Thank you.

Mr. ISSA. Very good round. And I will be brief in my second round.

Dr. Dahlman, as an old business man, the first question we always ask is what is our break even point. Do we have, today, the level of research to know where the break even point is? My understanding—the reason for the question—is that even our estimates of how much carbon we are emitting are inexact in many, many areas. Do we have it? If we don't have it, what tools are needed and what dollars are needed for those tools?

Dr. DAHLMAN. I haven't really thought about the carbon cycle in terms of a break even point. Maybe I can attempt to answer your question in terms of the major components of the carbon cycle. The emissions component of the carbon cycle is quite well characterized, and I think Mr. Gregg Marland will be able to give you some statistics on that. The atmospheric CO_2 concentration is measured quite accurately, so we know that quantity.

There are estimates of the amount of carbon that moves from the atmosphere into the ocean, and those estimates are pretty consistent, and they may be subject to some uncertainty. Where the largest uncertainty seems to be is the direct measurement of the carbon taken up by the terrestrial systems. That is where some of our priorities are and where investments are being focused, to understand those processes and quantities better.

Now, once we have improved results from that research, then I think we are in a better position to state quantitatively how well the global carbon cycle is balanced.

Is that getting at your question, sir?

Mr. ISSA. It is. Perhaps the way to put it, again, as a businessman, is if we assume that we stop putting more greenhouse gases—at least CO_2—into the atmosphere if we do X, Y, and Z, and we look at the cost of each of the Xs, Ys, and Zs, whether it is continuing to use fossil fuels but reducing what gets released, or it is alternatives such as producing 80 percent of the world's electricity with nuclear instead of fossil fuels, what will we achieve? One of the frustrations is I don't see a model that says, OK, if we are willing to spend X, we can get, with current technology, to either a lower sink rate or break even at this price. Then you can start evaluating over the next 20 years how much of that you do with existing technology and how much you invest into technologies to drive down the cost.

It appears as though everyone is looking at improvement, but no one is looking at break even. I, for one, have a hard time looking at a goal that is about doing better rather than doing enough, because I think the gentlelady would share this with me and I know my Governor in California would share this—the goal is to quit warming up the Earth, if in fact we are causing it. We are not going to quit warming it up until we get to that zero point, and it doesn't appear, today, from everything that I read in the material in preparation, that we have really figured out the break-even point and then started quantifying the cost.

So that is what I was hoping to get to. Trust me, Steve, you are next. [Laughter.]

I asked you because I was hoping that, when you look at the carbon cycle, that at some point we think of cost/benefit and break even so that we can start quantifying it. Everything helps, but what helps the most for the least dollars?

Dr. DAHLMAN. I think there are integrated assessment modeling approaches that consider the carbon cycle dynamics in relation to different energy emissions sources, and especially including the zero emission sources like nuclear power. Those analyses indicate that with a certain energy supply component that has a mix of different fossil technologies and non-fossil technologies, that the atmospheric CO_2 increase will reach certain levels within certain timeframes. Of course, these are scenario analyses, and you can——

Mr. ISSA. Right. These models tell us when we get to doomsday. What I want is how do we not get to doomsday.

Dr. DAHLMAN. Well, as long as we continue with the present investment in fossil technology and those emissions, atmospheric CO_2 is going to increase. It will take a considerable tradeoff of non-fossil technologies to reach some stabilization point that is not damaging. What is the language that is used with the framework convention? Dangerous levels of CO_2. Well, there is a lot of research trying to determine what that level is, sir, and much depends on what the mix of energy technologies will be for driving the country's and the world's economies in the future.

Mr. ISSA. OK, I will take that as as good an answer as exists, but you are a young man, I am sure we will have you back.

Steve, I have to tell you I know you have been chomping at the bit, so please answer that question. I would like to then followup on the big question for you, and I am going to put this one in in advance, because even though I am the chairman, I have a clock too. The United States is responsible for 20 percent of the world's annual carbon dioxide emissions. I was not a proponent of Kyoto for the following reason: China and India and other quickly developing nations were not part of it, so Kyoto would get to a zero net for developed nations while the world was not getting to a zero net.

I want you to talk specifically about efforts that the United States can or is taking to help get the world to that not-yet-defined zero net. Where are the investments in China and India and other developing nations, so that we are not simply energy and pollution laundering having our products delivered with less efficient energy-wise and pollution-wise technologies.

So those are the two questions, and I am done. All you have to do is talk until the gentlelady says your time is up.

Mr. EULE. You may regret saying that, Chairman.

With your permission, I am going to ask my colleague to bring up a couple of copies of the strategic plan because it gets to your question on cost.

Mr. ISSA. Thank you.

Mr. EULE. I would direct your attention to the chart on page 42.

Mr. ISSA. I assume this is available on a multi DVD set.

Mr. EULE. This is. But this is one of the most interesting figures in the report. I regret not having more copies available; they are being printed. On page 42 you see cost reductions associated with advanced technology scenarios compared to a baseline case without advanced technologies.

Our whole reason for being in CCTP is to reduce the cost and expand the options available to policymakers to mitigate greenhouse gas emissions, and we have some very bright people in the Pacific Northwest National Lab that run some scenario analyses for us. We don't need to get into great detail on this, but you see that there is a very high constraint and it goes all the way over to a low constraint.

I am sorry, can we—yes, Chapter 10, page 209 is a much clearer chart. I am sorry to do this.

But, really, what this shows is the baseline cost of reducing emissions under a very high constraint case exceeds $250 trillion—that is cumulative—to 2100. If we are able to develop the advanced technologies we have in the portfolio, we think that we can reduce the cost by about 56 percent to 68 percent with a very high constraint case over the coming century. As you can see, that rate stays pretty much the same. It actually grows a little bit as we move from the very high to the low constraint.

The take away message from this chart is that with these advanced technologies, we can significantly reduce the cost of achieving the goals of the Framework Convention and our own goals. This is really what our program is all about, reducing the cost.

When you consider carbon sequestration, for example, right now the cost to sequester a ton of carbon is about $100 a ton, roughly. The goal for the program is to reduce that to about $10 a ton. When you reduce sequestration to $10 a ton, it opens up a panoply of policy options that aren't available now. Even with a cap and trade system, if you consider that the highest cost for carbon in the European cap and trade system was the equivalent of about $40, that is not going to get you carbon sequestration at $100 a ton. At $10 a ton there is a whole host of policies that will do so.

So I would recommend the chart on page 209 to your attention.

To your other question, you raise an excellent point about the Kyoto protocol. Quite frankly, in the U.N. Framework Convention meetings that I have attended, the developing world has shown absolutely no interest in a specific constraint or target for greenhouse gas emissions. The Energy Information Administration is projecting that by 2010 non-OECD country emissions will surpass those from OECD country emissions.

The United States believes that to get these countries engaged, you just can't talk about climate change. You have to talk about energy security and pollution reduction. We have launched the Asia-Pacific Partnership. It was formally launched in January of this year. It includes Australia, China, India, South Korea, and Japan and the United States, and we are working with those countries to help them achieve their own goals as far as improved energy efficiency, reducing pollution, and mitigating greenhouse gases. It is a small group of countries, but it represents about half the world's GDP, half the world's population, half the world's energy consumption, amd half the world's greenhouse gas emissions, so it is a huge group as far as those metrics go. It is small, very manageable, but we are working closely with them. We have eight task forces that have developed action plans in various areas such as power generation, steel, and aluminum, to name but a few. We are working closely with them, and we think that is going to have a huge impact because it tackles problems that those countries are interested in. They are more interested in energy security than they are in climate change, to be frank. So we are attacking all of those at the same time.

Ms. WATSON. I just need a little clarification. You mention the cost of those technologies relative to emissions. Can you give me a scenario that would help me to understand the cost factor? I know you gave a humongous amount in the trillions, but are we saying that the cost factor will determine what technologies are used? Expand on that, please.

Mr. EULE. The point was that without advanced technologies the cost is tremendous. But if we are successful in developing the technologies that we have in the plan——

Ms. WATSON. That you have listed there, OK.

Mr. EULE [continuing]. The cost goes down tremendously. Carbon sequestration is a good example, from $100 to $10 a ton to sequester carbon. It is a huge cost differential and it can really drive the technology and make it more acceptable in the marketplace. This applies not only to carbon sequestration, but to a whole host of energy technologies. The goal is to lower the cost. If we lower the cost for the technologies, you lower the cost for mitigation and you expand the range of policy options available to decisionmakers.

Ms. WATSON. We all are concerned about the emissions that we are letting off into our environment, and as we watch the aftermath of Katrina and listen to the scientists and the forecasters talk about the warming of the water and so on, my concern goes to what is the length of time it would take to be able to come out with some draft report as to what technologies you feel will lower the cost so that we could start addressing the rising emissions into our atmosphere? Just, you know, kind of a ballpark figure as to how long these various departments and groups are going to be working before they can suggest.

Mr. EULE. You have raised a good point and it is a good question. In the plan we have timeframes where we think the technologies may be ready, and different technologies will have different timeframes. But let me give you a few examples.

In the hydrogen program, for example, we are looking at developing the technologies to the point where business can make a go, no-go decision by 2015, and maybe start deploying these technologies in 2020. When you look at the Generation IV program, they are looking at Next Generation nuclear power in the 2020 to 2035 timeframe. I mentioned fusion, 2050 timeframe; sequestration maybe 2020. So we have a continuum of advanced technologies that could become available over the course of the century. I would say that as a companion to the strategic plan we have our Technology Options Report, which lists many of the technologies that are available today or that could be available through these R&D programs. That is available on our Web page, and we would be happy to share that with you.

Mr. WATSON. Well, I just want to mention a scenario in California. We are both from the State of California, and we have worked for 20 years plus to improve the quality of our air and our environment. I think we have done an awesome job, because we have cleaned up our air somewhat. However, I represented a district central to Los Angeles at that time, and they came in and they told the shops that cooked barbeque that you are going to have to reduce your emissions. Of course, they all came to me and said but you have to have the smoke, if you are going to have smoke, you know, and all that. And so they said you have to do something to retrofit your systems so it would stop emitting so much of the carbon and so on.

So I heard the small shop owners complain about the cost and I heard our Cal-EPA say we have to set a time line and a cap if we are going to clean up the air. I could understand all that. So what I did was to initiate a bill that would allow the shop owners to be loaned money to borrow to be able to retrofit.

You had 12 different study groups, I think you mentioned, and you mentioned the cost, and I am sure some will be more costly than others. We might want to then create a way of helping manufacturers and businesses, because the economy is a consideration. So I am hoping that as the study groups develop their reports, they will take into consideration not only the cost, but how we can meet that cost if we are going to have a real serious impact on our air quality and the emissions greenhouse gases.

Mr. EULE. You raise a very good point. After you develop technologies, how do you deploy them?

Ms. WATSON. Yes.

Mr. EULE. This is a key question, and I think a great example is in Title VI of the Energy Bill. I think that will do more to spur nuclear power in this country than a whole host of incentives, because it goes to a specific risk that owners and operators face, and that is regulatory risk that really can't be addressed in any other way.

So I think you are right, we have to be creative in how we develop incentives to deploy these technologies, and that is something——

Ms. WATSON. We need a Marshall Plan for this particular battle.

Thank you very much, Mr. Chairman.

Mr. ISSA. Thank you for giving so much credit to the full committee chairman for that title.

I would like to thank you for all of your testimony. I would like to ask if you would mind taking some additional questions in writing to respond for the record.

I would like to place on the record that the barbeque place that I go to uses only wood fire; therefore, it is 100 percent renewable energy. And I retain the right to continue having barbeque that is wood-fired.

With that, we are going to recess for about 10 minutes and then take up the second panel. Thank you.

[Recess.]

Mr. ISSA. OK, if we can all start making our way back to the seats.

Thank you for all being patient as we went to other committees and back.

We now have our second panel. You already have been sworn in, and I will do you all one favor and point out the map that I am so proud of. This is from a Berkeley professor we had earlier, who was kind enough to give us a comprehensive map of what it would take to get to one terawatt of wind power with today's technology. The good news is that the map gets us to one terawatt, so we are self sufficient. The bad news is that only the black areas are what we would consider today to be really first-class locations. But to get to our base electric load, this is what it would take. When I asked him one followup question, which was, is this based on the fact that the wind doesn't blow all the time? He said, oh, no, no, this is the total power. This doesn't guarantee you get it when you want it.

With that, we announce our second panel. Dr. Marland, if you would go ahead. You have all been very good in the first panel on basically summarizing in 5 minutes. And, again, your entire statements will be placed in the record.

Please go ahead, Doctor.

STATEMENTS OF GREGG MARLAND, ECOSYSTEMS SCIENCE GROUP, ENVIRONMENTAL SCIENCES DIVISION, OAK RIDGE NATIONAL LABORATORY; STEVEN C. WOFSY, ABBOTT LAWRENCE ROTCH PROFESSOR OF ATMOSPHERIC AND ENVIRONMENTAL CHEMISTRY, HARVARD UNIVERSITY; AND DANIEL A. LASHOF, SCIENCE DIRECTOR, CLIMATE CENTER, NATURAL RESOURCES DEFENSE COUNCIL

STATEMENT OF GREGG MARLAND

Mr. MARLAND. I want to take 5 minutes to quickly consider three questions, and the three questions are: "Which carbon?" "How much carbon?" And "Whose carbon?"

On the "Which carbon?" Let me just say I am going to talk mostly about emissions from fossil fuels. This is the principal human impact that is perturbing the global carbon cycle. While we focus mostly on the magnitude of the emissions, I just wanted to point out that there are other characteristics of the emissions that are important in a variety of ways. We know how the emissions change with time. They change annually or through the course of a year. They change through the course of a day. We know how it is distributed in space. We know, for example, that 95 percent of emissions occur in the Northern Hemisphere. We know that emissions that come from fossil fuels are not the same as the CO_2 that is already in the atmosphere.

Wally Broker used to talk about red carbon and blue carbon, but the CO_2 that comes out of fossil fuels is recognizable by its carbon isotope signature, so it is clearly distinguishable from what mixes out of the ocean and what comes from volcanos, for example. We also know that when we are burning fossil fuels, as we put carbon dioxide into the air, we are taking oxygen out. All of these characteristics are important because they help us understand the details of the carbon cycle and they also help us to understand absolutely, without question, that the increase we are observing in the atmosphere is indeed due to fossil fuel burning.

To move to the question, "How much carbon?" I think many people have in their minds that emissions from fossil fuel use are in the order of 6 billion to 6.5 billion metric tons per year. The truth is, our most recent estimates suggest that 2006 is probably going to pass 8 billion metric tons. So the rate of increase is huge. The baseline for the Kyoto Protocol was 1990. It is likely that 2006 will be 28 percent above the 1990 value. Sorry, the 2005 value was 28 percent above the 1990 value. And the United States, in 2002, as has already been said, is roughly 22 percent, 23 percent of that.

The other thing that I think is interesting—and I am going to blame Joe for this—we have this vision that we have been burning fossil fuels and the atmosphere has been accumulating CO_2 for a long time. But half of the total emissions of CO_2 have occurred in Joe's lifetime. He was born in 1978, you said, and the midpoint for the total that has been emitting now is in 1981, roughly. In the late 1970's we were worried about running out of energy, but we burned more fossil fuel since the late 1970's than we did before.

Let me skip through some of the things that are clear in the written statement and say that the emissions from the U.S. amount to 5.4 tons of carbon per person per year in the United States. And if you compare that globally, we are running about five times the global average. This raises my third question, which is, "Whose carbon?"

There are movements in Europe, for example, that we should restrict carbon so that everybody is entitled to the same per capita emissions. But if you look in my testimony, there is a map of the United States which shows per capita emissions by State, and we have an order of magnitude difference between States in the United States. It is roughly 3 in California and 35 in Wyoming, and it makes you realize there is something going on there other than us just being evil. It has to do ultimately with climate, population density, the structure of the economy, and access to resources. You start to ask whose carbon. When we do per capita emissions for the United States, what are we counting in a global economy? How is that related to what is happening in the United States, the profit that we are getting?

I mentioned that there is this huge increase that has taken place from 1990 to 2005. In fact, if you go back and inventory that by country, almost half of it is in China. But some recent studies show that the best estimate is between 7 percent and 14 percent of emissions from China are to produce goods that will be exported to the United States. If you look at the national inventory for Canada, 6.6 percent of greenhouse gas emissions from Canada are to produce, process, and transport oil and natural gas that will be used in the United States.

So this whole idea of doing inventories, whether it is by State or community or even by country, is very complex. We are subdividing a global system into, again, my carbon and your carbon, and it becomes increasingly difficult to know really who should take credit for which.

In that same context, let me add one final point. If we are talking about managing the carbon cycle, which we are, then this my carbon and your carbon becomes a very critical issue. And the last diagram in my written statement is just a quick diagram of what happens when you try to sequester carbon by going to no till agriculture, and the answer is you don't just sequester carbon. You can't understand what you have done by measuring the amount of carbon in the soil. It changes the fuel use, it changes fertilizer use, it changes, perhaps, crop productivity. And I think it is very important that, as we progress, we make sure that we look at the full systems and not just my carbon and your carbon.

Thank you.

[The prepared statement of Mr. Marland follows:]

THE HUMAN COMPONENT OF THE GLOBAL CARBON CYCLE

Testimony before the Committee on Government Reform
Subcommittee on Energy and Resources
Darrell Issa, Chairman
September 27, 2006, 2:00 pm
Rayburn House Office Building
Room 2247

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The context

Fossil fuels (coal, oil, and natural gas) are used primarily for their concentration of chemical energy, energy that is released as heat when the fuels are burned. Fossil fuels are composed primarily of compounds of hydrogen (H) and carbon (C) and when the fuels are burned the H and C are oxidized to water (H_2O) and carbon dioxide (CO_2) and heat is released. If the H_2O and CO_2 are released to the atmosphere, the H_2O will soon fall out as rain or snow. The CO_2, however, will increase the concentration of CO_2 in the atmosphere and join the active cycling of C that takes place among the atmosphere, biosphere, and hydrosphere. Since humans began taking advantage of fossil-fuel resources for energy, we have been releasing to the atmosphere, over a very short period of time, C that was stored deep in the Earth over millions of years. We have been introducing a large perturbation to the active global cycling of C.

Estimates of fossil-fuel use globally show that there have been significant emissions of CO_2 dating back at least to 1750, and from the United States back at least to 1800. However, this human perturbation of the active C cycle is largely a recent process, with the magnitude of the perturbation growing as population grows and demand for energy grows. Over half of the CO_2 released from fossil-fuel burning globally has occurred since 1980 (Figure 1).

Some CO_2 is also released to the atmosphere during the manufacture of cement. Limestone ($CaCO_3$) is heated to release CO_2 and produce the calcium oxide (CaO) used to manufacture cement. In the United States, cement manufacture now releases less than 1% of the mass of CO_2 released by fossil-fuel combustion. However, cement manufacture is the third largest anthropogenic source of CO_2 (after fossil-fuel use and the clearing and oxidation of forests and soils). The CO_2 emissions from cement manufacture are often included with the accounting of anthropogenic CO_2 emissions from fossil fuels.

This paper addresses the magnitude and pattern of CO_2 emissions from fossil-fuel consumption and cement manufacture. It discusses how much carbon is released and poses the question of who is responsible for this carbon. It also comments briefly on the fate of carbon once released to the atmosphere and on alternatives to letting the carbon accumulate in the atmosphere.

Estimating CO_2 emissions

It is relatively straightforward to estimate the amount of CO_2 released to the atmosphere when fossil fuels are consumed. Because CO_2 is the equilibrium product of oxidizing the C in fossil fuels, we need to know only the amount of fuel burned and its C content (and if some of the fuel is used in ways that do not involve oxidation, e.g. for highway asphalt or to manufacture plastics). We can report either the amount of CO_2 produced or the amount of C in that CO_2, and in this paper we prefer to report the amount of contained C (the amount of CO_2 produced can be gained by multiplying the C content by the ratio of the molecular masses, 44/12). Throughout this paper "tons" are metric tons.

The rate of CO_2 emitted per unit of useful energy released is different for the different fossil fuels and depends on the ratio of H to C in the fuel and on the details of the organic compounds in the fuels. Roughly speaking, the numerical conversion from energy released to C released as CO_2 is about 25 kg C per 10^9 joules for coal, 20 kg C per 10^9 joules for petroleum, and 15 kg C per 10^9 joules for natural gas. Table 1 shows some of the exact coefficients reported by the Intergovernmental Panel on Climate Change (IPCC) for estimating CO_2 emissions.

The uncertainty in estimates of CO_2 emissions will thus depend on the variability in the chemistry of the fuels, the quality of the data or models of fuel consumption, and on uncertainties in the amount of C that is used for non-fuel purposes or is otherwise not burned. For countries like the US; with good data on fuel production, trade, and consumption; the uncertainty in estimates of national emissions of CO_2 is on the order of +/- 5% or less. In fact, the US Environmental Protection Agency (USEPA, 2005) suggests that their estimates of CO_2 emissions from energy use in the US are accurate, at the 95% confidence level, within –1 to +6 %. When national emissions are calculated by consistent methods it is likely that year-to-year changes can be estimated more accurately than would be suggested by the uncertainties of the individual annual values.

The magnitude of national and global CO_2 emissions

Figure 2 shows that from the beginning of the fossil-fuel era (1751 in these graphs) to the end of 2002, there were a cumulative total of 84.4 billion tons of carbon released as CO_2 from fossil-fuel consumption (and cement manufacture) in the United States. The global total was 298 billion tons of carbon so that the United States contribution is about 28.3%. Figure 3 shows the annual total of emissions from the United States and the contributions from the different fossil fuels. For the year 2002, the US contribution was about 22.7% of the global total. The US fraction of the global total has been shrinking with time.

Figure 4 provides our best estimates of the global total of CO_2 emissions for each year from 1750 to 2003 and includes our very recent estimates for 2004 and 2005. The 2004 and 2005 values are preliminary estimates based on energy data published by BP Company and are subject to revision, but they clearly show that emissions are increasing dramatically in the most recent years. The 2005 value is a 28% increase over the 1990 value.

Emissions by state and economic sector

To understand how CO_2 emissions from fossil-fuel use interact in the global and regional cycling of carbon, it is necessary to know the masses of emissions and their spatial and temporal distribution. We now have data sets that describe US emissions by state and by month (e.g., Blasing et al., 2005a and 2005b). To understand the patterns and trends of CO_2 emissions, the driving forces behind those trends, and the opportunities for reducing emissions, it is also useful to examine emissions by economic activity. These kinds of spatial and sectoral data also raise interesting issues abut the responsibility for CO_2 emissions, an issue that I will refer to as "my carbon and your carbon".

Before looking at some details of how energy is used and where CO_2 emissions occur in the United States and in the US economy, however, there are two indices of CO_2 emissions at the national level that provide perspective on the scale and distribution of emissions. These two indices are emissions per capita and emissions per unit of economic activity, the later generally represented by CO_2 per unit of gross domestic product (GDP). Figure 5 shows the 1950 - 2002 record of CO_2 emissions per capita for the 3 countries of North America and, for perspective, includes the same data for the global total. Note that per capita emissions in the United States are largely unchanged since 1970 and that they are roughly 5 times the global average. Similarly, Table 2 shows CO_2 emissions per unit of GDP for the three countries of North America and for the world total. Emissions of CO_2 per unit of GDP have been declining for over 2 decades in the United States (see U.S. DOE, 2005) and are only slightly higher than the global average value.

Emissions per capita and emissions per unit of GDP are, of course, very complex indices and though they provide some insight they say nothing about the details and the distributions within the means. The data on CO_2 per capita for the 50 U.S. states (Figure 6) show that even within the United States values range over a full order of magnitude, differing in complex ways with the structure of the economies and probably with factors like climate, population density, and access to resources (Blasing et al., 2005b; Neumayer, 2004). For example, Figure 6 provides an illustration of the role of the distribution of resources and of trade in energy intensive products. To take an extreme case, we can compare per capita emissions in Wyoming and California. Data from the Energy Information Administration show that per-capita energy use in 2000 differed by a factor of 4 between Wyoming and California, Figure 6 shows that per capita CO_2 emissions differed by a factor of nearly 12. A significant portion of the difference can be explained with data on how and where electricity is generated. In Wyoming, in 2000, 97% of electricity generation was using coal and 71% of the electricity generated was traded out of state. In California, in 2000, 1% of electricity generation was using coal and 23 % of the electricity consumed in California was imported from out of state. Per capita emissions from

Wyoming are very high because most of their electricity is generated with coal and because they generate electricity for other users. In essence, from the perspective of Wyoming, it is your electricity but my CO_2 emissions.

International data also illustrate the problem of subdividing the global system and trying to account for your C and my C. Of the growth in global CO_2 emissions from 1990 to 2005 (see Figure 4), nearly half can be found in China. But Shui and Harris (2006) estimate that 7 to 14% of current CO_2 emissions from China are a result of producing goods for consumption in the United States. Similarly, the Canadian national inventory of greenhouse gas emissions (Environment Canada, 2005) estimates that 6.6% of Canadian emissions are for the production, processing, and transport of natural gas and oil that are exported, mostly to the United States. Saving electricity in Norway likely results in reduced CO_2 emissions in Denmark, because it frees up Norwegian hydropower for export (Sjödin and Grönkvist, 2004). Of course, countries both import and export embodied CO_2 emissions in a great variety of commodities and finished goods. Thus, as countries (and other political subdivisions) rely increasingly on trade to meet their material needs, it is not an easy task to understand what the magnitude of domestic CO_2 emissions really means.

Estimating emissions by sector brings special challenges in defining sectors and assembling the requisite data. Nonetheless, the database of the International Energy Agency allows us a rough idea of how emissions are distributed among major sectors in the United States and how this compares with the other countries of North America (Table 3). The fact that the United States gets 51% of its electricity from coal while Mexico gets 68% from petroleum and natural gas and Canada gets 58% from hydroelectric stations gets superimposed on the differences in the structure of the economies and the varying importance of transport and factors as varied as climate and the mix and efficiency of industrial processes.

The US Department of Energy (2005a) shows similarly that 39% of US CO_2 emissions in 2004 came from generation of electric power with another 33% from transportation. Emissions of CO_2 have dropped from 0.205 kg C/kwh of electric power generation in 1970 to 0.167 kg C/kwh in 2004 as the mix of fossil fuels has evolved and the contribution of nuclear plus renewables has increased (Marland and Pippin, 1990; US Department of Energy, 2005b).

Full carbon accounting or life cycle analysis

The human component of the global carbon cycle has been seen to be interwoven with the global economic system. Changes in the stocks or flows of C in one place or one sector often have impacts on the stocks and flows of C in other places, other economic sectors, and other times. This suggests that strategies to manage CO_2 emissions be examined to see their full implications. Examining the complete life cycle of a product or service can reveal the range of impacts on the global cycling of carbon (and on emissions of other greenhouse gases). Conversion from conventional to no-till agriculture has been analyzed and provides a simple example of the full implications on the carbon cycle when agricultural practice is altered. Conversion from conventional to no-till agriculture has been recognized as a way to increase sequestration of C in agricultural soils and thus to reduce net CO_2 emissions to the atmosphere. This shift in practice also influences the amount of fuel used on the farm, the amount of fertilizer and other inputs to agriculture, and perhaps agricultural productivity. Our initial (Figure 7) analysis suggests that for average practice in the United States the sum of changes in greenhouse gas emissions is in fact greater than the amount of carbon sequestered in soils, but it demonstrates clearly that the affected system is larger than simply the C content of the soil.

Carbon management

When fossil fuels are burned the CO_2 is generally discharged to the atmosphere. Once in the atmosphere the active cycling of C will, over time, distribute this excess C among the atmosphere, the oceans, and the various components of the biosphere. It is possible to exercise some management over these processes by either promoting the removal of CO_2 from the atmosphere or collecting CO_2 at the points of fuel combustion or processing and putting it places where it is not mixed into the atmosphere.

Carbon removed from the atmosphere by photosynthesis can be managed to increase the C storage in forests or soils. Alternatively, the biological material can be harvested and used as a renewable fuel to displace fossil-fuel combustion. A third alternative is to harvest and use biological materials, such as wood, in the place of alternate materials that require more energy for their production and use.

The Intergovernmental Panel on Climate Change (IPCC, 2005) has estimated that there are nearly 8000 large, stationary, industrial sources (63% are large power plants) of concentrated CO_2 with emissions of more than 100,000 tons of CO_2 per year - and hence large enough to contemplate collection and storage of the CO_2. These large sources accounted for 60% of total global CO_2 emissions in 2000. The potential for long-term storage of this C in exhausted oil and gas fields, unminable coal seams, and deep saline aquifers appears to be very large and several demonstration projects are now proceeding worldwide. There is, of course, a cost for this CO_2 collection and storage, and it is estimated that 10% to 40% additional fossil fuel would have to be burned in order to get the energy to operate the capture and storage system.

Conclusions

Anthropogenic emissions of CO_2 to the atmosphere are large and growing. Humans have become a very important and very complex component of the global carbon cycle. Through use of fossil fuels and manipulation of the Earth's surface humans are significantly perturbing the natural cycling of carbon on a global scale. Increasing globalization of the economy and increasing linkage of human activities results in increasing complexity of the human component, and increasing difficulty in isolating my carbon from your carbon.

Acknowledgements

Ideas and illustrations in this short paper have been extracted from a number of papers with many co-authors. I thank Robert Andres, T.J. Blasing, Tom Boden, Christine Broniak, Veronika Dornburg, Jay Gregg, Leif Gustavsson, London Losey, Karen Treanton, and Tris West for their ideas and contributions. I have been supported by the US Department of Energy's Office of Science, Biological and Environmental Research Program and by Mid Sweden University.

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TABLES

Fuel	Emissions coefficient (kg C/10^9 J net heating value)
Lignite	27.6
Anthracite	26.8
Bituminous coal	25.8
Crude oil	20.0
Residual fuel oil	21.1
Diesel oil	20.2
Jet kerosene	19.5
Gasoline	18.9
Natural gas	15.3

Table 1: A sample of the coefficients used for estimating CO_2 emissions from the amount of fuel burned (from IPCC, 1997).

Country	1990	1998	2002
United States	0.19	0.17	0.15
Canada	0.18	0.18	0.16
Mexico	0.13	0.12	0.11
Global Total	0.17	0.15	0.14

Table 2: Emissions of CO_2 from fossil-fuel consumption (cement manufacture and gas flaring are not included) per unit of GDP for the United States, Canada, Mexico and for the global total. CO_2 is measured in kg C and GDP is in 2000 US$ purchasing power parity (from IEA, 2005).

Sector	United States	Canada	Mexico
Energy extraction and conversion[a]	46.2	36.2	47.7
Transportation[b]	31.3	27.7	30.3
Industry[c]	11.2	16.8	13.6
Buildings[d]	11.3	19.3	8.4

Table 3: Percent of CO_2 emissions by sector for 2003.

(a) the sum of three IEA categories, "public electricity and heat production", "unallocated autoproducers", and "other energy industries",

(b) IEA category "transport",

(c) IEA category "manufacturing industries and construction",

(d) IEA category "other sectors"

(from IEA, 2005)

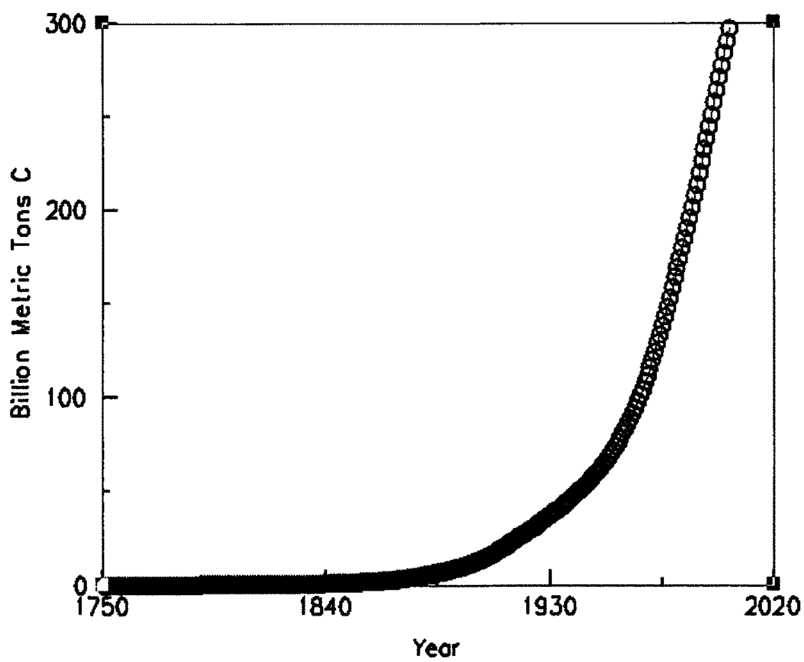

Figure 1: Cumulative global emissions of CO_2 from fossil-fuel combustion and cement manufacture from 1751 to 2002 (data from Marland et al., 2006).

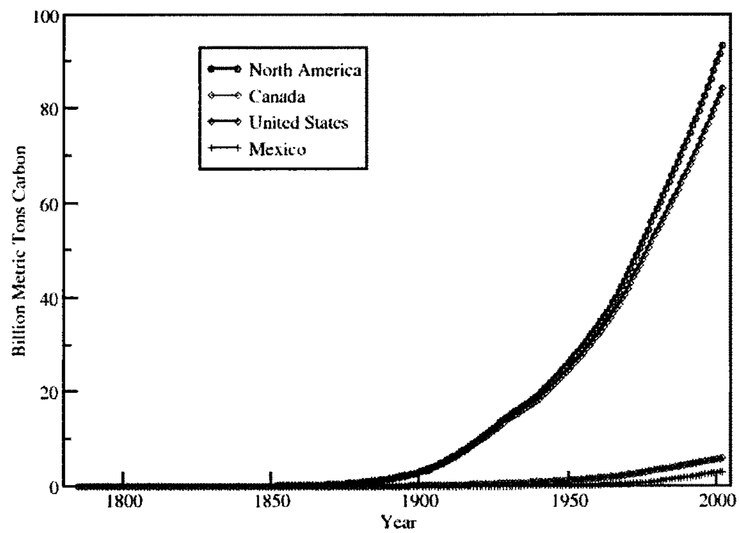

Figure 2: The cumulative total of CO_2 emissions from fossil-fuel consumption and cement manufacture, as a function of time, for the three countries of North America; and for the sum of the three (from Marland et al., 2006).

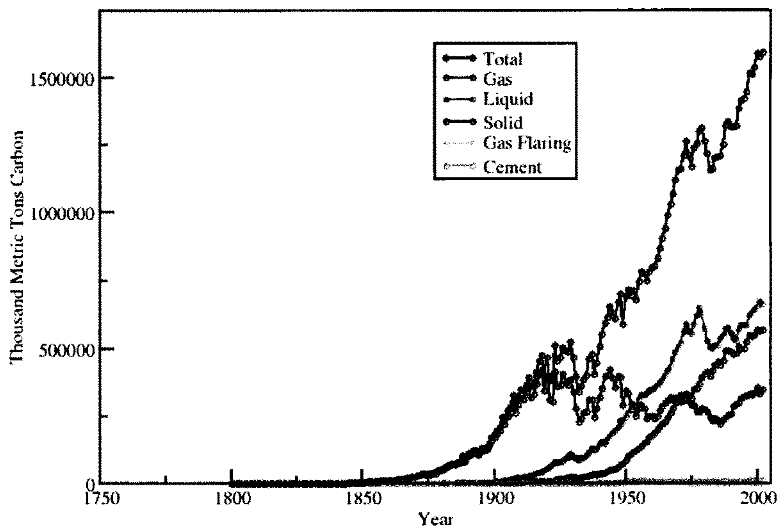

Figure 3: Annual emissions of CO_2 from fossil-fuel use, by fuel type, for the United States (from Marland et al., 2006). Gas, liquid, and solid refer to natural gas, petroleum products, and coal respectively. Small contributions from the flaring of natural gases at oil fields and from the manufacture of cement are included.

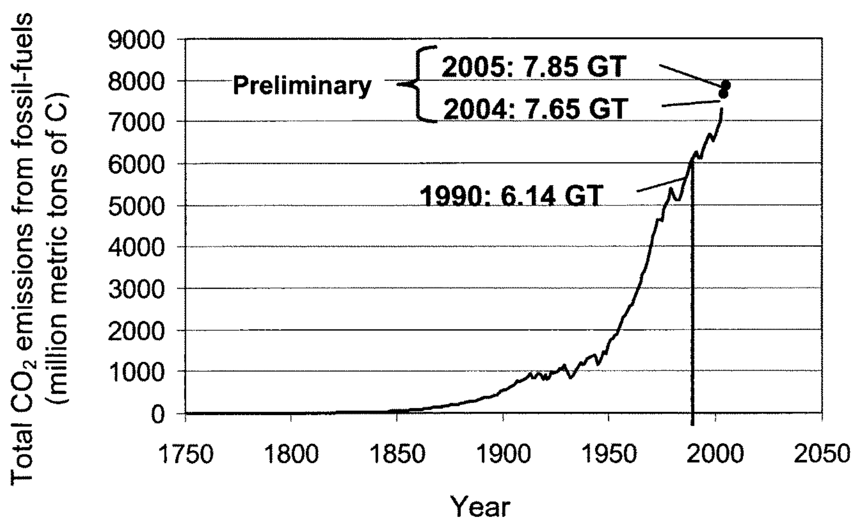

Figure 4: Total global emissions of CO2 from use of fossil fuels and manufacture of cement, 1751-2005. The values through 2003 are based on energy statistics from the United Nations for the period 1950 to 2003 and on energy statistics from a variety of sources for the period prior to 1950 (from Marland et al., 2006). Values for 2004 and 2005 are preliminary estimates derived by using energy statistics from the BP company to extrapolate from the earlier time series. The numerical value for 1990 is provided for reference. 6.14 GT C = 6140 million metric tons C.

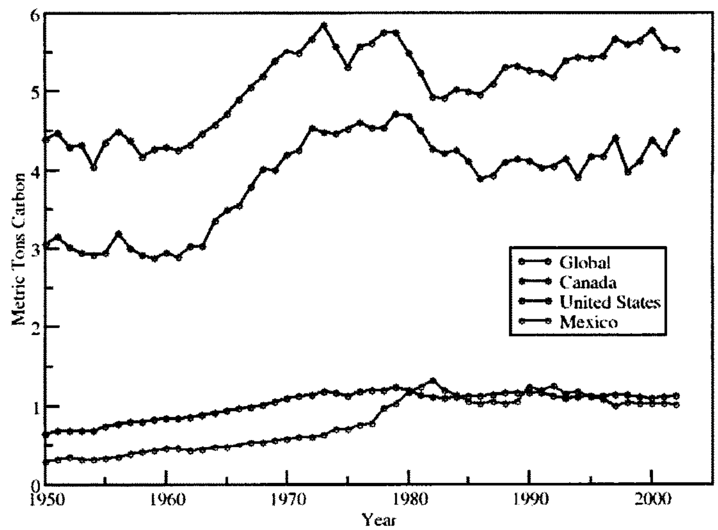

Figure 5: Per capita emissions of CO_2 (in metric tons of C per person per year) from fossil-fuel consumption (and cement manufacture) in the United States, Canada, Mexico, and for the global total of emissions (from Marland et al., 2005).

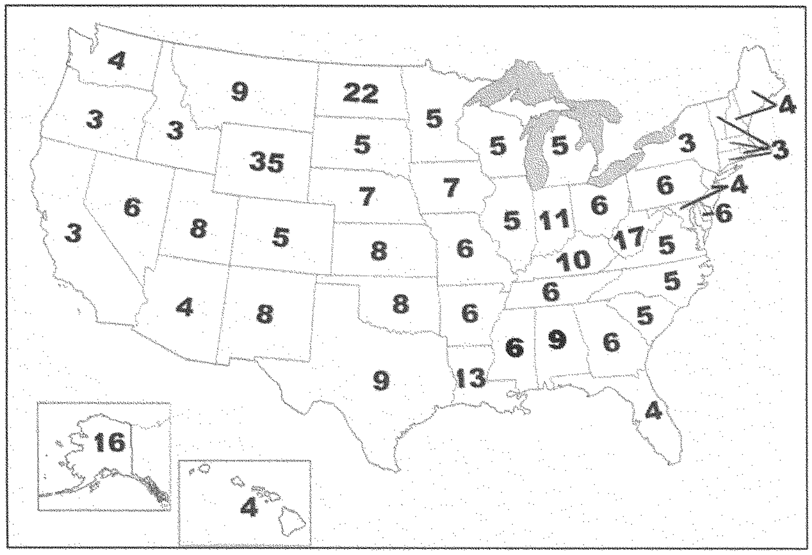

Figure 6: Per capita emissions of CO_2 from fossil-fuel consumption for the 50 U.S. states in 2000. To demonstrate the range, values have been rounded to whole numbers of metric tons C per capita per year (from Blasing et al., 2005b).

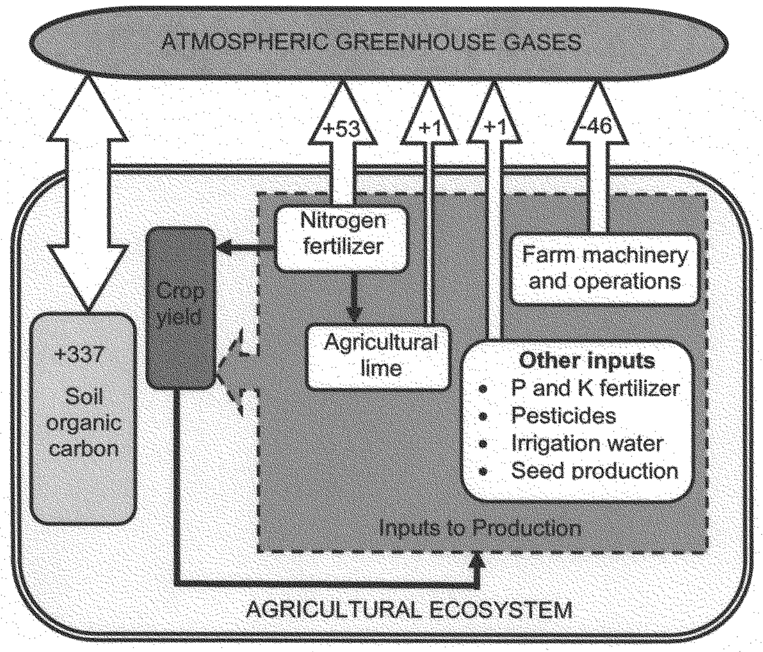

Figure 7: The net effect on greenhouse gas emissions for a change from conventional tillage to no-till agriculture. Data are based on average practice for all crops in the United States, circa 1995. Data are in kg C per hectare per year. The figure shows that while the organic C content of the soil is increased by 337 kg C per hectare per year, there is also a savings in emissions from fuel for farm machinery but an increase in emissions of the greenhouse gas nitrous oxide. Other inputs also change on average, and for any given location there may be a change in crop yield (from West and Marland, 2002).

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A. Education

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Washington University (St. Louis, MO)	1964-1966
University of Minnesota (Minneapolis, MN)	Ph.D, 1972

B. Positions

Distinguished Scientist, Oak Ridge National Laboratory, 2000-present
Guest Professor, Ecotechnology Program, Mid Sweden University, 2005-present
Senior Staff Scientist, Oak Ridge National Laboratory, 1987-2000
Staff Scientist, Institute for Energy Analysis, Oak Ridge Associated Universities, 1975-1987
Assistant Professor of Geology, Indiana State University, 1970-1975

C. Some Recent Professional Activities

1. National Research Council, Committee on Global Change Research, 2000-2002
2. IPCC (Intergovernmental Panel on Climate Change): Special Report on Carbon Capture and Storage, lead author, 2003-2005
3. IPCC: Third Assessment Report, lead author on Land-use Change and Forestry
4. IPCC: Special Report on Land Use, Land-Use Change and Forestry, lead author
5. IPCC: Second Assessment Report, lead author on Energy Primer
6. National Academy of Sciences: Policy Implications of Greenhouse Warming, panel member, 1990-1991
7. International Energy Agency/Bioenergy Agreement: U.S. team leader on Task 25 – biomass fuels and greenhouse gases, 1995-2001.
8. Council on Agricultural Science and Technology: Preparing U.S. Agriculture for Global Climate Change, panel member, 1991-1992
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Mr. ISSA. Thank you.
Dr. Wofsy.

STATEMENT OF STEVEN C. WOFSY

Mr. WOFSY. I would like to thank you very much for inviting me here, and I have actually got some visual aids which are intended to establish my position as the class geek among the six that have testified here.

I am going to address one question only. There are several things addressed in my testimony that I will not deal with. For example, some of the scientific issues about measuring, such as how do we measure the total amount of carbon coming from North America and from the United States? I think this is a very important question, but I won't bear on that in my oral testimony.

I am going to address the question of the land sink for CO_2. As we will see from this chart, which is also Table 1A in my written testimony, if you just look down that middle column, in North America we released 1,640 megatons, or 1.6 gigatons of carbon annually, on average, during the previous decade. About 35 percent of that is actually taken up by the land biosphere here in the United States and Canada. Very little, actually, in Mexico. So why is that and what role might that play in managing the carbon?

Why is it happening? It is happening because during the 18th and 19th centuries, the first part of the 20th century, we released a lot of carbon to the atmosphere by cutting down the forests and plowing the prairies and doing all that good stuff that we did. However, due to the intensification of agriculture and a number of other factors, including forestry and a bunch of other things like that, a lot of forests are regrowing where they had been before, and those forests are taking out a lot of carbon from the atmosphere, so what used to be a source is now a sink for carbon.

If you think about what is happening out there and you look at detail—we have a lot of scientific research, a lot of it supported by the DOE, actually, which examines what the forests are actually doing and why they are doing it, sort of on an ecological basis—what you find out is that one could manage the forests and other lands, range lands and crop lands, to increase carbon storage. You could do that in a very interesting way. You could do it in such a way that the costs involved were either not costs, you made money doing it, or you could do it in a marginal cost basis, for example, by incentivizing people to lengthen the rotation of timber harvests. A company has a forest growing and they wish to harvest it. If they wait, they pay an opportunity cost for the money, but they get a bigger crop. So that is one way that you can actually work on marginal costs. It is actually a very interesting option.

There is a risk, of course, that if you sequester carbon in ecosystems, that carbon can come back to you later through climate change, killing off the forest, or through people deciding that it was time to build a subdivision there or whatever——

Mr. ISSA. Or a California forest fire.

Mr. WOFSY. Well, the forest fires are actually a very interesting part of this. We could talk about that later. That is not unrelated to climate issues and also to other things like previous fire suppression in areas where fire is a normal part of the ecology. If you get more fuel, some bad things can happen, that is exactly right.

I am going to pass over the next several slides, and I would like to end, actually, with the one which is now way to the end of the thing, past where it says the end and go to where it says Figure 3. This is a result of research actually that we did at the Harvard Forest in central Massachusetts over the last 15 years as part of the Department of Energy AmeriFlux network. This is a complicated graph, so we are going to look at the top panel of the graph. What you see there is a line that shows how much carbon is taken out of the atmosphere for each hectare of land in the Harvard Forest. A negative means taking it out of the atmosphere. You may notice that the line is drifting more negative. In fact, in the last 5 years, Harvard Forest has taken out twice as much carbon per year from the atmosphere as it did in the first 5 years of the study, in the early 1990's. This is a very, very big surprise, and it looks like other sites in the AmeriFlux network are showing the same thing. One of the things we are going to want to do is to understand that.

It certainly is telling us—if I may wrap up—that the possibility of using sequestration in ecosystems could and should be part of the solution to this problem. There isn't, as you pointed out in your briefing document, there is not one solution to this problem. One of the nice things about this is that, unlike nuclear energy, this is working today on an enhanced basis. It is bigger now than it was 10 years ago. That is not true for the nuclear industry. So we have something that is actually responding quickly. Maybe it won't last as long. It is not clear how long this will go on, and it is not clear even, really, why it is happening. We need more scientific research to learn about that.

That is where I will end and take any questions. Thank you.

[The prepared statement of Mr. Wofsy follows:]

THE LAND SURFACE COMPONENT OF THE NORTH AMERICAN CARBON BUDGET

Testimony before the Committee on Government Reform
Subcommittee on Energy and Resources
Darrell Issa, Chairman
September 27, 2006, 2:00 pm
Rayburn House Office Building, Room 2154

Presented By
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I. Introduction

Science and policy questions for the carbon budget of North America

Reliable, specific knowledge of the sources and sinks of CO_2 in nations of North America is needed in order to formulate policy options for managing US emissions of CO_2 to the atmosphere. We consider here the scientific questions that must be addressed in order to provide the needed information to society and to decision makers.

Human-caused emissions of CO_2 are due primarily to combustion of fossil fuels, with small contributions from cement manufacturing and land use change.

- What are the current sources, past trends, and future projections for human-caused emission of CO_2 to the atmosphere?
- What are the underlying factors that regulate the past, present, and future emissions?

These questions are addressed in the testimony of Dr. Gregg Marland.

Managed and unmanaged ecosystems currently constitute a land sink for atmospheric CO_2 in North America.

- What is the magnitude of the current uptake of CO_2 from the atmosphere due to biological processes, past trends in this quantity, and projections of the future?
- What are the underlying factors that regulate the past, present, and future magnitude of this uptake?
- Can the "land sink" be managed to help offset fossil fuel emissions?
- What are the major uncertainties that need to be addressed by scientific research in order to provide society and decision makers with the best possible information about sources and sinks of CO_2 in North America?

These questions are addressed here, in response to the request of the Subcommittee for "testimony [that] detail[s] information regarding what is and is not known about carbon sinks in the United States and the exchange of carbon between the atmosphere and natural systems."

The State of the Carbon Cycle Report (SOCCR, 2006)

This testimony relies on a comprehensive assessment of the carbon budget for North America, the State of the Carbon Cycle Report [Dilling et al., editors], cited in this document as "SOCCR, 2006". SOCCR (2006) is element 2.2 of the Synthesis and Assessment Products of the U. S. Climate Change Science Program (CCSP), intended "to provide the best possible scientific information to support public discussion, as well as government and private sector decision-making, on key climate-related issues." It has been developed over a two-year period by dozens of scientists. It has received a first round of scrutiny and public review, and is currently undergoing the final stages of review. SOCCR (2006) is an authoritative reference to address questions of past, present, and future uptake of atmospheric CO_2 by land ecosystems in North America.

Currently, "bottom up" scientific studies (e.g. Houghton et al., 1999; Pacala et al., 2001) provide the principal sources of information for assessing the magnitude of sources and sinks of CO_2 in North America. These studies use inventories of timber stocks in forests (in the U.S., the USFS Forest Inventory Analysis) and soil organic matter in agricultural lands (in the U.S., the USDA National Resources Inventory), plus remote sensing, to construct a sophisticated spreadsheet detailing the total amount of carbon stored as organic matter across the continent. By examining the changes in these totals over time, a carbon budget has been constructed in SOCCR (2006).

Bottom-up carbon budgets require considerable extrapolation from the actual measurements. Lands in many cover classes are not inventoried, in particular, Western lands subject to woody encroachment are mostly not surveyed. In Canada and Mexico, national scale data are not available. Carbon budget analysis requires subtracting values for two inventories, and thus reliable values cannot be obtained for intervals shorter than 5-10 years. This requirement limits how much can be learned about *why* observed changes have occurred. Inventories are conducted to manage economically valuable resources, not for carbon accounting, and thus important pools of organic matter are omitted.

SOCCR (2006) points out that carbon budgets at sites in the DoE AmeriFlux network have converged with inventory budgets. The AmeriFlux "eddy covariance" towers make direct measurements at ~1 hr time resolution of fluxes from the whole ecosystem. Data for some of AmeriFlux sites extend to 10 years or more, and agreement with inventory data at these locations lends confidence to the inventory-based budgets. So far, however, this comparison can be carried out at just a handful of sites.

The North American Carbon Program (NACP; Wofsy and Harriss, 2002; Denning et al., 2005) is intended to develop and test an observing system capable of using measurements of atmospheric CO_2, combined with remote sensing and meteorological data, to provide a "top down" budget. Figure 1 displays a key element of the NACP strategy, a tall tower observation station (NOAA-ESRL) that continuously measures the concentrations of CO_2 and other gases several hundred meters above the ground. These data provide a measure of the net flux of CO_2 from the surface over a large area of North America, extending for several hundred miles. Many of these towers are needed to construct a reliable carbon budget for North America, and it remains scientifically challenging to validate the uptake rates derived from the data.

Other elements of the NACP include remote sensing data for vegetation state and CO_2 concentrations (NASA), enhancement of the inventory programs (DoA), the network of flux towers noted above (DoE), and intensive studies to validate methods (NSF). NOAA has prepared the equipment to set up a large number of tall-tower stations. The current phase of the NACP focuses on testing the concepts for the top-down determination of the North American carbon budget. Note that, since air does not recognize national borders, the top-down analysis necessarily treats the budgets of Mexico and Canada as well as in the US.

II. Summary of what we know

What are the magnitudes of the current uptake of CO_2 from the atmosphere due to biological processes, past trends in the carbon budget, and projections of the future?

SOCCR (2006) provided a summary of what we know about the contribution of vegetation and soils to the carbon budget for North America:

- During the 18th, 19th, and the first part of the 20th century, the plants and soils of the United States and Canada were sources for atmospheric CO_2 due to expansion of croplands into forests and grasslands. In recent decades these regions shifted from source to sink as forests returned to many areas, and as western woodlands and forests accumulated fuel due to fire suppression and reduced logging. In Mexico, emissions of carbon continue to increase from net deforestation.
- The future of the North American land carbon sink is highly uncertain. Uptake by recovering forests may decline as the forests mature, but we do not know how quickly this may occur. Moreover, some current uptake may be stimulated by deposition of nitrogen from air pollution and by rising CO_2 concentrations in the atmosphere. We do not understand the magnitude of these "fertilizing" effects, nor can we quantitatively assess the impacts of ozone pollution or climate change.
- There appear to be good options for mitigating (10-30%) fossil fuel emissions by managing North American forests, rangelands, and croplands to increase carbon storage, but current uncertainties are large. Ideas for managing ecosystem carbon budgets are most competitive when other goals are served at the same time, for example, conservation of soil and water resources, or production of food or fiber.
- There is a risk that carbon sequestered in land ecosystems may be released by natural phenomena or human activities.

Table 1 summarize these conclusions quantitatively, showing that the land sink currently removes from the atmosphere just over ¼ of the fossil fuel emissions from North America. Figure 2 disaggregates the land sink into sectors, including forest growth, woody encroachment due to fire suppression in semi-arid areas, wood products, accumulation in wetlands (natural zones for deposition), and trapping of eroded sediment in rivers, reservoirs, and estuaries.

What are the underlying factors regulating the past, present, and future magnitude of the "land sink"? Can management of ecosystems help offset fossil fuel emissions?

Forest growth and wood products are, together, by far the largest and best-studied components of the land sink, with comprehensive data from forest inventories. Most current forest growth is a legacy of prior land use, especially reforestation of the Northeast and Southeast in the 19th and 20th centuries as agriculture industrialized and moved elsewhere. There are subtleties in accounting for this uptake in a policy context, especially for any system of "carbon trading" that might be considered. Industrialized agriculture is energy intensive, and thus the forest carbon sink comes at the cost of energy use elsewhere. Nevertheless the sink is surprisingly large. It appears feasible, and likely economically profitable, to adopt management practices which sustain and enhance storage of carbon, particularly when combined with economic activities that produce renewable fuels, fiber, or food, or with efforts to protect water, air, or biological resources.

Data from several of the longer-running stations of the DoE AmeriFlux network have tended to indicate increasing rates of uptake of CO_2 from the atmosphere over the past 10—15 years, even in places like the 85-year–old Harvard Forest in Petersham, MA

(Figure 3; source: Urbanski et al., 2006) or the 160-year-old Thompson site in Manitoba (Dunn et al., 2006). The hourly data from the AmeriFlux "eddy covariance" towers provide a direct measure of the carbon flux from a whole forest ecosystem, including soil processes. Acceleration of uptake in these older sites is very surprising, and it appears to support the view that could be sustained and enhanced. The underlying causes are not known, however, and uptake data are available for just a few sites. Possibilities include favorable shifts in climate just at these sites, global-scale stimulation of plant growth by rising CO_2, and other factors. This is an area of active scientific research, although it requires long-term research that may be difficult to support on a sustained basis.

Woody encroachment in fire-prone areas of the West represents the second largest component of the land sink, and the most uncertain. These lands have low commercial value and most are not inventoried. Unlike the beneficial and valuable carbon stored in forests, the accumulation of fuel in these areas represents a problem, threatening more severe fires with the high risk of rapid return of sequestered carbon to the atmosphere. Likewise the trapping of sediment in reservoirs is problematic, resulting from soil loss and limiting the lifetime of water projects.

Carbon sequestration in agricultural soils results largely from shifts to minimum tillage or no tillage. The associated uptake is quite small, limited by the cropping regime and other factors. However, reduced tillage practices offer significant benefits in soil conservation, conditioning, and reduction of inputs. Carbon sequestration enhances those values for the farmer and for society.

Wetlands naturally trap organic matter, growing and shrinking over centuries and millennia. They contain vast stores of carbon, preserved by anaerobic conditions in waterlogged soils. The response to climate change of organic matter in wetlands is one of the major uncertainties for the future of the carbon budget, as noted below.

Projections into the future generally predict constant or declining uptake of CO_2 by the land sink, in North America and globally. A number of carbon—climate coupled models were run recently in preparation for the fourth report of the IPCC (Friedlingstein et al., 2006). The models generally agree in projections that show negative impacts of climate change on vegetation and soils at low latitudes, where temperatures are projected to rise and soils to become drier. Affected areas may include the Southeastern U.S. (e.g. Fung et al., 2005; Figure 4). However, there are major differences between the models for high latitudes, with some predicting net carbon gains and some losses. These discrepancies largely reflect differences in the model projections for soil moisture.

III. Summary of what we don't know, but would like to understand

What are the major uncertainties that need to be addressed by scientific research in U.S. in order to provide society and decision makers with the best possible information about sources and sinks of CO_2 in North America?

There are two scientific issues of the highest priority needed to provide key information to society and to policy makers:

(1) *We must develop the capability to make accurate, reliable measurements of the carbon emissions and uptake for North America, resolved by season and region.* This is the primary information needed to make informed judgments about non-fossil sources

and sinks for CO_2, to assess the efficacy of any strategies adopted to restrain CO_2 increase in the atmosphere, and to ascertain the effects of climatic anomalies and trends on the North American carbon budget.

Determination of the carbon budget on regional and continental scale requires strong research efforts to strengthen both bottom-up (inventory) and top-down (atmospheric) methods, and eventually to combine these into a "data fusion" approach. The strategy for this program is set forth in NACP planning documents (Denning et al., 2005; Wofsy and Harriss, 2002). Multi-agency coordination and innovative research programs are the foundation of the plan.

The core observational elements of the top-down method are the NOAA ESRL tall tower network and associated weekly aircraft ascents, remote sensing data for vegetation state and CO_2 total column (NASA), and improved high-resolution meteorological analysis products (NOAA). Significant developments of theory and of computer models are needed to use these data (supported by many agencies). Intensive validation studies using aircraft and ground observations (NASA, NSF) are essential for success of the program.

The main elements of the bottom-up method are the inventories (DoA), which need to be expanded to cover all major vegetation types and land uses and to account for all significant pools of organic matter, plus remote sensing (NASA). Hence we need substantial enhancement of the inventory programs. The AmeriFlux program (DoE) of ecosystem flux observations provides essential validation for this effort.

(2) *We need to understand the processes that regulate the carbon cycle on regional and continental scales in North America.* These insights are required to provide increased confidence in projections of future carbon budgets, and to devise management strategies that enhance carbon sequestration in North American ecosystems while simultaneously optimizing other economic and social values. The elements laid out in (1) provide the foundation for gaining mechanistic understanding. In addition, large—scale ecosystem manipulations (DoE, NSF, DoA) are essential to probe the response of ecosystems to future conditions of climate, atmospheric CO_2, nutrient deposition, air pollution, and management.

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V. Tables and Figures

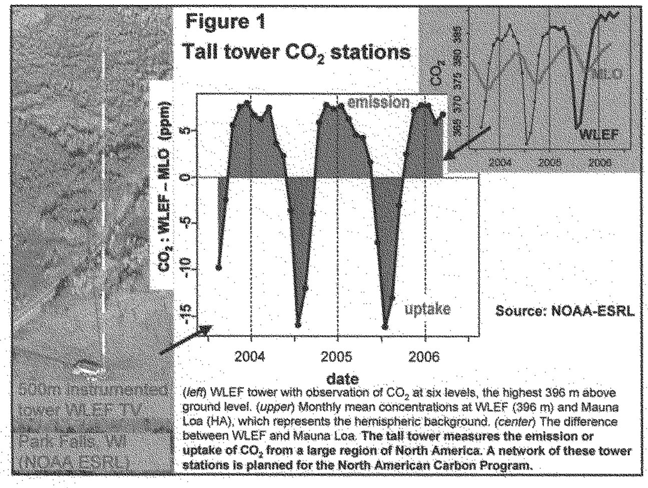
Table 1a. North American contribution to the global carbon budget of approximately the 1990s. Global values are from IPCC (2001). The North American terrestrial sink estimate is from SOCCR (2006). Values are in millions of tons of C per year, positive ⇒ emissions to the atmosphere, negative ⇒ uptake from the atmosphere.

Component	**Global budget[a] (Mt C yr^{-1})**	**North America[b] (Mt C yr^{-1})**	**North American fraction (%)**
Atmospheric increase	3200 ± 100	*not applicable*	*not applicable*
Human-caused emissions (fossil fuel, cement)	6300 ± 400	1640 ± 164[c]	26%
Ocean-atmosphere flux	–1700 ± 500	20 ± 20	1%
Emissions from land-use change	1600 ± 800[d]	–37[e]	2%
Terrestrial Sink	–2300 ± 1300	–600 ± 300[g]	26%

[a] Global uncertainties are ± 1 standard error (67% confidence intervals) (IPCC, 2001).
[b] North American uncertainties are 95% confidence intervals (see Chapter 3 SOCCR, 2006).
[c] Average emissions for 1990–1999 (Marland *et al.*, 2006). [d] Estimate for 1989–1995 (IPCC, 2000).
[e] U. S. only, for the 1980s (Houghton *et al.*, 1999).
[g] Estimated from changes in inventories of carbon stored in plants and soils.

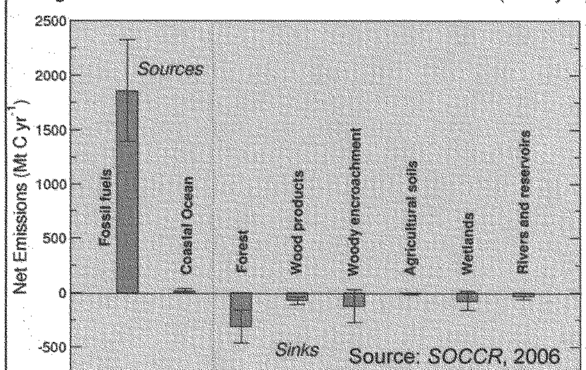
Table 1b. Nonfossil carbon sink, by country and sector. (Source: SOCCR, 2006)

Source (positive) or Sink (negative)	**United States**	**Canada**	**Mexico**	**North America**
Fossil source (positive)				
Fossil fuel (oil, gas, coal)	1582	164	110	1857
Nonfossil carbon sink (negative) or source (positive)				
Forest	–259	–99	+52	–306
Wood products	–57	–10	ND	–67
Woody encroachment	–120	ND	ND	–120
Agricultural soils	–4	–0	0	–4
Wetlands	–41	–25	–4	–70
Rivers and reservoirs	–25	ND	ND	–25
Total carbon source or sink	**–506**	**–134**	**48**	**–592**



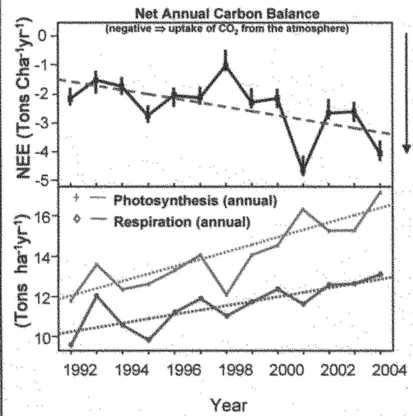
(*left*) WLEF tower with observation of CO_2 at six levels, the highest 396 m above ground level. (*upper*) Monthly mean concentrations at WLEF (396 m) and Mauna Loa (HA), which represents the hemispheric background. (*center*) The difference between WLEF and Mauna Loa. **The tall tower measures the emission or uptake of CO_2 from a large region of North America. A network of these tower stations is planned for the North American Carbon Program.**

Fig. 2. North American carbon sources and sinks (Mt C yr^{-1})



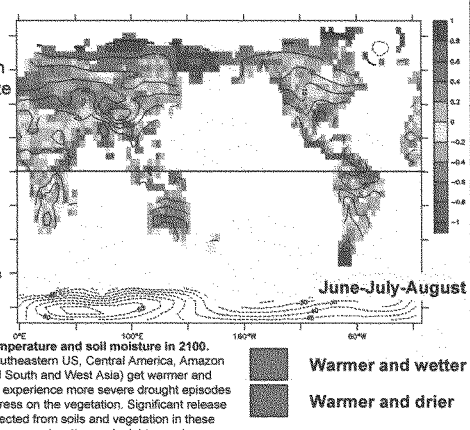
Height of a bar indicates a best estimate for net carbon exchange between the atmosphere and the indicated element of the North American carbon budget in 2003. Error bars indicate uncertainty in that estimate, and define the range of values that are believed to include the actual value with 95% certainty.

Figure 3. Carbon budgets of whole forests



Long-term carbon balance in a New England Forest. The DoE AmeriFlux Network uses advanced methods to directly measure the carbon balance ("NEE", Net Ecosystem Exchange) of forests every hour. Data for long-running stations using this "eddy covariance" technique have tended to indicate increasing rates of uptake of CO_2 from the atmosphere, even in places like the 85-year-old Harvard Forest in Petersham, MA (data shown at the left; source: Urbanski et al., 2006).

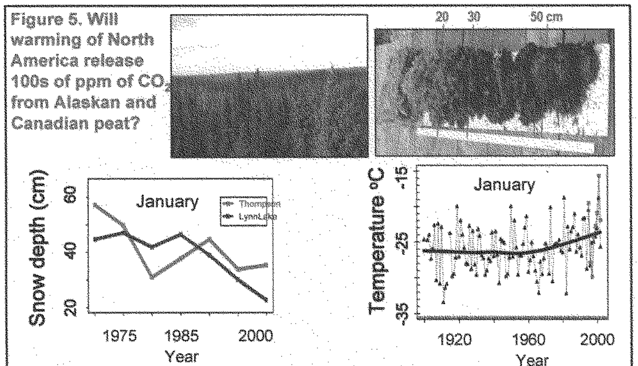
Figure 4. Temperature-Soil Moisture Correlation for Projected Climate in 2100.



Source: I. Fung, S. Doney, K. Lindsay, J. John, P. Friedlingstein, 2005. Colors show correlation coefficients for T and soil moisture between 2000 and 2100.

Projected changes in temperature and soil moisture in 2100. Areas shown in green (Southeastern US, Central America, Amazon Basin, most of Russia and South and West Asia) get warmer and drier, and are projected to experience more severe drought episodes and increased moisture stress on the vegetation. Significant release of CO_2 from would be expected from soils and vegetation in these areas. Areas in red get warmer and wetter, and might experience increased carbon sequestration.

Figure 5. Will warming of North America release 100s of ppm of CO_2 from Alaskan and Canadian peat?



Forests and bogs in Canada, Alaska and Siberia contain vast stores of organic matter in peat-laden soils (*upper panels*), equivalent to 200—400 ppm of CO_2 if oxidized and released to the atmosphere. The peat accumulated over thousands of years, preserved by being waterlogged and/or frozen. Climate has warmed markedly in these regions since 1960, and snow cover has declined (*lower panels*). Accumulated peat could be oxidized quickly by microbial activity or by combustion, should it thaw and dry out. Some climate models predict vast releases of CO_2 by this process due to climate change in this century, but others project increased precipitation that preserves and enhances stores of peat. (Thompson, MB, photos and data; Source: Dunn et al., 2006)

Mr. ISSA. Thank you.
Dr. Lashof.

STATEMENT OF DR. DANIEL A. LASHOF

Mr. LASHOF. Thank you.

It is a pleasure to be before this committee led by two Californians, where I did my dissertation research on the carbon cycle a few years ago at the University of California. I would like to make five points today with the help of a few slides as well. I will cover the five points quickly and then go back and explain them.

First, the carbon cycle has never been as far out of balance as it is today, so the title you have given this hearing is very apt. We need to act to rebalance it. Second, because of that, the amount of carbon dioxide in the atmosphere is higher than it has been in at least 650,000 years, and the amount is continuing to rise rapidly. Third, the imbalance in the carbon cycle has thrown the Earth's energy balance out of wack and that is causing dangerous global warming which threatens our environment, health, and economy. Fourth, we can rebalance the carbon cycle in time to prevent the most dangerous effects of global warming, but we are running out of time to do that, and we are running out of time very quickly. Fifth, only an enforceable limit on global warming and pollution, in my view, can drive the market for clean technologies fast enough to get the job done in time.

So let me explain those points in the few minutes that I have.

In the next slide I show a very simplified picture of the carbon cycle. This may be a little bit out of date. Gregg just told us that current emissions are maybe closer to 8 billion tons. But the basic picture here is that when we burn fossil fuels—coal, oil, natural gas—we are putting 7 billion to 8 billion tons of carbon into the atmosphere. About 3 billion tons of that is being removed by forests, other biological systems, and the oceans. That means there is 4 billion tons left, and that translates into a two part per million increase in CO_2 in the atmosphere.

If you look at the next slide, that is what we are seeing. This is the actual record of CO_2 in the atmosphere since 1958. And what we know from this and other data is that we now have over 380 parts per million in the atmosphere. That is more, as I said, than we have seen in over 650,000 years, and the growth rate has accelerated in the last few years. Three out of the last 4 years have seen an increase of two parts per million or more. As I said, that extra CO_2 in the atmosphere is trapping heat, driving global warming and causing a whole range of consequences that we are really beginning to see. To name a few, we are experiencing more severe hurricanes as ocean temperatures rise, more severe droughts and wildfires, and, as you mentioned, Mr. Chairman, particularly in the Western United States, as mountain snow pack declines and the higher temperatures increase evaporation rates, increased risk of fire, coastal flooding and innundation as ice sheets and glaciers melt, and more deaths from severe heat waves, particularly in our urban areas.

To get to the fourth point, we are running out of time to stop this.

Here is our choice. If we start cutting emissions in the United States now, and work with other countries using our leadership to leverage them to take similar action, we can rebalance the carbon cycle in time to avoid the most dangerous consequences of global warming, and we can do it at a pace that is gradual enough that we can afford to do it. In this curve, we ramp up to about a 3 percent per year reduction in CO_2 emissions. This goes to the question you asked to the previous panel. This is the kind of reduction that we need to do to solve the problem, not just to reduce how bad it is. Eventually, if we keep doing that, we can reduce the emissions of carbon dioxide to the level where the emissions are equal to the removals and then we have balanced it out. We think there is growing evidence that we need to do that at no higher than about 450 parts per million in the atmosphere. We are at 380 today. That means we have to get started right away.

A paper that Jim Hansen headed at NASA Goddard Institute of Space Science, published just yesterday, argues that we have no more than 10 years to turn the corner on CO_2 emissions if we are going to get where we need to go.

So let me get to my last point. The technologies are available today to get this job done, and here is a portfolio of technologies. They are described in more detail in the September issue of "Scientific American," which we have made available to all the Members of the House. We can get started with the technologies that we have now.

There is no question that additional technology development will help us do this more cost effectively, but here is the irony: the administration is calling for a big government technology R&D program with no assurance that this technology will actually be used to reduce carbon dioxide emissions. Supporters of global warming emission limits have united behind a market-based solution that would put a cap on the total emissions of carbon dioxide and let market-based trading figure out the most efficient way of achieving that cap. Without that kind of cap that would drive the private sector investments in deploying these technologies to reduce emissions, all the R&D in the world won't solve this problem.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Lashof follows:]

NRDC
THE EARTH'S BEST DEFENSE

NATURAL RESOURCES DEFENSE COUNCIL

Testimony of Daniel A. Lashof
Science Director, Climate Center
Natural Resources Defense Council

Hearing on

Rebalancing the Carbon Cycle

Committee on Government Reform
Subcommittee on Energy and Resources
House of Representatives

September 27, 2006

Thank you Mr. Chairman for holding this hearing on what I believe should be a critical priority for the federal government: rebalancing the carbon cycle. My name is Daniel A. Lashof, and I am the science director of the Climate Center at the Natural Resources Defense Council (NRDC). NRDC is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1.2 million members and online activists nationwide, served from offices in New York, Washington, Los Angeles and San Francisco. I have worked at NRDC since 1989 and have served on committees of the National Research Council, the President's Council of Advisors on Science and Technology, and the Intergovernmental Panel on Climate Change. Prior to joining NRDC I was a scientist at the Environmental Protection Agency, where I was the lead author of a report to Congress on policy options for stabilizing global climate. I am particularly pleased to appear at this hearing because my doctoral dissertation at the University of California addressed the role of the biosphere in the global carbon cycle.

Out of Balance

Mr. Chairman, this hearing is particularly timely because the carbon cycle today is more out of balance than at any time in history. Each year emissions from burning fossil fuels and destroying forests put about twice as much carbon dioxide (CO_2) into the atmosphere as natural sources can remove. As a result, the amount of carbon dioxide in the atmosphere is rising worldwide and the rate of growth is increasing. The average CO_2 concentration in Earth's atmosphere is now over 380 parts per million by volume (ppm), which is higher than it has been for at least 650,000 years[1]. In 2005 the concentration of carbon dioxide in the atmosphere increased by 2.5 ppm, the third largest annual increase ever recorded[2]. Although there is considerable variation from year to year in the rate of increase in atmospheric carbon dioxide, the rise has been more than 2 ppm in 3 of the last 4 years and preliminary 2006 data indicate that this trend is continuing.

The unprecedented buildup of carbon dioxide in our atmosphere endangers our environment, our health, and our economy. Carbon dioxide traps heat in the earth's atmosphere, preventing it from escaping into space. So the imbalance in the carbon cycle has also thrown the earth's energy balance out of whack, which means that each year the earth absorbs more energy from the sun than it radiates back into space. Global warming is the inevitable result and the human fingerprint on Earth's climate is now clearly visible. The consequences have become all too apparent in recent years:

- More severe hurricanes as ocean temperatures rise[3];
- More severe droughts and wildfires, particularly in the western United States, as mountain snowpacks decline and evaporation rates increase[4];
- Coastal flooding and inundation as melting mountain glaciers and polar ice sheets raise sea levels[5];

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[1] Siegenthaler, U., T.F. Stocker, E. Monnin, D. Luthi, J. Schwander, B. Stauffer, D. Raynaud, J. Barnola, H. Fischer, V. Masson-Delmotte, and J. Jouse (2005) Stable Carbon Cycle-Climate During the Late Pleistocent, *Science*, 310, p. 1313-1317.
[2] Tans, P. (2006) Trends in Atmospheric Carbon Dioxide, NOAA ESRL, available at: http://www.cmdl.noaa.gov/ccgg/trends/
[3] Mann, M.E. and K.A. Emanuel (2006) Atlantic Hurricane Trends Linked to Climate Change, *Eos*, 87(24), p. 233-244.
[4] Westerling, A.L., H.G. Hidalgo, D.R. Cayan and T.W. Swetnam (2006) Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity, *Science*, published in Science Express on 6 July 2006, doi: 10.1126/science.1128834
[5] Overpeck, J.T., B.L. Otto-Bliesner, G.H. Miller, D.R. Hugs, R.B. Alley and J.T. Kiehl (2006) Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise, *Science*, 311, p.1747-1750.

- Ecosystem destruction and species extinctions as climate change and ocean acidification destroy polar bear habitat, spread disease among harlequin frogs, and dissolve coral reefs[6].

Time Is Running Out

The good news is that we can avoid the worst effects of global warming if we act decisively now to begin rebalancing the carbon cycle by reducing emissions of carbon dioxide from power plants, automobiles, and other sources. Significant emission reductions are needed, and delay only makes the job harder. As the National Academy of Sciences stated last year:

> Despite remaining unanswered questions, the scientific understanding of climate change is now sufficiently clear to justify taking steps to reduce the amount of greenhouse gases in the atmosphere. Because carbon dioxide and some other greenhouse gases can remain in the atmosphere for many decades, centuries, or longer, the climate change impacts from concentrations today will likely continue well beyond the 21st century and could potentially accelerate. Failure to implement significant reductions in net greenhouse gases will make the job much harder in the future—both in terms of stabilizing their atmospheric abundances and in terms of experiencing more significant impacts.[7]

We are already beginning to see the effects of global warming and scientists are increasingly concerned that we are approaching a tipping point beyond which severe and irreversible impacts will become inevitable. For example, recent observations show that the Greenland ice sheet is melting more rapidly than expected and that global warming of as little as 2 degrees Celsius (3.6 degrees Fahrenheit) from 19th Century levels could

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[6] Pounds, J.A., M.R. Bustamante, L.A. Coloma, J.A. Consuegra, M.P.L. Fogden, P.N. Foster, E. La Marca, K.L. Masters, A. Merino-Viteri, R. Puschendorf, S.R. Ron, G.A. Sanchez-Azofeifa, C.J. Still and B.E. Young (2006) Widespread amphibian extinctions from epidemic disease driven by global warming, *Nature*, 439, p. 161-167, doi:10.1038/nature04246.
[7] National Academy of Sciences, *Understanding and Responding to Climate Change: Highlights of National Academies Reports*, p.16 (October 2005), http://dels.nas.edu/dels/rpt_briefs/climate-change-final.pdf (emphasis added).

cause it to eventually collapse, raising sea levels by as much as 20 feet[8]. A similar amount of warming could put millions of people at risk of water stress, hunger, and malaria and cause the collapse of many vulnerable ecosystems, including most alpine meadows and more than 90% of coral reefs[9].

We have a reasonable chance of staying within this 3.6 degree Fahrenheit envelope if atmospheric concentrations of CO_2 and other global warming gases are kept from exceeding 450 ppm CO_2- equivalent. This implies a budget for cumulative global and U.S. carbon dioxide emissions designed to rebalance the carbon cycle in time to stay within this 450 ppm target. A reasonable allocation of that budget to the United States over the period 2000 to 2050 would limit cumulative U.S. emissions over that period to less than 40 times our emissions level in 2000. To live within this budget we must stop U.S. emissions growth within the next 5-10 years and cut emissions by 60-80 percent over the next 50 years. U.S. action on this scale – together with similar cuts by other developed countries and limited emissions growth followed by reductions from developing countries – would keep the world within that 450 ppm limit.

So here is our choice. If we start cutting U.S. emissions soon, and work with other developed and developing countries for comparable actions, we can stay on the 450 ppm path with an ambitious but achievable annual rate of emission reductions – one that gradually ramps up to about 3.2% reduction per year. (See Figure 1.)

But if we delay a serious start and continue emission growth at or near the business-as-usual trajectory for another 10 years, the job becomes much harder – the

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[8] Overpeck et al, 2006.

[9] Warren, R. (2006) Impacts of Global Climate Change at Different Annual Mean Global Temperature Increase, in H. Schellnhuber, et at., (*eds.*) *Avoiding Dangerous Climate Change*, Cambridge University Press, New York.

annual emission reduction rate required to stay on the 450 ppm path jumps between two- and three-fold, to 8.2% per year. In short, a slow start means a crash finish – the longer emissions growth continues, the steeper and more disruptive the cuts required later.

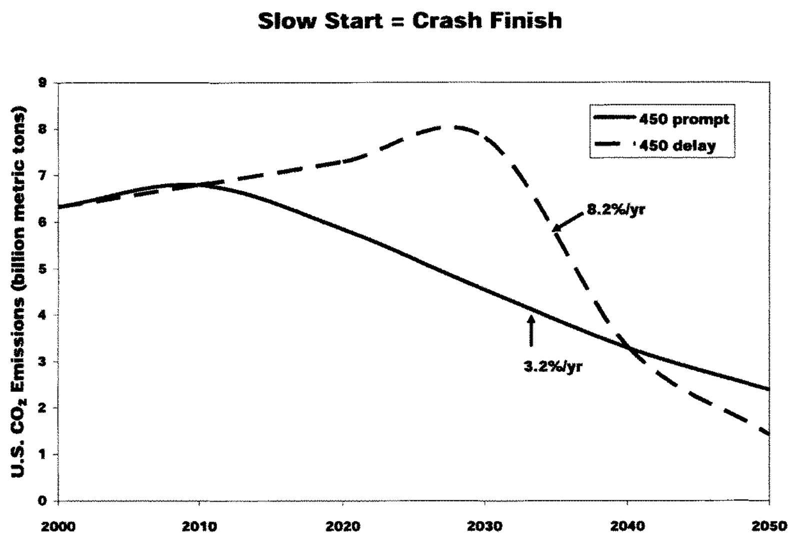


Figure 1. Prompt start and delay pathways consistent with stabilizing heat-trapping gases at 450 ppm CO_2-equivalent. Global emissions 2000-2100 are 1760 Gt CO_2 from Meinshausen's S450Ce scenario.[10] The U.S. share of global emissions is assumed to decline from 25% to 5% linearly between 2000 and 2100. This results in an emissions budget for the U.S. of 308 Gt CO_2 in the 21[st] Century. In the prompt start case emissions decline by 1.5%/yr from 2010 to 2020, 2.5%/yr from 2020 to 2030 and 3.2%/yr thereafter. The delay case assumes that emissions grow by 0.7%/yr from 2010 to 2030, a reduction of 0.5%/yr compared to the Energy Information Administration forecast;[11] they must decline by 8.2%/yr thereafter to limit cumulative 21[st] Century emissions to 308 Gt CO_2.

[10] Simple Model for Climate Policy assessment (SiMCaP), available at: http://www.simcap.org/

[11] Reference case from U.S. Department of Energy, Annual Energy Outlook 2006 with Projections to 2030, Report # DOE/EIA-0383(2006)

Here's a common sense illustration of what this means. Imagine driving a car at 50 miles per hour, and you see a stop light ahead of you at a busy intersection. If you apply the brakes early, you can easily stop your car at the light with a gentle deceleration. The longer you wait to start braking, the harder the deceleration. There's some room for choice. Within some limits, you can brake late and still stop in time. But the higher your speed, the earlier you must start braking. If you wait too long, you'll find yourself in the middle of the intersection with your forehead through the windshield.

The captain of the Titanic learned a similar lesson. If he had started turning just a couple of minutes earlier, he would have missed the iceberg. But traveling at full speed, by the time he saw the iceberg, it was too late to miss it. He lost his ship. Will we repeat the same mistake?

Administration officials suggest that, rather than establish enforceable emission limits now that begin to gradually reduce emissions within a few years, it is still cheaper to delay mandatory emission cuts because (somehow) we will develop breakthrough technologies in the interim and these will enable faster reductions later at lower cost. But this argument is implausible for two reasons. First, as already demonstrated, delaying the start of reductions dramatically increases the rate at which emissions must be lowered later. Reducing emissions by more than 8 percent per year would require deploying advanced low-emission technologies at least several times faster than conventional technologies have been deployed over recent decades. Second, delay means that a whole new generation of capital investment will be made in billions of dollars of high-emitting capital stock – conventional power plants, vehicles, etc. that will be built or bought during the next 10-20 years in the absence of meaningful near-term limits. Under the delay scenario, our children and grandchildren would then have to bear the costs of prematurely retiring an even bigger capital stock than exists today. Even taking discounting into account, it is virtually impossible that delaying emission reductions is cheaper than starting them now.

Voluntary Measures Won't Balance the Carbon Cycle

Limited as it is to R&D and voluntary measures, the administration's Climate Change Technology Program has no hope of preventing the "crash finish" scenario. The inadequacy of a voluntary program is plain to see for a growing number of business leaders, state and local elected officials, and a majority of the U.S. Senate, as well as to nearly all other nations.

In 2002, President Bush recommitted the United States to "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" – the objective of the climate change treaty (the U.N. Framework Convention on Climate Change) adopted and ratified by his father. The president said his goal was to "slow, stop, and reverse" U.S. global warming emissions growth. He set a purely voluntary target of reducing the emissions *intensity* of the U.S. economy – the ratio of emissions to GDP – by 18 percent between 2002 and 2012.

But emissions *intensity* is a deceptive measure, because what counts for global warming is *total* emissions. Even if the president's target were met (and recent reports indicate that it may not be), *total* U.S. emissions will still increase by 14 percent between 2002 and 2012 – exactly the same rate as they grew in the 1990s. (See Figure 4.)

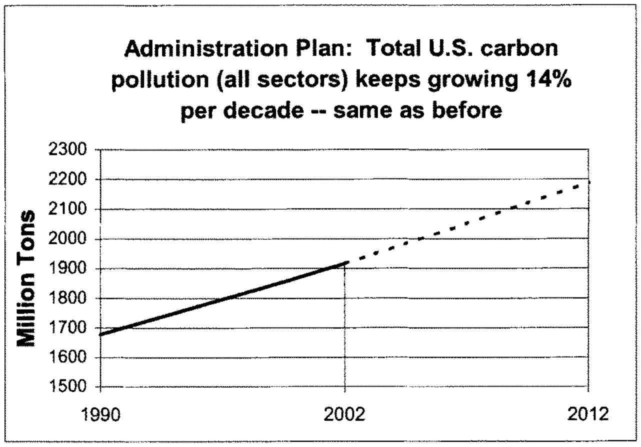


Figure 2

While the administration clings doggedly to the voluntary fiction, most political, civic, and business leaders in the United States are moving on. As Science Committee Chairman Boehlert told this Committee last week:

> As many outside commenters have noted, the plan does not establish clear priorities or a method for doing so. It does not provide clear criteria for determining which programs to fund, when to fund them, or how much funding to provide. It does not clearly connect specific programs with any particular policy goal, such as the Administration's (rather minimal) goal of reducing greenhouse gas intensity. Given that the Plan is about three years late, these failings are particularly unfortunate. The Plan also explicitly fails to deal with what is perhaps the key issue in climate change technology - technology deployment. Creating a market for technologies that could limit climate change - especially, creating a market soon enough that the action can make a real difference - will require government policy, whether that be tax incentives, regulations or some other measures. Simply undertaking research and development (R&D) is not enough, to put it mildly.

A majority of the Senate agrees, having voted last year for a Sense of the Senate resolution endorsing the need for "mandatory, market-based limits" that will "slow, stop, and reverse the growth" of global warming pollution. The resolution affirms that U.S.

mandatory action can be taken without significant harm to the economy and that such action "will encourage comparable action by other nations that are major trading partners and key contributors to global emissions."

State and local governments are leading, with mandatory limits on power plant emissions in the northeast and in California. California and 10 other states have adopted limits on global warming emissions from motor vehicles. Last month, California – the 12th largest emitter in the world – enacted the most far-reaching state plan to reduce the state's global warming pollution to 1990 levels by 2020. The state's new law enjoys wide support from businesses and other constituencies, going well beyond the usual environmental suspects: PG&E; Silicon Valley Leadership Group; Bay Area Council; Sacramento Municipal Utility District; Waste Management; Calpine; California Ski Industry Association; the cities of Los Angeles, San Francisco, Oakland, and Sacramento; the American Academy of Pediatrics; the California Nurses Association; CDF Firefighters; and Republicans for Environmental Protection.

Many other states have adopted standards to increase the percentage of renewable power generation. Stakeholder processes to address global warming are underway or in development in a growing number of states in all regions of the country. More than 200 cities have announced plans to reduce their global warming pollution.

The constituency for real action is broadening and growing. Earlier this year, more than 80 evangelical leaders called for mandatory limits on global warming pollution, citing their duty to care for God's creation.

In April, appearing before the Senate Energy Committee, some of the largest electric utilities, suppliers of generating equipment, and electricity customers called for mandatory limits. Huge companies such as Duke Energy, Exelon, and GE said that voluntary programs won't work and that they need certainty and clear market signals in order to make sensible investments in new power plants that will last 50 years. Big electricity consumers like Wal-Mart endorsed mandatory limits and committed to cut their energy use and emissions through investments in energy efficiency and renewable energy.

They all get it. Voluntary programs and tax incentives are insufficient to get these technologies deployed at a sufficient scale and speed to avoid a climate catastrophe. The market conditions for these new investments will not be created without a limit on CO_2 emissions.

Technologies for Balancing the Carbon Cycle

Scientific American devoted its September issue to "Energy's Future Beyond Carbon." This special issue includes five articles that describe technologies available today to reduce carbon dioxide emissions by improving energy efficiency in transportation, buildings and industry, and by harnessing renewable energy sources and scrubbing carbon dioxide from fossil fuels. With appropriate policy support these technologies can be deployed in a portfolio capable of keeping the United States within the carbon budget described earlier, which is necessary to avoid dangerous global warming. There are many options for assembling such a portfolio. In the scenario illustrated below the largest reductions are obtained from energy efficiency improvements in electrical end uses, non-electric stationary end uses, and motor vehicles.

Additional reductions come from renewable fuels and electricity and carbon capture and disposal at coal-fired power plants and other high-concentration industrial CO2 vents.

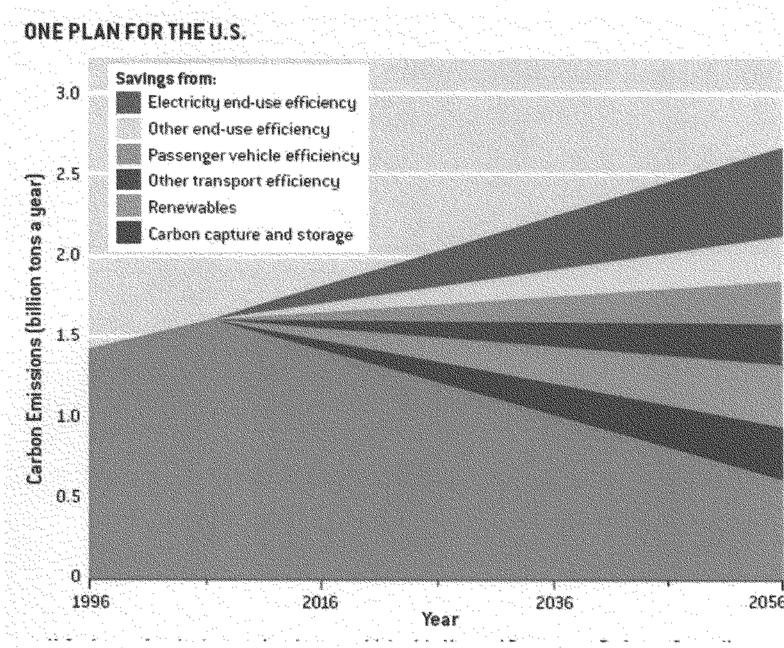


Figure 3. *Source*: Lashof and Hawkins, NRDC, *in* Socolow and Pacala, *Scientific American*, September 2006, p. 57

The elements of this scenario are briefly outlined below.

1. **Electric end-use efficiency (0.54 GtC):** Efficiency improvements in motors, lighting, refrigeration and other electrical equipment reduce total electricity consumption by 40% in 2056 compared to BAU. Resulting total electricity consumption is 4400 billion kilowatt-hours (BkWh), 20 percent greater than current consumption levels. California has demonstrated in practice that such reductions are possible. Sustained policies to promote energy efficiency through a combination of appliance standards, building code enforcement, and utility

efficiency programs have stabilized per capita electricity consumption in California over the last 30 years while national per capita electricity use continued to grow such that per capital electricity consumption in California is now more than 40% lower than in the rest of the country.[12]

2. **Other end-use efficiency (0.28 GtC):** Improvements in building designs and industrial processes result in a 40 percent reduction in non-electric energy consumption by stationary sources compared to BAU. Overall emissions from these sources decline by 15 percent from current levels.

3. **Passenger vehicle efficiency (0.27 GtC):** Widespread use of hybrid vehicles, as well as improvements to conventional vehicles, raises the average fuel economy of the in-use vehicle fleet to 54 miles per, compared with 24 mpg under BAU.

4. **Other transport efficiency (0.23 GtC):** Heavy truck fuel economy increases to 13 mpg, compared with 7 mpg under BAU and aircraft efficiency increases to 105 seat miles per gallon (smpg), compared with 80 smpg under BAU. In addition, smart growth policies reduce total travel demand by 10 percent.

5. **Renewable energy (0.39 GtC):** Renewable energy (e.g. wind and biomass) accounts for 30 percent of total electricity generation by 2050, compared with less than 5 percent under BAU. This much electricity could be supplied by 500 GW of wind (e.g. 250,000 2-MW-turbines). Turbines would be spread over 20 million acres, but the land could also be used for crop production or livestock grazing. In addition, 40 percent of transportation fuel is provided by sources with zero net CO_2 emissions (e.g. cellulosic ethanol with soil carbon increases compensating for fossil carbon inputs; Fischer-Tropsch diesel from biomass with geologic carbon sequestration compensating for fossil carbon inputs; renewable electricity supplied to plug-in hybrids). This corresponds to 80 billion gallons of biofuels, which could be supplied from energy crops grown on 60 million acres of land, assuming productivity of 12 tons/acre.[13] Alternatively, this could be supplied by 40 billion gallons of biofuels plus 520 billion kWh of additional renewable electricity supplied to plug-in hybrids.[14]

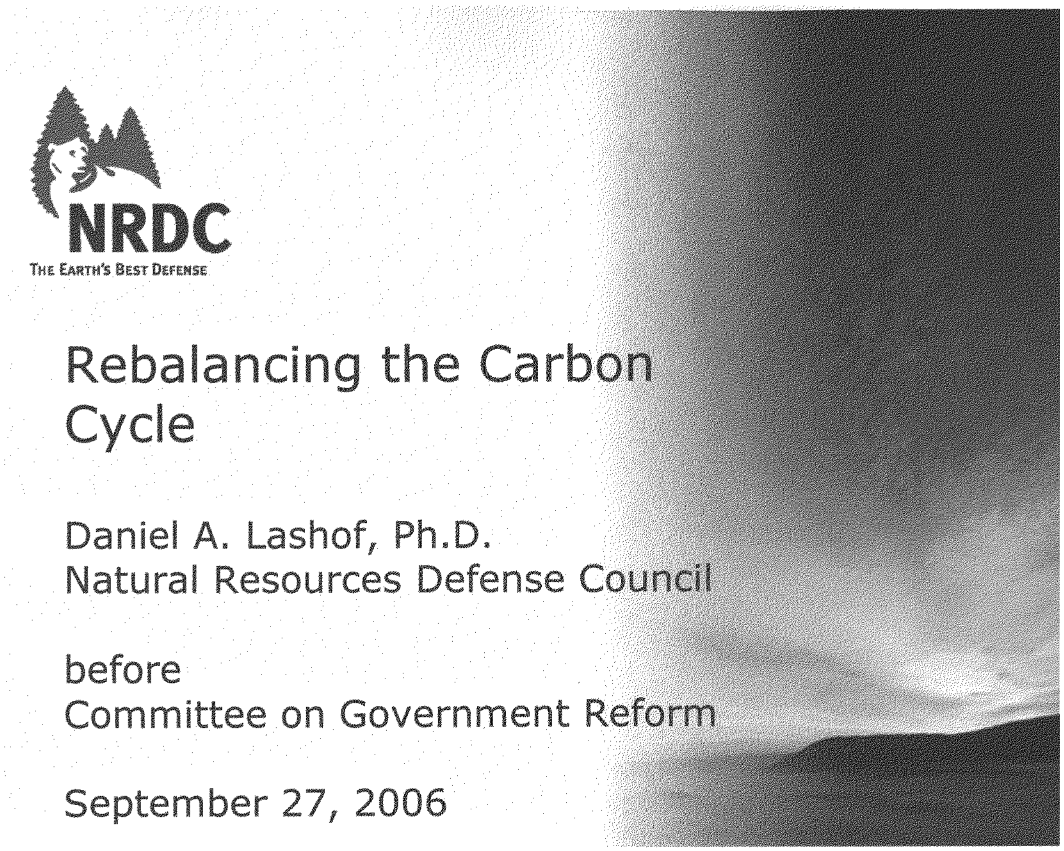
6. **Carbon capture and storage (0.32 GtC):** Carbon capture and storage technology is applied to 160 GW of coal-fired integrated gasification combined cycle power plants, capturing 0.19 GtC in 2050. Additional carbon dioxide is captured from natural gas production facilities, large industrial sources, and ethanol plants, contributing 0.12 GtC to the 2050 emission reductions. The total volume of carbon dioxide put into storage would be 30 times the volume currently used for enhanced oil recovery and would be equivalent to 5 times the annual flow of natural gas through buffer storage facilities. In addition, increased thermal

[12] http://www.nrdc.org/air/energy/fcagoals.asp
[13] N. Greene, et al., 2004. *Growing Energy: How Biofuels Can Help End America's Oil Dependence.* (NRDC, New York, 2004)
[14] Assumes 13 kWh displace 1 gallon of gasoline in a plug-in hybrid.

efficiency at power plants from replacing older units reduces emissions by 0.03 GtC.

Conclusion

The carbon cycle is out of balance, causing an accelerating build up of heat-trapping carbon dioxide in the atmosphere that endangers our environment, our health, and our economy. The good news is that with decisive action initiated now we can deploy available technologies to rebalance the carbon cycle in time to avoid the worst consequences of global warming.


NRDC
THE EARTH'S BEST DEFENSE
Rebalancing the Carbon Cycle
Daniel A. Lashof, Ph.D.
Natural Resources Defense Council
before
Committee on Government Reform
September 27, 2006

Carbon deficit spending— Do the math

Global annual carbon emissions from energy:

7 billion tons C

Removals by oceans, soils, trees:

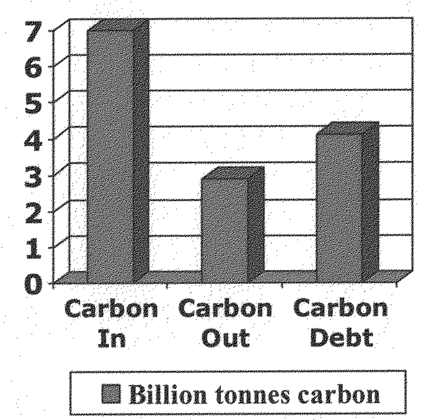
- 3 billion tons C

Net buildup in air:

= 4 billion tons C or

~2 ppm of CO_2

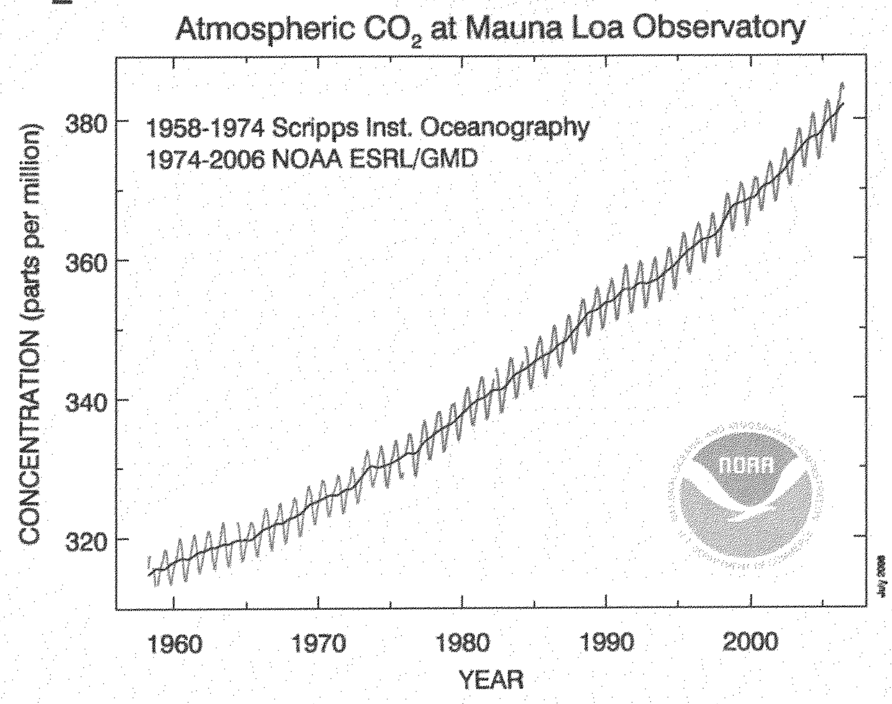
Annual Carbon Debt Growth



NRDC

September 2006

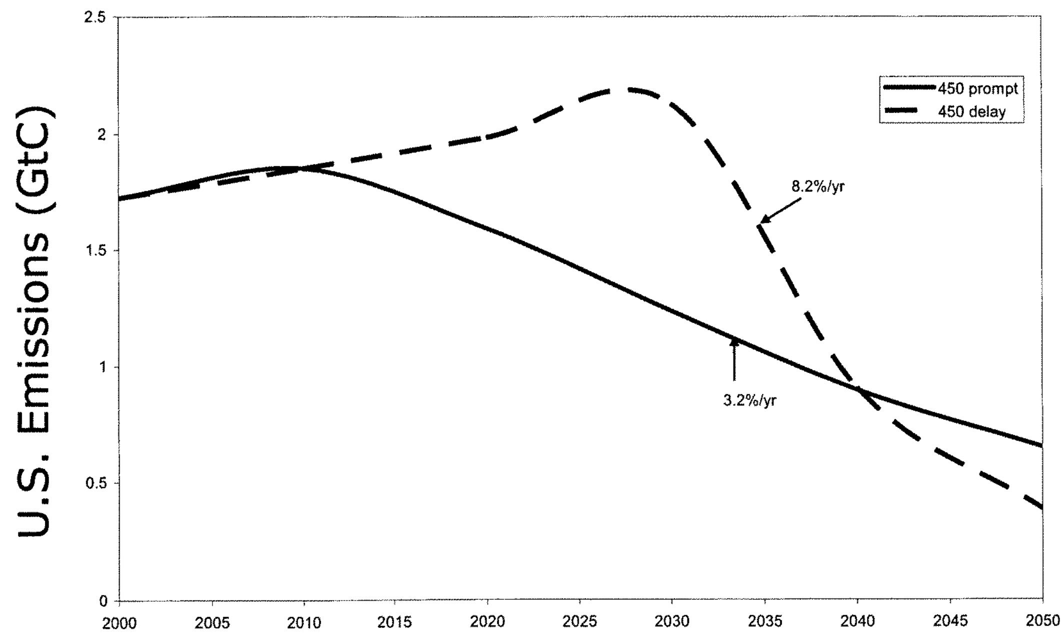
CO_2 levels are increasing



NRDC

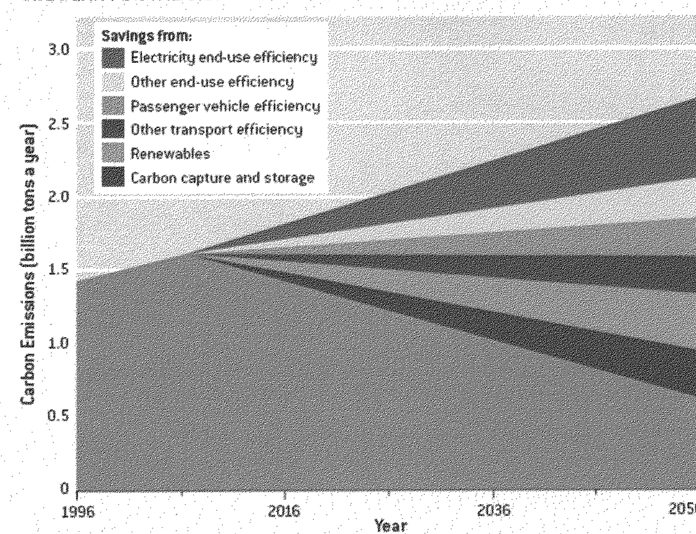
September 2006

Slow start, crash finish



U.S. Wedges

ONE PLAN FOR THE U.S.



▲ U.S. share of emissions reductions could, in this Natural Resources Defense Council scenario, be achieved by efficiency gains, renewable energy and clean coal.

Source: Lashof and Hawkins, NRDC, *in* Socolow and Pacala, *Scientific American*, September 2006, p. 57

NRDC

September 2006

Mr. ISSA. Thank you.

And if the gentlelady is not back by the end of my questioning, we may take a short recess, with your indulgence. She has been tied up at International Relations. Welcome to the end of a Congress.

Dr. Wofsy, let me just ask about missing carbon. I find missing carbon to be an amazing subject, because I have always asked myself a question: As carbon levels rise, does the Earth begin to deal with the higher level of carbons in some affirmative way? As a result, if we find out about missing carbon, do we, at the same time, change all of our curves about the growth in temperature and the growth of greater emissions? Is there a stabilizing point?

Mr. WOFSY. We are learning more about that over the last 10 years. A lot of progress has been made. I wish I could be more encouraging. The ocean's capacity to take up carbon does appear to be decreasing gradually with time, which is actually what would be forecast based on simple chemistry. The fertilization, if you want to call it, of the land biosphere by CO_2 is a phenomenon. If you grow plants in a chamber that has more CO_2 than the current atmosphere, they tend to grow faster, and some of them do. But the capability of that to actually stimulate storage of carbon appears to be lower than one might have hoped. It is not zero, but it does not seem to be something that is going to save us.

So I believe the answer is that some of this increase in the uptake of CO_2 that we saw at Harvard Forest, for example, could be due to increasing concentrations of CO_2. We don't think that is most of it, but that is still an area of active scientific research. I would say that anybody who wanted to rely on this kind of greening of the Earth would be ill advised to do so. It is a factor, but it is not going to save us.

Mr. ISSA. Thank you.

Dr. Marland, could you put the wedge slide back up, if you would, please? I think you are familiar with it.

This is a slide of the United States. If we reduce emissions as called for in this slide and the world does nothing, what will be the effect on global carbon?

Mr. MARLAND. It is basically an economics question, and I am not an economist. But there are some analyses, and it starts to come up in Europe now when you are interested in electricity. When you start to do that in some small number of countries, then things start to move around between countries. I have been intrigued, for example, that wood chips are now harvested in Canada from forests and they are shipped to Europe because there are incentives in Europe to bring down CO_2 emissions locally. Now, logically, it makes more sense to use the wood chips closer to home to replace fossil fuels in Canada. But the economic situation has been arranged, and the set of incentives are in place in Europe, so it becomes economically profitable to ship wood chips to Europe.

Mr. ISSA. A trade distorting subsidy, pray tell?

Mr. MARLAND. Well, we have a global system. I talk about my carbon and your carbon and our carbon. It is my carbon and your carbon when we burn the fuel, but in the atmosphere it is our carbon. Somehow there has to be cooperative arrangements so that the objective is our carbon. The objective is not my carbon or your carbon, it is our carbon, and there has to be some kind of a systematic way of addressing the whole system rather than subsets thereof.

Mr. ISSA. Excellent.

Dr. Lashof, I am going to ask you two questions about this slide. One is a followup on what I asked Dr. Marland, which is if I read correctly this slide, if we were to do all of these things—and, by the way, I am a supporter of doing all of these things—the reduction would not equal the increase over the same period of time that we expect from China alone. I would like you to comment on that, because I want to be a good world player, but we can't be a world player in a vacuum. We have to bring the entire biosphere with us.

Second, along with this chart, my biggest question, my biggest concern is I see no nuclear in it, even though we had the founder of Greenpeace telling us that nuclear is critical to the foreseeable future's sustainable atmosphere.

Mr. LASHOF. I will try to address both those questions.

The specific quantitative comparison that you asked about I am not sure how those numbers work out. I mean, the United States is still the largest source of carbon dioxide emissions worldwide. People focus on China's growth, which is absolutely stunning and obviously a big problem. This chart is intended to be the U.S. contribution to a global effort. There is no question you have to bring the rest of the world along. There is some argument about how you do that. I believe the United States has to show leadership. We have to make commitments. Governor Schwarzenegger believes that as well, obviously, in signing the legislation today.

Mr. ISSA. Isn't it great to have all Californians here? Even your education.

Mr. LASHOF. I love it. It is a great day, actually, in my view. The Governor's signature on an Assembly Bill 32, would clearly put California in a leadership role. He knows that California, by itself, can't solve the global warming problem, but California leadership will, I believe, lead to U.S. leadership. U.S. leadership has to lead to a worldwide solution. I should say we certainly have a lot of work to do particularly with China and India, which have a lot of coal and are growing rapidly, but we certainly wouldn't be alone. The other countries in Europe, as well as Japan, are making significant investments in reducing their emissions of global warming pollution, so it is not like the United States is stepping out all by itself.

I have just one more point about this figure. It appears on page 57 of the Scientific American of this month. The previous page actually shows how it fits in to a global framework, and I will bring that to you so you can see that.

With respect to your other question about nuclear power, I did construct this portfolio without including a contribution from expanded nuclear power in the United States. I did that for several reasons. One is that I believe there are ongoing issues in terms of the cost, waste disposal, and proliferation from nuclear power that may make it difficult or impossible to greatly expand nuclear power in an acceptable way in the United States and around the world.

Second, I did it intentionally because I think there has been a lot of claims that it is impossible to deal with global warming without nuclear power. I wanted to show that it is possible. Nuclear is one option, no question about it, because it produces electricity withoutgenerating CO_2. It could make a contribution, and in the original wedges diagram that Professor Sokolow developed, nuclear is one of the 15 options that he puts forward, no question. But I wanted to make the point that if it doesn't pan out, if we can't address those issues which are challenging, in my view, there is still a way to get to where we need to go.

Mr. ISSA. Thank you.

I wouldn't be a Member of Congress if I didn't note that in my home district, in San Diego, some of the technologies that have been developed have near zero residue and have the additional ability to burn—let me rephrase, to consume plutonium for the purposes of creation of electricity. So I often bring that up simply because the idea that we would take the weapons grade leftovers of the cold war and turn them into electricity to me is too intriguing not to invest at least in that. Perhaps we could also invest in reprocessing a dramatic portion of what now is planned to be put in Yucca Mountain, which I certainly would agree with.

I asked the previous panel this question, I will ask each of you the same question. There are clearly a lot of uncertainties, both in the testimony and in the answers to questions earlier, about the carbon cycle, exactly what it is, perhaps even my businesslike question about where the break even is, and so on. One, is there sufficient research, knowing that perhaps there never is? But at least is the level of research somewhat the magnitude that it should be? If not, where would you each say the biggest gaps are in that funding? If you had the power of the purse, as this body does, where would you make the biggest additional contributions?

Dr. Marland. You can go in any order.

Mr. MARLAND. It is a tough question, of course, and that is why you are asking it.

Mr. ISSA. And you all may revise and extend, so you only have to start here, and then we will let you go on.

Mr. MARLAND. We had reference here to Rob Sokolow and his paper in "Scientific American." Some months ago, in another article on carbon capture and storage, he starts out with the very nice statement: "If there were an easy answer, we would be doing it." That represents a faith in humanity, but I agree with that. If there were an easy answer, we would be doing it. You know, once we found substitutes for the freons, it was easier to address the hole in the ozone layer. So you pay a few bucks and you solve the problem. I don't think that is true in global change. It is fundamental to our society.

But I think at the core of it there is population. I was startled the other day to realize that the population on the Earth is three times what it was when I was born. That is an astonishing number. No matter what we do, as the population grows, there are huge numbers of us, and as long as you have money, you spend it, and whatever you spend it on has energy implications. If you don't spend money on this, you spend it on something else. And the worst thing you can do with your money is burn coal.

But my sense is, if you have money, what you should spend it on is for things that are not energy intensive and beautify life. You should buy original art and concert tickets, you know? But any time, if you don't work and you go out on your boat on the lake, you are——

Mr. ISSA. Please, let it be a sailboat.

Mr. MARLAND. Yes. Exactly right. It is really very tough.

The research question, I think we really don't understand the climate system still. I have been intrigued with this idea of managing the land surface, but the land surface impacts the climate in multiple ways, it is not just through the carbon budget. We affect the water budget. We affect the reflected radiation. If we plant trees, do we change the albedo of the surface? Are we doing something else besides affecting the carbon budget?

So I think there is a great deal to be understood yet on the full climate system and how changes in the land surface, changes in the distribution of activities, and changes in urbanization ultimately affect the climate system in ways other than through the carbon budget.

Mr. ISSA. Thank you. If this were McLaughlin, I would say and your answer is people.

Mr. WOFSY. So if I understood the answer that Mr. Stephenson gave to you, research in this area, scientific research has basically been level funded in constant dollars for 15 years or 13 years, whatever his baseline number was. I think we are going to need to fix that. The issues that we need to deal with, I believe, are very much the ones that Gregg talked about. So if you think about the terrestrial ecosystem, which is the one I was talking about, currently they are removing around 30 percent of the CO_2 that we emit. In a future climate, they could turn around and introduce 30 percent. They could go from minus 30 to plus 30. We really don't have a good understanding of that.

We have done an awful lot of planning for various scientific programs to examine some of these questions, and I would really love to see some of these plans given priority and move forward. So the last thing I would say is if you could startup a new research program that learned how to de-politicize this question and turn it into a question that people just dealt with on its merits, that would really be worth doing too. I have no idea how to do that, but you are in the business, maybe you know how to do it.

Mr. ISSA. It is a shame the ranking member isn't here so when I say after I win re-election, return as the chairman of this subcommittee again, we will be able to do that, so that she could at least look at me with the broad smile that says no, no, we are switching chairs. So, clearly, an election being immediately behind you does give you that opportunity. Whatever we are doing here on a bipartisan basis I suspect we will do even more bipartisan in the first stage of a new Congress, no matter who has this chair.

Did you have a comment also?

Mr. LASHOF. Yes, Mr. Chairman. I guess I would make three points. First, I would say I think we know enough to know that we have to reduce the emissions of CO_2 from fossil fuels by at least 60 percent if we are going to reach the break even point that you mentioned. There are important uncertainties about the carbon cycle, but if emissions from fossil fuel combustion continue to grow at the pace that they have been growing, a business-as-usual kind of course, then those opportunities fundamentally are irrelevant because all of the natural removal processes get overwhelmed by those emissions. So those uncertainties remain interesting scientifically, but they are not going to matter very much from a policy perspective.

Having said that, I do think it is important to continue to invest in our research in this area, and I would suggest two areas that deserve more attention. One, Steve Wofsy just suggested, which is that there is this very significant risk of what we call positive feedbacks in the system. As global warming occurs and causes more forest fires, for example, CO_2 is put back into the atmosphere. As permafrost melts, CO_2 and methane can go into the atmosphere and then that causes more warming. We know that over a geological timeframe, those kinds of feedbacks have been important. We really don't know how significant they could be over the next decades to a century, and we really need to pay more attention to that.

The second area I would say is we need to do a better job and have a more focused effort to reconcile our estimates of how much carbon the forests of North America are taking up between two different approaches. We basically look at this question in two ways. One is we can look at the concentration of CO_2 in the atmosphere and the pattern of that concentration, and look at some of the details of isotopes and infer what the sinks are by knowing where the emissions are coming from and looking at some of these concentration numbers. The other way is sort of the traditional forest inventory: you go out on the landscape and you measure the diameter of trees at breast height and try to calculate it, add it up from the group up. So there are bottom-up and top-down approaches. They tend to lead to different results. There has been some improvement in that reconciliation, but when the carbon cycle assessment says that the estimate is still uncertain by a factor of two about how much total carbon is being absorbed in the forests of North America, it is because we haven't achieved that reconciliation. So I think that is an important area.

Mr. ISSA. Thank you.

I guess we have spurned more comments. Yes, in the order in which the fingers were raised. Gregg.

Mr. MARLAND. In the first go-around I ignored your question about the break even business issue, and I would just like to come back to that very quickly, because there are a variety of scenarios that have been run with carbon cycle models. You can ask, if we would like the carbon concentration in the atmosphere to go no higher than 550 parts per million, what does the future emissions trajectory have to look like? If we want to go no higher than 450, what does it have to look like? The answer really is not unlike this diagram that Dan has shown, the green area.

If we want a stabilization at maybe 550, we have to take this kind of a path. But if we emit a pulse of carbon dioxide into the atmosphere, what the carbon cycle does is redistribute that, and ultimately a large portion of it is going to end up in the ocean, but it takes time. It is never going to go, well, in human time scales it is not going to go away. If we put extra CO_2 into the atmosphere, it redistributes amongst the ocean, the biosphere. It takes time to do that, but it is going to relax down. But presumably we can prevent it from going over some number like 550 by implementing something that would maintain the fossil fuel use in the shape something like what Dan shows here in the green. There are numeric solutions, as best we understand the carbon cycle, to show what that path looks like.

Mr. ISSA. Dr. Wofsy.

Mr. WOFSY. Just a brief comment. I am very glad that Dan brought up this question about the top-down and bottom-up, which I deal with at length in my written testimony . I just wanted to point out that in addition to filling in a place on the table, that is one of the key tools, if we can develop it scientifically, to understand how this system will respond to climate change and how we can expect it to behave going forward.

Mr. ISSA. Thank you.

And I would like to thank this panel, in addition to the first panel, for a very informative hearing. The gentlelady, the ranking lady, was not able to return, she has been tied up elsewhere, and I would ask that each of you be willing to respond to hers and other questions in writing. We will leave the record open for 2 weeks past your answers to any questions submitted to you.

I want to close by summarizing, if I may, because I think it is very important. This is the end of a Congress. This is the end of a number of hearings that we have held on energy and climate, and I think, with the work that you have done and some of the earlier hearings, you have made a couple of clear points I would like to make for the record.

One is that population is a factor that has to be considered. I am not just referring to population growth, but the populations of the Third World that presently consume dramatically less energy than they are likely to consume as they reach an equilibrium with the rest of the developed world.

Two, although we have put a lot of money into research, it is clear here today and throughout the Congress that research has been insufficient to give us the answers to critical questions, including where the carbon all comes from, how we absorb it, and one that was not mentioned, but that is of critical concern, at least to the Chair. That is, is there a tipping point and where is it? Have we already reached it? Is it ahead of us? Is it behind us? Is it 550 parts per million or is it perhaps 480? We are not looking at that as a point at which, even if we do everything, the Earth will begin working against us in order to reach that point.

I think, Steve, you did a good job of talking about what some of the factors that can trigger a reversal in the absorption rate.

Last is action. I want to note that although I would clearly very much insist that nuclear be part of the solution, because it is an action we can take today in addition to every one of these others, and it is a definable action that we can measure with far greater impact than any of these that take out until 2056. But having said that, for this subcommittee on a bipartisan basis, at the end of the Congress, all actions must be taken. That includes very much the next Congress doing more to ensure a reduction in greenhouse emissions, a reduction in fossil fuel consumption, at least on a per GDP basis.

I don't think I can begin to summarize the work of 2 years, but I want to thank all of you for being here in the last hearing before the election and the last hearing probably on this subject. I will take a liberty, on behalf of the two Californians that were here today, and thank you and thank Governor Arnold Schwarzenegger for taking the lead in bringing up the importance of the carbon cycle and the recognition that as goes California, so goes the Nation; as goes United States, so goes the world.

And, with that, we stand adjourned.

[Whereupon, at 4 p.m., the subcommittee was adjourned.]

[The prepared statement of Hon. Dennis J. Kucinich follows:]

Statement of Rep. Dennis J. Kucinich
U.S. House of Representatives
Subcommittee on Energy and Resources of the
Government Reform Committee

Hearing on "Rebalancing the Carbon Cycle"

September 27, 2006

The situation is urgent. The United Nations has declared that at least 5 million cases of illness and more than 150,000 deaths every year are already attributable to global warming. The 2003 European heat wave killed over 30,000 people. The ten hottest years on record have occurred in the last 15 years. New research is revealing massive deposits of greenhouse gasses stored in the tundra and in ocean floors that, if released by warmer temperatures, could more than double the amount of global warming pollution in the span of only a few years. Findings like these have caused reputable scientists to publicly state that a tipping point will be reached in a few years.

The Administration's response? Largely research and voluntary action, neither of which is even close to sufficient. It is long past time for substantive action.

First, we need to know where we're going. Then we need to know how to get there. The best science tells us we need to reduce our levels of global warming pollution by 80% by 2050. That's why I am a cosponsor of the Safe Climate Act, which codifies that target.

And we know how to get there. For starters, we need to update CAFÉ standards to 55 MPG. We need a Manhattan Project for sustainable energy choices like wind, solar, ocean, and geothermal that surpasses the investments by countries like Germany, Spain and Japan that are leaving us behind. We need to phase out nuclear power starting immediately to avoid going from an addiction to oil to an addiction to a more dangerous and much more expensive technology. We need to drastically increase the efficiency of our homes, workplaces, and energy generation methods. We need a progressive carbon tax to create the right financial incentives while holding harmless our nation's disadvantaged. And that is only the beginning.

This transition from an archaic energy America to a clean energy America will not be driven by fear, but by hope. In fact, benefits of the coming transition are enough to inspire the most cynical. A clean energy America can create millions of new jobs. It will grow our economy. It will make us energy independent. It will drastically reduce the harmful air pollution that causes asthma and increases the rates of heart attacks. It can reduce energy costs that create such a drag on our economy and our wallets. It can free us from the grip of big oil companies that turn grossly inflated gas price revenue into record-breaking profits and elaborate campaigns to obfuscate the truth of global warming, just like tobacco companies obfuscated the truth about cigarettes.

In other words, during this inevitable transition, we can create a more just, equitable, and sustainable world if we do it right. What an incredible opportunity we have before us. But we can only do it right if we can control it. If we wait too long, the transition will be forced upon us, denying us all but the most extreme options. And we're running out of time.