BUSINESS ACTIONS REDUCING GREENHOUSE GAS EMISSIONS

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

JUNE 8, 2005

Serial No. 109–16

Printed for the use of the Committee on Science

Available via the World Wide Web: http://www.house.gov/science

U.S. GOVERNMENT PRINTING OFFICE

21–708PS WASHINGTON : 2005

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

COMMITTEE ON SCIENCE

HON. SHERWOOD L. BOEHLERT, New York, *Chairman*

RALPH M. HALL, Texas
LAMAR S. SMITH, Texas
CURT WELDON, Pennsylvania
DANA ROHRABACHER, California
KEN CALVERT, California
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
GIL GUTKNECHT, Minnesota
FRANK D. LUCAS, Oklahoma
JUDY BIGGERT, Illinois
WAYNE T. GILCHREST, Maryland
W. TODD AKIN, Missouri
TIMOTHY V. JOHNSON, Illinois
J. RANDY FORBES, Virginia
JO BONNER, Alabama
TOM FEENEY, Florida
BOB INGLIS, South Carolina
DAVE G. REICHERT, Washington
MICHAEL E. SODREL, Indiana
JOHN J.H. "JOE" SCHWARZ, Michigan
MICHAEL T. MCCAUL, Texas
VACANCY
VACANCY

BART GORDON, Tennessee
JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
DARLENE HOOLEY, Oregon
MARK UDALL, Colorado
DAVID WU, Oregon
MICHAEL M. HONDA, California
BRAD MILLER, North Carolina
LINCOLN DAVIS, Tennessee
RUSS CARNAHAN, Missouri
DANIEL LIPINSKI, Illinois
SHEILA JACKSON LEE, Texas
BRAD SHERMAN, California
BRIAN BAIRD, Washington
JIM MATHESON, Utah
JIM COSTA, California
AL GREEN, Texas
CHARLIE MELANCON, Louisiana
DENNIS MOORE, Kansas

CONTENTS

June 8, 2005

Page

Appendix 2: Additional Material for the Record

BUSINESS ACTIONS TO REDUCE GREENHOUSE GAS EMISSIONS

WEDNESDAY, JUNE 8, 2005

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 10:10 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood L. Boehlert [Chairman of the Committee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Business Actions to Reduce Greenhouse Gas Emissions

Wednesday June 8, 2005

10:00 AM – 12:00 PM
2318 Rayburn House Office Building (WEBCAST)

Witness List

Mr. James E. Rogers
Chairman, CEO and President
Cinergy Corporation

Dr. Mack McFarland
Environmental Manager
Fluorochemicals Business
E.I. DuPont de Nemours and Company

Mr. Ronald E. Meissen, P.E.
Senior Director, Engineering
Environment, Health & Safety
Baxter International Inc.

Dr. Robert H. Hobbs
Director of Operations
United Technologies Research Center
United Technologies Corporation

Section 210 of the Congressional Accountability Act of 1995 applies the rights and protections covered under the Americans with Disabilities Act of 1990 to the United States Congress. Accordingly, the Committee on Science strives to accommodate/meet the needs of those requiring special assistance. If you need special accommodation, please contact the Committee on Science in advance of the scheduled event (3 days requested) at (202) 225-6371 or FAX (202) 225-0891.

Should you need Committee materials in alternative formats, please contact the Committee as noted above.

HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Business Actions to Reduce Greenhouse Gas Emissions

WEDNESDAY, JUNE 8, 2005
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On June 8, 2005, the Science Committee will hold a hearing on what several leading businesses in a variety of industries are doing to reduce emissions of greenhouse gases.

The Bush Administration has initiated a number of programs to encourage businesses to take voluntary actions to reduce emissions of greenhouse gases. Either as part of the Administration programs or other efforts, many U.S. companies are working to reduce greenhouse gas emissions. (See attached list.) Some companies have begun simply by taking stock of the emissions they produce. Others have set targets for reducing their emissions and are taking steps to meet them by improving energy efficiency, switching to energy sources that produce fewer greenhouse gases, or eliminating greenhouse gases from manufacturing processes.

The motivations of these companies vary. Some find the scientific evidence of a changing climate compelling. Others face domestic or international competitive pressure, while others face pressure from lenders or shareholders. Some see advantage in creating new products or businesses that may hold a competitive advantage in future markets. Still others see financial risk to their businesses should the climate change substantially.

The Committee plans to explore the following overarching questions at the hearing:

1. What concrete actions are businesses taking to reduce greenhouse gas emissions? In what ways are these actions beneficial to the company?
2. Why are businesses taking these actions and what are the most important drivers for them?

Witnesses

James E. Rogers, Chairman, CEO and President, Cinergy Corp. Based in Cincinnati, Cinergy provides electricity to 1.5 million customers in Ohio, Indiana and Kentucky, has more than 7,000 employees, and generated $4.7 billion of revenue in 2004. It owns 13,000 megawatts of electric generating capacity and is largely reliant on coal as a fuel source. Cinergy and Duke Power, a major utility in the Southeast United States, recently announced plans to merge.

Dr. Mack McFarland, Environmental Manager, Fluorochemicals Business, E.I. DuPont de Nemours and Company. As a multinational chemical and product manufacturer based in Delaware, DuPont ranks 66 among the Fortune 500, with 55,000 employees worldwide and 2004 revenues of $27.3 billion.

Mr. Ron Meissen, Senior Director, Engineering, Environment, Health & Safety; Baxter International Inc. Baxter is a global health care company that supports treatment of medical conditions including hemophilia, immune disorders, kidney disease, cancer, trauma and other conditions. Based in Deerfield, Ill., and with facilities throughout the United States and the rest of the world, Baxter has 51,000 employees and generated $8.9 billion of sales in 2003.

Robert Hobbs, Director of Operations, United Technologies Research Center, United Technologies Corporation (UTC). Ranked 22 among the Fortune 500 and based in Connecticut, UTC businesses include Carrier heating and cooling, UTC Fire & Security systems, Hamilton Sundstrand aerospace systems and industrial products, Otis elevators and escalators, Pratt & Whitney aircraft engines, Sikorsky helicopters and UTC Power fuel cells. In 2004, UTC had 210,000 employees and generated $37 billion in revenue.

Background

Carbon dioxide (CO_2) is a greenhouse gas and an inevitable product of combustion. It is the greenhouse gas that has received the most attention, but others gases such as methane, nitrous oxide, hydrofluorocarbons and sulfur hexafluoride are also produced by human activities and have a greater greenhouse effect than CO_2.

In a speech in February 2002, President Bush "reaffirmed America's commitment. . .to stabilize atmospheric greenhouse gas concentrations at a level that will prevent dangerous human interference with climate," and initiated a number of voluntary programs aimed at reducing greenhouse gas emissions. Specifically, the President has committed to reducing the Nation's greenhouse gas intensity—the amount of greenhouse gases emitted per unit of economic activity—by 18 percent by 2012. Several states and other countries have contemplated or are now attempting to implement mandatory emission-reduction policies.

In May 2001, the Bush White House requested a report from the National Academy of Sciences on the status of scientific understanding of climate change. The Academy's reply is attached.

What are companies doing to reduce their greenhouse gas emissions?

A number of United States-based businesses have begun to inventory and reduce their greenhouse gas emissions. These are some of the activities companies are undertaking:

Identifying and tracking greenhouse gas emissions. An inventory is necessary to establish a company's baseline of greenhouse gas emissions. It is usually the first step for any company planning to set a reduction target, to develop options for reducing emissions, and to track progress toward a target. It is also necessary for any company wishing to accurately assess the risk posed by any particular shareholder resolution, regulatory proposal, or lending policy related to climate change. Moreover, it is essential for companies participating in voluntary or mandatory greenhouse gas trading market. According to economists, trading markets would lower the costs of any future greenhouse gas regulation, should one be implemented.

Companies have developed a variety of approaches for inventorying their greenhouse gas emissions. While all companies generally include direct emissions from internal operations, they must also decide whether to include indirect emissions generated from the electricity they buy or from the products they sell. Utilities, for example, tend to count only those emissions that are directly the result of generating electricity. Energy intensive manufacturers, however, include not only the emissions generated in their manufacturing processes, but also usually include in their inventories emissions generated by the electricity they purchase to power their operations. Appliance manufacturers and other companies whose largest emissions arise from the use of their products often include those emissions in their inventories. Companies participating in emissions trading markets have realized that it is important to maintain careful accounts of each type of emission to avoid double counting or trading the same emissions twice. Most companies report that they have developed their inventories through a "learn by doing" approach.

Setting targets for reduction. A number of companies have set targets for reducing the greenhouse gas emissions in their inventory. Some have set targets in absolute terms, while others have pledged to reduce emissions relative to production or revenue. Still others have expressed their commitment in terms of cutting energy use. Among the companies that have set absolute emission reduction targets, Nike has pledged to reduce greenhouse gas emissions 13 percent below its 1998 inventory by 2005. DuPont set a goal (and has already surpassed it) of reducing greenhouse gas emissions 65 percent below its 1990 inventory by 2010. Using the same target date and baseline date, Alcoa has pledged a 25 percent reduction, British Petroleum 10 percent, and Johnson & Johnson 7 percent. Eastman Kodak has committed to reducing its energy use 15 percent by 2004 below the amount it consumed in 2000.

Among companies that have pledged to reduce emissions relative to output or revenue rather than in absolute terms, Pfizer has plans to reduce its greenhouse gas emissions by 35 percent for every dollar in revenue the company earns by 2007 using 2000 as its baseline year. Baxter International has pledged to make a 30 percent reduction per unit of production value by 2005 using 1996 as its baseline year. And United Technologies Corporation committed to a 40 percent reduction per dollar of revenue by 2007 using 1997 as its baseline and has already met that target.

Improving energy efficiency. Improving energy efficiency reduces greenhouse gases, and may also save a company money. Some companies are improving the efficiency of their manufacturing processes or their lighting and heating systems. Reductions of greenhouse gas emissions, which accompany these efficiency gains, are often viewed as a bonus. For example, United Technologies Corporation and IBM have found that energy efficiency provides a significant opportunity to save money and reduce greenhouse gas emissions.

Changing manufacturing processes. Some companies are altering their manufacturing process to reduce emissions of potent greenhouse gases such as nitrous oxide or fluorocarbons. For example, DuPont met a substantial portion of its commitment to reduce greenhouse gas emissions by reducing emissions of nitrous oxide in the nylon manufacturing process. IBM pledged to reduce emissions of perfluorocarbons, a potent greenhouse gas, by 40 percent per unit of production (and 10 percent in absolute terms) from its semiconductor manufacturing operations.

Green power purchasing. In states that allow consumers to choose among utilities, companies can reduce emissions by switching, in whole or in part, to "green power" suppliers, which generate electricity from renewable energy sources that do not emit greenhouse gas, such as wind, solar, biomass, and geothermal. For example, Staples, Bristol-Myers Squibb and Johnson & Johnson have purchased or are purchasing "green power" that allows them to claim significant reductions in greenhouse gas emissions.

Sequestration. A number of businesses have been "road-testing" carbon sequestration projects—the long-term storage of carbon dioxide in its organic form in forests or soils, or in liquid form in the ocean, so as to prevent its release into the atmosphere. For example, DTE Energy, Wisconsin Energy Corporation, Georgia-Pacific, and Weyerhaeuser, are working to enhance carbon sequestration in forests and soils to offset their greenhouse gas emissions. American Electric Power and British Petroleum are developing technologies to sequester carbon dioxide in the ocean or in underground, depleted oil and gas reservoirs, coal seams, or saline aquifers. Many scientists believe that there is much still to learn about whether the carbon dioxide placed in these so-called carbon sinks can be considered to be permanently removed from the atmosphere.

Why are companies reducing greenhouse gas emissions?

According to a variety of recent reports that have surveyed business practices,[1] businesses that are investing to reduce greenhouse gas emissions do so because they believe such investments will help them compete.

Reducing greenhouse gases can make a company more competitive in a variety of ways. Actions to reduce emissions can make a company more energy efficient or can lead it to develop new products. Such advantages can benefit a company's bottom line, even if the company never encounters pressure to reduce greenhouse gases in the future.

Companies also decide to reduce greenhouse gases as a way to manage future risks as many appear to view as real the possibility that shareholders, creditors, or governments may some day require them to reduce their emissions of greenhouse gases. Some companies take the position that the scientific evidence that man-made greenhouse gas emissions may be harming the climate is credible.[2] Others are "hedging their bets" either about future climate change or about future constraints on emissions. In the process, some companies have discovered that emission reductions can in fact benefit them today. For example, while compiling a greenhouse gas inventory, some companies have discovered opportunities to improve efficiency that they had not previously identified.

These are some of the reasons that businesses have found compelling enough to justify their taking steps to inventory or reduce greenhouse gas emissions:

Increased efficiency saves money. Investments in energy conservation and efficiency can yield direct savings in energy costs and lower the per-unit cost of production for some companies. For example, between 1990 and 2000 DuPont held its energy use constant while boosting its production by 35 percent, saving the company $2 billion. Efficiency and conservation are particularly valuable to companies whose

[1] See World Resources Institute, "A Climate of Innovation: Northeast Business Action to Reduce Greenhouse Gas Emissions," (2004); Pew Center on Global Climate Change, "Corporate Greenhouse Gas Reduction Targets," (2001); Kolk, A., and J. Pinske, "Market Strategies for Climate Change," *European Management Journal,* 22 (3):304–14 (2004); Coalition for Environmentally Responsible Economies (Ceres), "Electric Power Climate Risk Disclosure: A Comparison of 2004 Reports Released by American Electric Power, Cinergy and TXU." (2005). In addition, a number of companies have issued annual reports, which describe their actions to reduce greenhouse gas emissions and their rationale.

[2] The aluminum manufacturer Alcoa, Inc., has said on its website that "the time for debate is long past" and that while "the science may or may not be incomplete, [i]f you get this one wrong, you don't get a second chance." On its website, British Petroleum says, "There is an emerging consensus that climate change is, at least in part, linked to the production and consumption of carbon based fuels. As a major supplier of these fuels it's only right that we play a part in finding and implementing solutions to one of the greatest challenges of this century."

greenhouse gas emissions come from the energy purchased from electric utilities, as reducing expenditures for electricity purchases can directly benefit such a company's bottom line.

Competitive advantages may go to innovators. A number of companies are betting that future markets will favor more energy efficient products. For automobile and appliance manufacturers that make products that use electricity or that themselves emit greenhouse gases, creating more efficient products may give these companies a competitive advantage. It may also improve the public's perception of the company as being environmentally responsible. For example, a number of automakers are investing in hybrid vehicle technologies, which are up to 50 percent more efficient than conventional gasoline engines. Whirlpool, whose products are responsible for 95 percent of its greenhouse gas emissions, has committed to reducing the emissions from its products by three percent between 1998 and 2008. General Electric recently announced plans to double its spending on developing environmental and energy-efficient products and to double revenue from those products to $20 billion by 2010.

Early action is a hedge against future regulations or other pressures. Although companies are facing a good deal of investment and regulatory uncertainty surrounding reduction of greenhouse gas emissions, some companies have decided that acting in the near-term is more cost-effective than reacting later when there may be less uncertainty, but potentially higher costs. They believe that beginning to reduce emissions now and continuing steadily over time will be cheaper than being forced to make large reductions all at once in the future should it become necessary to do so. For example, companies are measuring and tracking their greenhouse gas emissions and participating in a variety of emissions trading programs to learn how to track and trade emissions. Dow Corning and Baxter International are two of a number of companies participating in the Chicago Climate Exchange, a voluntary market to demonstrate trading of CO_2 emissions. These companies appear to believe that first-hand knowledge of how greenhouse gas markets work may benefit them in the future.

Direct financial risk from climate change. Some companies face direct financial risks from climate change. For example, insurance companies and the companies that reinsure them are beginning to recognize financial risks from climate change. On its website, Swiss Re, one of the leading global reinsurers, says that "the world of insurance and re-insurance will have to face a new challenge: developing and implementing strategies and business solutions to deal with climate change and a carbon-constrained future." The company says that climate change may alter not only the average losses faced by insurers, but the range and annual fluctuations of those losses.

Pressure from investors and lenders to reduce risk. Individual and institutional shareholders as well as the lending arms of major financial institutions are increasingly concerned with the risks they might face should regulation, public perception or other pressures one day induce companies to emit fewer greenhouse gas emissions. They are beginning to recognize that some companies within a given sector will likely perform better than others should reductions in greenhouse gas emissions ever be required. To protect the future value of their stocks, an increasing number of investors have introduced shareholder resolutions calling on companies to develop climate change strategies, cut greenhouse gas emissions, invest in renewable energy, and disclose greenhouse gas information. In addition, lending institutions, such as Bank of America and JPMorgan Chase, have committed to figuring out how to take these considerations into account in their investment decisions. There has also been growth in specialized stock indices, such as the Dow Jones Sustainability Index, that recognize companies that are taking early action and that attract some investors seeking "green" stocks.

Influencing the policy and regulatory debate. Some companies believe that their experience in applying various approaches to reducing greenhouse gases to their operations will lend credibility to their efforts to shape climate policy. For example, American Electric Power has committed to reduce or offset emissions by four percent between 2003 and 2007 and is gaining real world experience in tracking, reducing and trading greenhouse gas emissions by participation in the Chicago Climate Exchange. These actions, the company has said, have put it in a better position to inform the current policy debate on climate change. Duke Power's CEO recently announced steps that his company would take to reduce greenhouse gas emissions. In addition, in an attempt to influence the national policy debate, he also called for an economy-wide, mandatory carbon tax to reduce the dependence of our economy on fossil fuels and thus lower greenhouse gas emissions.

Questions to the Witnesses

The witnesses were asked to respond in their testimony to the following questions:

James Rogers, Cinergy

- What concrete actions is Cinergy taking to reduce greenhouse gas emissions? In what ways are they beneficial to Cinergy?
- Why is Cinergy taking these actions and what are the most important drivers for them?

Dr. Mack McFarland, Dupont

- What concrete actions is DuPont taking to reduce greenhouse gas emissions? In what ways are they beneficial to DuPont?
- Why is DuPont taking these actions and what are the most important drivers for them?

Ronald Meissen, Baxter International

- What concrete actions is Baxter Health Care taking to reduce greenhouse gas emissions? In what ways are they beneficial to Baxter?
- Why is Baxter taking these actions and what are the most important drivers for them?

Robert Hobbs, United Technologies Corporation

- What concrete actions is UTC taking to reduce greenhouse gas emissions? In what ways are they beneficial to UTC?
- Why is UTC taking these actions and what are the most important drivers for them?

The following companies are among those that are taking action to address greenhouse gases. The lists include companies participating in the Pew Center's Business Environmental Leadership Council (BELC) or the Environmental Protection Agency's (EPA) Voluntary Climate Leaders Program. Some companies participate in both.

According to the Pew Center's web site, members of the Business Environmental Leadership Council (BELC) are taking any of the following types of action to address greenhouse gas emissions: set targets for emissions reductions; implement innovative energy supply and demand solutions; participate in emissions trading; and invest in carbon sequestration opportunities and research. They also agree on several beliefs:

1. We accept the views of most scientists that enough is known about the science and environmental impacts of climate change for us to take actions to address its consequences.
2. Businesses can and should take concrete steps now in the U.S. and abroad to assess opportunities for emission reductions, establish and meet emission reduction objectives, and invest in new, more efficient products, practices and technologies.
3. The Kyoto agreement represents a first step in the international process, but more must be done both to implement the market-based mechanisms that were adopted in principle in Kyoto and to more fully involve the rest of the world in the solution.
4. We can make significant progress in addressing climate change and sustaining economic growth in the United States by adopting reasonable policies, programs and transition strategies.

According to EPA's Climate Leaders web site, EPA's Climate Leaders program is an EPA industry-government partnership that works with companies to develop long-term comprehensive climate change strategies. Partners set a corporate-wide greenhouse gas (GHG) reduction goal and inventory their emissions to measure progress. By reporting inventory data to EPA, Partners create a lasting record of their accomplishments. Partners also identify themselves as corporate environmental leaders and strategically position themselves as climate change policy continues to unfold.

3M
ABB
Air Products
Advanced Micro Devices, Inc.
Alcan Aluminum Corporation
Alcoa
American Electric Power
Ball Corporation
Baltimore Aircoil Company
Bank of America Corporation
Baxter International
Boeing
BP
California Portland Cement
Calpine
Caterpillar, Inc.
CH2M Hill
Cinergy Corp.
Cummins, Inc.
Deutsche Telekom
DTE Energy
DuPont
Eastman Kodak Company
EMC Corporation
Entergy
Exelon Corporation
Fetzer Vineyards
First Environment, Inc.
FPL Group, Inc.
Frito-Lay, Inc.
GAP Inc.
GE Transportation
General Motors Corporation
Georgia-Pacific
Green Mountain Energy Company
Hasbro, Inc.
Hewlett-Packard Company
Holcim
IBM
Intel
Interface, Inc.
International Paper
Johnson & Johnson
Johnson Controls, Inc.
John Hancock Financial Services
Lafarge North America Inc.
Lockheed Martin
Mack Trucks, Inc.
Marriott International, Inc.
Maytag
Melaver, Inc.
Miller Brewing Company
National Renewable Energy Laboratory
NiSource Inc.
Noble Corporation
Norm Thompson
Oracle Corporation
Outfitters, Inc.
Novartis
Ontario Power Generation
Pfizer Inc.
PG&E Corporation
Polaroid Corporation
Praxair, Inc.
PSEG
Quad/Graphics Inc.
Raytheon Company
Rio Tinto
Roche Group U.S. Affiliates
Rohm and Hass
Royal Dutch Shell
Shaklee Corporation
SC Johnson
St. Lawrence Cement
Staples, Inc.
STMicroelectronics
Sun Microsystems, Inc.
Sunoco
Target Corporation
Tenneco Automotive
The Collins Companies
The Hartford
Toyota
TransAlta
Tyson Foods, Inc.
U.S. Steel Corporation
United Technologies Corp.
Unilever HPC
Volvo Trucks North America, Inc.
We Energies
Weyerhaeuser
Whirlpool
Wisconsin Energy Corporation
Xerox Corporation

Source:
http://www.pewclimate.org/companies_leading_the_way_belc/company_profiles/
http://www.epa.gov/climateleaders/partners/index.html

Chairman BOEHLERT. Good morning. It is a pleasure to welcome everyone here this morning for this important and, I hope, eye-opening hearing.

We spend a lot of time in Washington talking about what might or might not be done about climate change in theory, but meanwhile, out in the "real world," real companies that make real money, making real products for real people are taking action.

So we ought to be sure that our debate here is informed by the real experience. We need to understand why your companies are taking steps to reduce greenhouse gas emissions and what you have learned through your actions.

I don't want to say much more than that. I think today's testimony speaks for itself, and my own views on climate change are well known.

I just want to thank our witnesses for being here today. I think that you and your companies are real heroes. You are taking a broad view while still remaining hardheaded, bottom line-oriented business people who have an obligation to protect your companies. But you are putting the enlightened back in self-interest. Somewhere Adam Smith's invisible hand is applauding.

I thank you for appearing today.

And I recognize Mr. Gordon for any comments he might care to make.

[The prepared statement of Chairman Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD L. BOEHLERT

It's a pleasure to welcome everyone here this morning for this important and, I hope, eye-opening hearing. We spend a lot of time in Washington talking about what might or might not be done about climate change—in theory—but meanwhile, out in the "real world" real companies that make real money making real products for real people are taking action.

So we ought to be sure that our debate here is informed by that real experience. We need to understand why your companies are taking steps to reduce greenhouse gas emissions and what you've learned through your actions.

I don't want to say much more than that. I think today's testimony speaks for itself, and my own views on climate change are well known.

I just want to thank our witnesses for being here today; I think that you and your companies are real heroes. You're taking a broad view, while still remaining hard-headed, bottom-line oriented business people who have an obligation to protect your companies. But you're putting the "enlightened" back in self-interest. Somewhere Adam Smith's "invisible hand" is applauding.

Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman, and good morning. And as usual, I concur with your remarks. And I want to thank you for calling this hearing on the voluntary efforts that U.S. businesses are making to improve their energy efficiency and reduce their greenhouse gas emissions.

It is refreshing to hear something positive on this issue. The programs these companies have initiated demonstrate that not all efforts to reduce emissions result in economic losses or put our businesses at an economic disadvantage.

These programs are obviously not cost-free, but they appear to be cost-effective. The firms represented here have made investments that are returning economic and environmental dividends.

The voluntary programs undertaken by these firms and others can also help us to better understand how far current technologies can take us in reducing greenhouse gases and what level of investment is required to achieve them.

Perhaps the experience gained through this type of voluntary effort will give us insights into the types of government research and development efforts we should focus on and the type of adjustment programs that might be needed to reduce the costs and improve the effectiveness of technologies that reduce energy consumption and emissions.

So once again, thank you, Mr. Chairman, for calling this hearing, and I look forward to hearing from our informed witnesses.

[The prepared statement of Mr. Gordon follows:]

PREPARED STATEMENT OF REPRESENTATIVE BART GORDON

Good morning. Thank you, Mr. Chairman for calling this hearing on the voluntary efforts that U.S. businesses are making to improve their energy efficiency and reduce their greenhouse gas emissions.

It is refreshing to hear something positive on this issue. The programs these companies have initiated demonstrate that not all efforts to reduce emissions result in economic losses or put our businesses at an economic disadvantage.

These programs are obviously not cost free, but they appear to be cost effective. The firms represented here have made investments that are returning economic and environmental dividends.

The voluntary programs undertaken by these firms and others can also help us to better understand how far current technologies can take us in reducing greenhouse gases and what level of investment is required to achieve them.

Perhaps the experience gained through this type of voluntary effort will give us insights into the types of government research and development efforts we should focus on and the type of adjustment programs that might be needed to reduce the costs and improve the effectiveness of technologies that reduce energy consumption and emissions.

These programs demonstrate that we have technologies available today to reduce energy use and emissions. We may not be able to address all of our energy and environmental security issues through voluntary efforts alone, but the reductions achieved by these companies show that we can begin to improve our energy efficiency.

I look forward to hearing your testimony and thank you for appearing before the Committee this morning.

Chairman BOEHLERT. Thank you very much, Mr. Gordon.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

I want to thank Chairman Boehlert and Ranking Member Gordon for bringing the issue of global climate change and the control of greenhouse gases before the Committee today. I appreciate their continued leadership on science and environmental policy issues.

I am pleased to hear from businesses that have had the foresight and the capability to begin developing suitable and equitable approaches in solving this shared problem of the control of greenhouse gases.

Business leadership is necessary if we are to avoid further catastrophic effects of our actions on the environment.

One of the most profound challenges we face in the 21st century is the problem of global climate change.

Time and again, the world's leading atmospheric scientists have warned us about the devastating impact of climate change. We now have irrefutable proof of its impact on our economy, our way of life, our health and our children.

Because our country is leading the world in the output of those negative elements that lead to climate change, I am embarrassed that we are one of the last industrialized nations to accept responsibility to clean up our environment.

I realize that solutions may not be easy, quick, or cheap; however, if we do not address this problem now, future costs will be measured in dire consequences to our lives and our children's lives.

Mr. Chairman, I want to acknowledge and applaud TXU and UPS for their clean air efforts in the right direction in my district. It will take efforts like this where businesses, based on their own set of values and their sense of right and wrong, will step up to the plate and make the right decisions about what effect their companies activities are having on the environment.

An effective program to fight climate change need not involve huge increases in energy prices or draconian rules that choke industries and damage a company's economic well-being. There are immense business opportunities in creating approaches to sustainable growth and development.

We must invest in the development of new technologies that will provide new and environmentally friendly sources of energy that include both conventional and non-conventional energy sources. We must work with other nations in a cooperative manner. A well-crafted strategy can address global climate change and maintain our preeminent economic position in the world.

What gives me hope is the fact that the same science and technology that discovered and produced the harmful effects of climate change is the same type of science and technology that Congress and businesses can depend on to come up with solutions to the threat climate change poses.

In Texas, a slight change in the average temperature has already begun to adversely affect our inland and marine fisheries, beaches, forest composition, water supply, agribusiness and health (more Lyme disease and asthma, for example).

The suffering is unacceptable and unnecessary in the richest and most innovative country in the world. Increasing health care costs strain an already struggling health care system.

I urge all of my colleagues to look at this issue closely, and I am looking forward to working with businesses, non-profits and my colleagues to reduce the impact of carbon emissions from coal-burning plants, greenhouse gases, and other human-generated pollutants upon our citizens.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Mr. Chairman and Mr. Ranking Member, thank you for holding this hearing.

It is inspiring to hear that the four companies' represented before us have been able to simultaneously lower energy costs while voluntarily reducing greenhouse gas emissions (GHG). The efforts of these companies should be applauded and imitated by others.

The United States accounts for between one-fifth and one-fourth of current global GHG emissions annually. These companies have volunteered to help in reducing GHGs and in doing so have been positive examples. Yet, our nation as a whole has a responsibility to address our role in GHG emissions and in the larger issue of climate change.

I believe we can do more in the area of reducing emissions. Earlier this year, I sponsored an amendment to the Energy Bill that would offer tax credits for hybrid vehicles to both manufacturers and consumers. I hope that industry and government alike can examine areas where everyone can work together to reduce greenhouse gas emissions.

I welcome the witnesses to our committee today and look forward to hearing their testimony. Thank you.

Chairman BOEHLERT. And our distinguished panel, and it is a very distinguished panel. It consists of Mr. James R. Rogers, Chairman and CEO and President of Cinergy Corporation; Dr. Mack McFarland, Environmental Manager, Fluorochemicals Business, E.I. DuPont de Nemours and Company.

And for the purpose of an introduction, the Chair recognizes Mrs. Biggert.

Ms. BIGGERT. Thank you, Mr. Chairman.

It is a privilege for me to introduce Mr. Ron Meissen, a Senior Director at Baxter International who manages the company's worldwide environment, health, and safety resources. With an MBA and Bachelors and Masters degree in civil engineering, Mr. Meissen is a 30-year employee of Baxter Global Health Care Company that produces medical supplies and biopharmaceuticals for the treatment of hemophilia, immune disorders, kidney disease, cancer, trauma, and other conditions. Baxter generated $8.9 billion in sales in 2003 thanks to the hard work of 51,000 employees at 64 different facilities in seven states, one U.S. territory, and numerous foreign facilities in other countries.

Headquartered in my home state, Baxter is one of Illinois' great corporate citizens in part because of its commitment to reducing energy consumption and associated greenhouse gas emissions. So I would like to welcome Mr. Meissen to the hearing today.

Thank you, Mr. Chairman. I yield back.

Chairman BOEHLERT. Thank you very much for that commercial. It is a pleasure to have that introduction.

And our final witness, Dr. Robert Hobbs, Director of Operations, United Technologies Research Center, United Technologies Corporation.

And I just might add that all of these witnesses are very distinguished in their careers and their accomplishments, and I very much appreciate, gentlemen, you serving as resources for this committee, because we have so much to learn from people with real-life experiences in the "real world." Sometimes we are insulated from the "real world," so we welcome the "real world" to Capitol Hill.

With that, let me start out with Mr. Rogers, who will be—oh, let me also add that the Whirlpool Corporation has submitted testimony, and we appreciate that, for the record. *(See Appendix 2: Additional Material for the Record.)*

Mr. Rogers, and all of the witnesses, your full statements will appear in their entirety in the record. We would ask that you try to summarize your remarks, which will afford us ample opportunity to sort of pick your brains some more.

Mr. Rogers, welcome.

STATEMENT OF MR. JAMES E. ROGERS, CHAIRMAN, CEO, AND PRESIDENT, CINERGY CORPORATION

Mr. ROGERS. Thank you, and good morning.

I appreciate the opportunity on behalf of Cinergy to testify today at what I hope will be a series of hearings on the issue of global warming.

My name is Jim Rogers. I am the CEO of Cinergy. We serve approximately 1.5 million customers in Ohio, Indiana, and Kentucky. As you know, we have recently announced a merger with Duke Energy, which is headquartered in Charlotte, North Carolina.

As a Midwest utility, coal fuels most of our generating plants. We burn approximately 30 million tons of coal a year. That makes us the fifth largest consumer of coal. And despite this utilization of coal, which is one of our greatest resources in this country, we recently, in fact, in 2003, announced a voluntary commitment to reduce greenhouse gas emissions to five percent below our 2000 levels and to do this by the period 2010 to 2012.

To reach that goal, we are going to spend over $21 million on a variety of projects that we anticipate, with these projects, cutting about 30 million tons of greenhouse gas emissions.

We are not alone in this country in industrial America in terms of working to reduce greenhouse gas emissions. There are 94 Fortune 500 companies that are working today to reduce emissions.

The question you are probably asking yourself is: “Why would a primarily coal-burning utility in the Midwest take on such a commitment?” And as I think about it, I look back over the last decade and we spent $1.7 billion to reduce the emissions of SO_X, NO_X, and Mercury from our plants. We are looking, over the next five years, to spend roughly $1.8 billion to reduce SO_X, NO_X, and Mercury from our plants.

My position and our company’s position on the issue of global warming has evolved. This is not an overnight recognition on our part. We have opportunities for research and participate in domestic and international economic and environmental discussions, and from these various vantagepoints, we have come to believe several things. One is the world is warming. Two, human activities have contributed to the warming. Thirdly, and this is the part that needs more work, it is not clear, and I don’t think we fully understand what the impact should be.

But understanding all of that, it has led us to the conclusion that the prudent path at this point in time is to take actions today to prepare to live in a carbon-constrained world tomorrow.

But the question you have to ask is, and I have asked myself is: “What if we were wrong. What if the scientists that say this is a problem are wrong? Will the steps we have taken be inappropriate? Will it leave the world in a worse spot than it would have been otherwise?”

And I believe the answer is simply this. As we work to reduce greenhouse gas emissions, we will work to create environmentally-friendly technologies. We will be pursuing methods of saving energy far more efficiently than we have before. We will be working in this country to lower our dependency on foreign oil by encouraging the development of numerous auto fuel sources. These advantages can shape our economy into one that is cleaner and more self-reliant, and who can argue with that outcome?

In our 2004 annual report, we did something quite different. We focused on the issue of global warming. And the headline was, “Can we find common ground?” So rather than rely on all of the smart people, the scientists, and all of the others, we went to the people who have a stake in our company: the investors, the employees, the customers, policy-makers. And we asked them: “How should we, as a company, be thinking about this issue?”

And I would urge you to look at our website, because you could see our annual report there, and you could look at what people were saying. But let me quickly tell you the signposts that have motivated us to deal with this issue.

One signpost is the states are increasingly taking on the role of regulation of greenhouse gas emissions. Just look across this country, and there are over eight states that are now either registering your CO_2 emissions or looking at ways to regulate it.

Congress is continuing to look at this issue as signpost two. Not only is this committee addressing how businesses are reacting to global warming, the Senate, as you know, has been tackling the issue in a number of ways.

We believe that the Clear Skies legislation that is now pending, this multi-emission legislation, is stalled because of the lack of progress on carbon.

The third signpost that we see is that Kyoto was approved, and we believe that can have possible trade implications going forward.

And the fourth point that I would highlight is that our shareholders are increasingly asking companies to quantify their greenhouse gas emissions. Several years ago, we had a shareholder proposal, and that has helped stimulate and accelerate our thinking on these important issues.

The other signpost I would mention is that trading markets are developing both here and abroad, and so smart people that make money from having markets develop are already anticipating that this is going to be an issue and that there will be a trading of emission allowances from reduction of CO_2.

And the last point I would make is as you look around our society, look at the movies, look at the books, and look at the cover of *Business Week* and the cover of *National Geographic,* it is all about global warming. It is in the consciousness of people across this country.

So our—my challenge to you, and the challenge that we have, is to find a way to reduce emissions, to find a way to invest more in technology, and to make sure that we have technology to do that.

And I would say in conclusion that we have invested in IGCC coal gasification. We were one of two companies that participated in a project in the early 1990s. We built a coal gasification facility using Dow technology. And we are currently in negotiation with GE and Bechtel to build another coal gasification. We believe that is an important technology to allow us to utilize one of the greatest resources we have in this country, and that is coal.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Rogers follows:]

PREPARED STATEMENT OF JAMES E. ROGERS

Good Morning. My name is Jim Rogers, I am Chairman, CEO and President of Cinergy. Cinergy was formed ten years ago by the combination of PSI Energy in Indiana and Cincinnati Gas & Electric. As you know, Cinergy also recently announced a merger with Duke Energy based in Charlotte, North Carolina.

Let me tell you a bit about our company before I explore our interest in greenhouse gas emission policies.

Cinergy serves approximately 1.5 million customers in Ohio, northern Kentucky and much of Indiana. We operate nine coal-fired generating stations that burn almost 30 million tons of coal per year.

As a Midwest utility Cinergy has ample access to coal. And with rising natural gas prices, coal is the most economical choice for supplying our customers with electricity. Despite our generating choice, in 2003 Cinergy committed to reducing our greenhouse gas emissions to five percent below 2000 levels during the period of 2010 and 2012. To reach that goal we are spending $21 million to fund projects through the remainder of the decade. We plan on reaching the goal despite a growing demand for electricity in our region, and taking into account the electricity penalty we will realize when the bulk of our generating units are outfitted with pollution control equipment to meet new Environmental Protection Agency regulatory requirements.

All in all we expect that we will need to cut greenhouse gas emissions by a total of 30 million tons.

While electric rates in the Midwest are likely to increase as a result of pollution control expenditures to reduce sulfur dioxide, nitrogen oxide and mercury, no increases will be due to our carbon commitment.

We made our decision to reduce GHG emissions despite the fact that there currently is no commercially viable method of capturing and sequestering carbon from coal fired power plants. However there are new technologies on the horizon and research on carbon capture and sequestration applications will and must continue to keep coal a viable and necessary fuel for the future.

In fact, Cinergy is completing a feasibility study on the construction of an Integrated Gasification Combined Cycle power plant (IGCC)—the state of the art coal plant technology available to us today. It is relatively easier and less energy intensive to capture CO_2 from an IRC's high pressure synthesis gas than from conventional pulverized coal flue gas. In addition, sulfur dioxide, nitrogen oxide and mercury emissions are substantially reduced with IGCC technology and because it is more efficient even without carbon capture components, it does reduce carbon emissions.

According to industry analysts' estimates, the cost of IGCC is 10–20 percent more then traditional pulverized coal. Those costs will come down, however, if the appropriate incentives are made available and we are able to deploy five or more facilities over the next decade. It is also a technology that is a necessary component of any international technology transfer program. Developing countries that today operate plants without even the simplest of pollution control equipment can with technologies such as IGCC begin reducing all emissions more efficiently and completely.

Let me turn to the subject at hand. Why has Cinergy taken on this commitment and why expend so much attention on greenhouse gas emissions?

I spend a good deal of my time, not just in running the company—but also in researching and participating in domestic and international economic and environmental conferences so that I can appropriate the wisdom from those venues back to our shareholders and all of our stakeholders. Over the past several years I have developed a better understanding of climate change and I see the debate in the scientific world honing in on a few basic facts: that the world is warming and that human activities have contributed to the warming. What the impacts will be I don't think we yet fully understand.

Because of this, I believe people increasingly will believe that greenhouse gas emissions should be reduced and that actions should begin today to prepare for that eventuality.

But what if I and the multitude of scientists and industries agreeing with that premise are wrong? If we approach this issue appropriately, then we will have worked to create new environmentally friendly technologies, pursued methods of saving energy far more efficiently and work to lower our dependence on foreign oil. We will have advanced to a multitude of fuel sources and technological configurations that will help move our economy into a cleaner and more self reliant future. And I don't know anyone that can argue effectively against that outcome.

Let me share with you some of what I call signposts that I have observed over the past several years which helped guide me to the development of our position today. We published these signposts in our 2004 annual report because we chose not to ignore the issue of greenhouse gases but to address it in a positive manner.

Signpost #1
The states are taking action

Four states have an overall cap on GHG emissions and two have a cap on power plant CO_2 emissions. Eight states regulate GHG emissions. And, eight states have filed suits against Cinergy and four other utilities to curb their GHG emissions, while others are involved in suits with EPA over the need to regulate carbon.

A coalition of nine northeast states has initiated the regional greenhouse gas initiative which would create a regional market based cap and trade program.

Governor Schwarzenegger of California an executive order identifying a goal to reduce emissions including:

- By the year 2010, to reduce California's GHG emissions to less than those produced in 2000.
- By 2020, to reduce GHG emissions below 1990 levels.
- By 2050, reduce overall emissions a full 80 percent below 1990 levels.

He noted that the state is going to accelerate the timetable to get more energy from renewable sources 20 percent by 2010 and a third by 2020.

These sources include solar, wind, geothermal, and biomass from agriculture and other waste.

The state's fleet of government vehicles, all 70,000 of them, will be replaced with hybrids.

Signpost #2
An increasing number of Members of Congress are expressing concern about global warming.

While in 1997 the U.S. Senate voted to reject the Kyoto Protocol, that did not mean they were rejecting the issue. I think that it is important to remember that the ratified 1992 Agreement of the Parties has an objective of stabilizing atmospheric greenhouse gas concentrations "at a level that prevents dangerous anthropogenic interference with the climate system" has never been refuted.

Senators McCain and Lieberman have introduced and modified their climate reduction proposal and those voting favorably have increased even though there are still not enough votes to pass the Senate.

Multi-Emissions legislation, which I have championed for years, sadly can't move past the Senate Environmental and Public Works Committee because the issue of climate remains unresolved. That hurts the utility industry and its customers because also unresolved are rules that regulate sulfur dioxide, nitrogen oxide and mercury as well—all which will undoubtedly cost rate payers millions in unneeded expenditures because the roadmap for an eventual solution to those issues will be tied up in courts for years.

Signpost #3
Kyoto has been approved by 38 Industrial nations this year.

Europe wants to accelerate GHG mitigation and some countries, including Tony Blair with whom I met yesterday, are interested in exploring what lies beyond Kyoto's 2012 expiration.

I think that it is also important to consider that while industry in Europe is mandated to deal with emissions reductions, that issue could become increasingly confrontational in trade discussions as the lack of a U.S. policy could possibly be considered a trade subsidy.

Signpost #4
A growing number of shareholders are asking companies to quantify the risks associated with GHG emissions.

Increasingly investor groups are asking utilities and other companies to quantify their GHG emission risks and to determine what steps are being taken to manage those risks.

The assets of socially responsible mutual funds are growing faster then the mutual fund industry as a whole.

And, the California Public Employee Retirement System (CalPERS) announced that it will sign onto the Global Carbon Disclosure Project, an international effort to improve the transparency of business risks associated with climate change.

Signpost #5
CO_2 and GHG emissions trading markets are developing in Europe and the U.S.

The EU initiated its emissions trading scheme this year and facilitates the trading of CO_2 allowances among 12,000 EU industrial installations.

The Chicago Climate Exchange established in 2003, has grown from 13 to 85 members.

Signpost #6
Global Warming is becoming part of our everyday consciousness.

The issue served as cover stories for *Business Week* and *National Geographic* in 2004.

And this past Saturday's *New York Times* included a front page story discussing world-wide technology advances in energy efficiency. The story highlighted countries that have outperformed the U.S., from Japan with its newly manufactured kilowatt saving refrigerators and air conditioners to Germany with its impressive new fuel efficient homes and to Singapore which is placing new restrictions on autos to encourage increased bus and rail usage.

Increasingly, U.S. businesses are stepping up to take action. Not just in the utility industry but if you look at the President's voluntary climate reduction program, numerous business have made commitments to reduce emissions. Even Exxon-Mobile is now advertising voluntary actions it is taking to reduce its impact on climate trapping emissions.

But what does all of this domestic and international activity mean for the U.S.? While other countries are incentivizng new technologies in a comprehensive fashion, we are arguing about what to do. And where will those other countries take those technologies? To China which according to the *New York Times* consumes 11.5 times the energy of Japan to produce the same industrial output.

Despite the fact that Japan is far from meeting its Kyoto target—it is already moving from industry to home and automobile—in attempts to dramatically increase efficiency and alternative vehicle use. And who is dominating the world market on hybrid vehicle sales? The Japanese car manufacturers. Meanwhile Japan has nearly tripled its industrial output from 1973 to today while keeping its overall energy consumption roughly flat.

While the world is deploying leapfrogging technology in an effort to deal with climate change, the U.S. lags sorely behind; concerned that movement to address the climate issue might create some kind of economic instability.

So how do you and we in industry alter the climate paradigm?

I think that it will require a number of steps—smaller steps then embracing Kyoto that will set us on the right path.

First, again, there are aspects of climate science that are indisputable even thought significant additional scientific work remains to refine the unknowns.

- CO_2 is at its highest concentrations in the past 400,000 years
- The Earth is getting warmer
- The warming is caused by a combination of human and natural processes.

Second, I think that we have all recognized that Kyoto was a 10,000 pound gorilla, and too much for the U.S. to tackle. As a result, I think that it is important to eliminate the linkage between any kind of carbon reduction policy and Kyoto.

While I believe that the best approach to climate is an economy wide approach—I think the path there may need to be more creative and perhaps even incremental in order to demonstrate the ability to control emissions in an economically viable way.

Whatever emission reduction approach is adopted, I believe that coupling it with legitimate methods of advancing technology is crucial. I know that this committee focuses on Research and Development. I believe that taking a hard look at what programs are funded and what can be jump-started in order to bring them closer to commercial adaptation is important. Much of the discussion on R&D tends to focus on the R and not so much on the D—development or what I think we need to see is Deployment. Getting these technologies into the marketplace earlier and more effectively is an issue that I believe is often overlooked.

And, I think that beyond traditional government programs, the development of technology funds to help offset the costs of meeting emission reduction targets can work, not only by spreading out the cost of those targets throughout the entire economy but by also helping the U.S. regain the lost momentum to lead the energy efficiency technology race. Ideas abound about how to fund these off budget—and they may not be practical right now—however beginning the discussion is important if optimal solutions to meeting a greenhouse gas reduction target are to be utilized.

Third, I also think it's important to greatly simplify the implementation of taking on emission reduction commitments. As a Utility company executive I am mystified each and every time the issue of meeting climate reduction programs or even the development of a voluntary registration of emissions arises, with it surfaces the host of issues that makes a solution all but impossible. How do you deal with past actions, additionality, every household and homeowner taking on a commitment? The Answer: Don't.

Let's not follow the complicated example of our friends across the "pond" that have developed hundreds of varying allocation rules for every industry or fuel type. Keep it simple. Make a forward looking commitment, meet it and if you go below it—allow those tons to be used to trade with others.

And finally as the Committee continues to examine greenhouse gas emissions I would urge you to be creative. This commitment in my own company has empowered our employees to creatively address how best to meet that commitment. The Acid Rain Program reforms to command and control regulations helped minimize the role of the government in business decisions and unleashed the power of the market by making reductions a good investment. This is the one of the economically efficient paths forward. To take another approach provides naysayers with the unwavering momentum that challenges the possibility of forward movement.

I believe that the country needs leadership in this area. I don't believe that I am being disloyal to the President whom I support, to Congress or to my shareholders when I say that the time is now to move positively toward reachable goals that will not only put us on track to operate in a greenhouse constrained environment, but on a track that will also make this country the technological leader it once was and can be again.

Measuring Baseline GHG Emissions

The table below summarizes Cinergy's baseline 2000 GHG emissions. Cinergy is reporting corporate-wide GHG emissions that include all of Cinergy's business activities.

2000 Cinergy's CO_2 Equivalent Baseline Emissions (tons)	
Legacy Electricity Generating Units	69,768,000
Merchant Electricity Generating Units	0
Fugitive Natural Gas	409,000
Cinergy Solutions Projects	3,454,000
Fleet Vehicles	36,000
SF_6 Emissions	176,000
Total CO_2 equivalent emissions	**73,843,000**
Cinergy's GHG emissions goal	**70,151,000**

Cinergy GHG Goal Reductions

Cinergy chose to adopt a voluntary GHG emissions cap of five percent below Cinergy's 2000 GHG emissions for the period 2010 through 2012 because we wanted to emphasize on-system GHG reductions. Cinergy could have chosen a different goal such as committing to reduce our GHG emissions one (1) percent per year beginning 2004. However, such a commitment would probably have to be met through the purchasing of offsets. To identify, design, and implement on-system reductions will require a certain amount of lead-time. Cinergy believes that the results of on-system reductions will be much more beneficial to the Company and to the electric industry in general. Cinergy designed its GHG goal to provide an opportunity for the Company to first explore implementation of cost-effective on-system methods of reductions.

Part of Cinergy's GHG Management Goal was a pledge to spend up to $21 million on CO_2 reducing and offsetting projects from 2004 to 2010. In 2004 and 2005 Cinergy allocated $3 million in each year to various projects designed to reduce, offset, or provide research in the reduction of Cinergy's CO2 emissions. The projects selected by the internal Cinergy GHG Management Committee included:

2004 Projects	Estimated Annual CO_2 Reductions (tons)
Markland Dam Control Upgrade	7,400
Wind & Solar Demonstration Projects	68
Heat Rate Improvement Projects to Various Cinergy Electric Generating Units	349,882
Purchase of Hybrid Vehicles	26
Reforestation Project	1,000
Energy Conservation	62
Research and Development Project	0
Total Annual CO_2 Reductions	358,438

2005 Projects	Estimated Annual CO_2 Reductions (tons)
Heat Rate Improvement Projects to Various Cinergy Electric Generating Units	206,387
Energy Conservation with Cinergy Customers	16,764
Wind & Solar Demonstration Projects	37
Purchase of Hybrid Vehicles	65
Reforestation Project	350
Research and Development Project	0
Total Annual CO_2 Reductions	223,585

Prior to 2004 Cinergy has implemented a number of projects and activities specifically for the reduction of GHG emissions or for other business reasons that have reduced or offset our GHG emissions in the following areas:

- Power plant efficiency
- Combined heat and power
- Landfill gas capture and electric generation
- End-user energy conservation
- Renewable energy generation
- Terrestrial sequestration
- SF_6 usage reduction
- Fly ash reuse
- Materials recycling

These past and future projects and activities that are not directly connected to the expenditure of the $21 million will continue to reduce GHG emissions.

The table below presents the amount of GHG reductions or offsets for each of the project categories. Emission reductions for 2004 are still being calculated.

Cinergy GHG Reductions and Offsets				
Project Area	2001	2002	2003	2004
Power Plant Efficiency	122,000	109,000	241,000	
Combined Heat & Power	1,552,000	1,450,000	1,756,000	
Landfill Gas[1]	1,021,000	1,177,000	899,000	
End-User Conservation	750,000	748,000	743,000	
Natural Gas Recovery	0	14,000	13,000	
Renewable Energy	0	0	10	
Terrestrial Sequestration	47,000	39,000	39,000	
SF_6 Reductions	7,000	71,000	63,000	
Alternative Fleet Fuels	120	120	100	
Beneficial Reuse of Fly Ash	109,000	138,000	168,000	
Materials Recycling	15,000	13,000	0	
Total Reductions & Offsets	3,624,000	3,760,000	3,921,000	

1 Landfill gas (methane) only include Cinergy's ownership share of the landfill gas reductions made at various landfills where Cinergy has an ownership interest in the landfill gas collection system and/or the electric generation.

The table below provides aggregated data for Cinergy's GHG emissions and reductions for the years 2001 through 2003. Data for 2004 is still being aggregated. The company's reduction target is based on Cinergy's baseline emissions that include its large generating plants, non-regulated generating plants, combined heat and power plants, fugitive natural gas emissions, SF6 emissions, and emissions from fleet vehicles.

Year	2001	2002	2003	2004
Cinergy GHG Emissions	66,608,000	66,443,000	68,324,000	
Total GHG Offsets	3,624,000	3,760,000	3,921,000	
Cinergy Net GHG Emissions	62,984,000	62,683,000	64,403,000	
Cinergy GHG Goal 95% of 2000 GHG Emissions	70,155,000	70,155,000	70,155,000	
GHG Emissions Over/Under Goal	-7,171,000	-7,472,000	-5,752,000	

The reader should not assume that Cinergy has already met its GHG goal of reducing its GHG emissions more than the five percent below our 2000 GHG emissions. While Cinergy's GHG emissions were below our year 2000 corporate baseline emissions of more than 73 million tons, the lower emissions are due to the slow economy in 2001 and 2002 and mild summer and winter weather in 2002 and 2003. GHG emissions in 2003 were higher because of increased economic activity. The slow economy and mild weather lowered demand for electricity so Cinergy generated less and therefore lower associated GHG emissions. Cinergy cannot predict future weather or economic conditions with absolute certainty. Cinergy uses internal models to project electricity demand into the future. Based on certain scenarios modeled during evaluation of the Cinergy GHG goal, Cinergy anticipates that the demand for electricity will grow and that our GHG emissions will exceed our 2000 baseline emissions anywhere from one million tons to more than 12 million tons annually during the 2010 through 2012 time period.

BIOGRAPHY FOR JAMES E. ROGERS

Mr. Rogers, 57, has been CEO for more than 16 years—at PSI and now at Cinergy. Prior to the formation of Cinergy, he joined PSI Energy, Inc., in 1988 as the company's Chairman, President and Chief Executive Officer. Prior to joining PSI, he was Executive Vice President, Interstate Pipelines for the Enron Gas Pipeline Group. Before joining Enron Corp., Mr. Rogers was a partner in the Washington, D.C. office of Akin, Gump, Strauss, Hauer & Feld (a law firm based in Dallas, Texas). He represented energy companies before the Federal Energy Regulatory Commission (FERC), the Department of Energy, various Congressional committees and federal courts.

Immediately before joining Akin, Gump, Strauss, Hauer & Feld, Mr. Rogers was Deputy General Counsel for Litigation and Enforcement of the FERC. In this position he directed all aspects of the FERC's litigation and enforcement. Previously, Mr. Rogers served as Assistant to the Chief Trial Counsel at the FERC, as a Law Clerk for the Supreme Court of Kentucky, and as Assistant Attorney General for the Commonwealth of Kentucky, where he acted as intervener on behalf of State consumers in gas, electric, and telephone rate cases. He was a reporter for the *Lexington* (Kentucky) *Herald-Leader* from 1967 to 1970.

Mr. Rogers has served more than 38 years cumulatively on the boards of Fortune 500 companies. He is currently a director of the following corporations: Cinergy Corp., Fifth Third Bancorp and Fifth Third Bank. He serves as 2nd Vice Chairman of the Board, is on the Executive Committee and is Chairman of the Strategic Planning Committee of the Edison Electric Institute. He previously served as Chairman of the Environmental Policy Committee. He also serves on the Board of the American Gas Association and the U.S. Chamber of Commerce.

Mr. Rogers also serves on numerous civic boards and has published numerous articles on energy and environmental issues. He formerly served as director of the following corporations: Duke Realty Corp., Bankers Life Holding Corporation; A O Irkutskenergo (a Russian hydroelectric/coal-fired steam utility), INB (Indiana National Bank) and NBD Indiana Inc. He has testified before Congressional Committees 13 times since 1989.

Mr. Rogers attended Emory University (Atlanta, Georgia) and holds a B.B.A. and J.D. degree from the University of Kentucky, where he was a member of the Kentucky Law Journal and Beta Gamma Sigma (Academic Honorary Society). He was named to the Hall of Fame at the Carol Martin Gatton College of Business and Economics and the Hall of Fame of the College of Law, both of the University of Kentucky. He also received an honorary Doctor of Law degree from Indiana State University.

Chairman BOEHLERT. Thank you very much, Mr. Rogers.

Dr. McFarland.

STATEMENT OF DR. MACK McFARLAND, ENVIRONMENTAL MANAGER, FLUOROCHEMICALS BUSINESS, E.I. DuPONT DE NEMOURS AND COMPANY

Dr. MCFARLAND. Good morning, Chairman Boehlert, Mr. Gordon, and members of the Committee.

My name is Mack McFarland, and I am the Global Environmental Manager for DuPont's Fluorochemicals Business.

In that role, I advise our worldwide operations on a range of environmental and business matters. I appreciate this opportunity to share our experiences regarding greenhouse gas emission reductions with you.

DuPont is a science-driven company with a commitment to safety, health, and environmental protection. We use science to derive products and services that improve the quality and safety of people's lives. We also use science to drive how we develop, manufacture, and manage our products throughout their life cycle.

As a 200-year-old company, we take the long view and strive for sustainable growth that benefits our shareholders, the societies in which we operate, and the global environment. It is that commitment to sustainable growth and the science that underpins our approach to global climate change.

Our experience with climate change actually began with another global environmental issue, stratospheric ozone depletion. DuPont developed the first fluorochemical refrigerating gases, CFCs, in the 1930s. In the 1970s, when it was proposed that CFCs might deplete stratospheric ozone, DuPont delved into the science. In 1988, based on the scientific consensus presented in the International Ozone Trends Panel Report and our evaluation of that science, we voluntarily and unilaterally committed to phase out CFCs.

We also used our science capabilities to lead in the development of alternative products to meet the growing societal demand for air conditioning and refrigeration. This experience with the CFC ozone issue provided us with a keen understanding of the implications of environmental issues that are global in scope and decades to centuries in duration.

Global climate change was a natural extension of this experience. With the beginning of the negotiations of the UN Framework Convention on Climate Change, we again delved into the science. We concluded that the scientific understanding, while imperfect, was certainly sufficient to indicate a legitimate issue. In 1991, we took a hard look at our own greenhouse gas emissions and realized that they were not insignificant. While we recognize that it would take concerted global action across all economic sectors to address global climate change, we determined that we needed to take responsible action and reduce our own emissions footprint.

The largest contributors to our footprint were unintended by-product emissions, nitrous oxide associated with the manufacture of a key raw material for nylon, and HFC–23 associated with the manufacture of a fluorochemicals refrigerant.

We set aggressive goals to reduce our greenhouse gas emissions by 40 percent on a global carbon equivalent basis by the year 2000, using 1990 as a base year. We also set goals to address carbon dioxide emissions from energy use, aiming to keep energy use flat, even as production grew.

By the year 2000, we exceeded our original goals globally. In 1999, with our 2000 goals in sight and the scientific case for climate change continuing to strengthen, we reaffirmed our commitment to action on greenhouse gases and set aggressive new goals for the year 2010. We committed to reduce our global carbon equivalent greenhouse gas emissions by 65 percent, using 1990 as a base year. We committed to continue to hold our global energy use flat. And finally, we committed to acquire 10 percent of our global energy in the year 2010 from renewable resources. By the year 2004, we had exceeded the emission reduction goal and had held energy use flat while global production grew by over 30 percent.

We are also making steady progress on our renewable energy goal. We have spent over $50 million to achieve the byproduct emission reductions and have made additional investments in energy efficiency. On the other hand, achieving the energy flat goal has saved us over $2 billion.

In conclusion, first, we determined that enough was known about global climate change to provide a basis for concern and warrant prudent action on our part. Second, we set and achieved aggressive greenhouse gas emission reduction goals that, while costly to pursue, have created an overall cost savings for the company due to reduced energy use. Third, we believe that climate change is clearly an environmental, social, and economic challenge and must be addressed with all of these aspects in mind. Fourth, although we have no regrets over taking these actions, we do have a concern that developing policy regimes around the world do not adequately account for the actions of early movers. This can place the early movers at a competitive disadvantage and act as disincentives to others to step up with bold, voluntary action.

Thank you. I will be happy to answer any questions.

[The prepared statement of Dr. McFarland follows:]

Prepared Statement of Mack McFarland

Good morning Chairman Boehlert, Mr. Gordon, and Members of the Committee. My name is Mack McFarland, and I am the Global Environmental Manager for DuPont's fluorochemicals business. In that role I advise our worldwide operations on a range of environmental and business matters. I appreciate this opportunity to share our experiences regarding greenhouse gas emission reductions with you.

DuPont is a science driven company with a commitment to safety, health and environmental protection. We use science to derive products and services that improve the quality and safety of people's lives. We also use science to drive how we develop, manufacture and manage our products throughout their life cycle. As a 200-year-old company we take the long view, and strive for sustainable growth that benefits our shareholders, the societies in which we operate and the global environment. It is that commitment to sustainable growth and dedication to science that underpins our approach to global climate change and greenhouse gas emissions reductions.

Our experience with greenhouse gas reductions actually began with another global environmental issue; stratospheric ozone depletion. DuPont developed the first fluorochemical refrigerant gases, chlorofluorocarbons, or CFCs, in the 1930s. They were developed as safe alternatives to the more dangerous refrigerants then in use, such as ammonia. In the 1970s when it was proposed that CFCs might deplete stratospheric ozone DuPont delved into the science. In 1988, based on the scientific consensus presented in the International Ozone Trends Panel Report, and our evaluation of that science, we voluntarily and unilaterally committed to phase out CFCs. We also used our science capabilities to lead in the development of alternative products to meet the growing societal need for air conditioning and refrigeration. This experience with the CFC/ozone issue provided us with a keen understanding of the implications of environmental issues that are global in scope and decades to centuries in duration.

Global climate change was a natural extension of this experience. With the beginning of negotiations for the UN Framework Convention on Climate Change we again delved into the science. We concluded that the scientific consensus, while imperfect, was certainly sufficient to indicate a legitimate issue.

In 1991 we took a hard look at our own greenhouse gas emissions and realized that they were not insignificant. While we recognized that it would take concerted global action across all economic sectors to address global climate change, we determined that we needed to take responsible action to be part of the solution, and to reduce our own emissions "footprint." The largest contributors to our footprint were unintended by-product emissions associated with manufacture of a key raw material for nylon and with manufacture of a fluorochemicals refrigerant; nitrous oxide from our nylon plants and trifluoromethane or HFC–23 from some of our fluorochemical plants. Both have significant global warming potentials.

We set aggressive goals to reduce our global greenhouse gas emissions by 40 percent on a carbon-equivalent basis by the year 2000, using 1990 as a base year, with most of our actions targeted at nitrous oxide and HFC–23. We built a detailed inventory of our global emissions and a system to search out the lowest cost emissions reductions in our global operations, as well as a system to track and publicly report our ongoing emissions. We also set goals to address carbon dioxide emissions from energy use, aiming to keep energy use flat even as production grew.

We recognized that this was a significant undertaking that needed to be done in as flexible and cost effective a manner as possible. This, of course, is as true for a national or global program as it is for a single company's actions. The byproduct emissions were reduced both by traditional abatement technologies and, more importantly, by changing our manufacturing processes to avoid producing them in the first instance. We pursued our energy goals through a wide variety of large and small projects, including everything from expanding our use of highly efficient cogeneration to changing light bulbs in our offices.

So, how have we done against these goals? By the year 2000, we exceeded our original goals globally. In 1999, with our 2000 goals in sight and the scientific case for climate change continuing to strengthen, we reaffirmed our commitment to action on greenhouse gases and set aggressive new goals for the year 2010.

- *First, we committed to reduce our global carbon-equivalent greenhouse gas emissions by 65 percent using 1990 as a base year (vs. our original 40 percent goal).*
- *Second, we committed to continue to hold our global energy use flat using 1990 as a base year.* The achievement of this goal will require that our business growth be much less raw material and energy intensive than in the past—a move that is very consistent with our overarching goals of sustainable growth.
- *Third, we have committed to acquiring 10 percent of our global energy use in the year 2010 from renewable resources.* We want to show that we are serious about the need for renewable energy to be a part of our future. We also want to indicate that we are prepared to work with energy suppliers and others to develop a robust renewable energy market.

We have been making steady progress on our 2010 goals. Through a technology breakthrough in our fluorochemical operations, we have reduced our global carbon-equivalent emissions by over 72 percent. We also continue to hold our energy use flat while our global production has grown over 30 percent since 1991. This has resulted in a reduction of 420 million cumulative metric tons of greenhouse gas emissions from our global operations versus business as usual. We are also making solid progress in meeting our renewable energy goal with about five percent of our current energy use from renewable resources such as wind, hydropower and landfill gas.

In 2004 we divested our nylon business and we are now in the process of recalculating our goals by subtracting the emissions of that business from both our 1990 baseline and from the emissions for subsequent years. We will of course make the recalculated goals public.

Let me share with you a few of the things we have learned from our experience with reducing greenhouse gas emissions.

- First, these kinds of reductions are not a simple matter and have economic ramifications. We have spent over $50 million dollars in our efforts to reduce nitrous oxide and HFC–23, as well as spending on energy efficiency projects.
- That leads me to a happier second key learning—the sort of programmatic actions necessary to address greenhouse gases can lead to unexpected benefits. Our hold-energy-use-flat goal has helped us to focus effort on energy savings activities and projects that might not have otherwise risen far enough up on our capital spending priorities to have been pursued. The result? We have saved over $2 billion dollars on energy costs since 1991, and this is the "gift that keeps on giving" in ongoing operating cost savings.
- Third, as various greenhouse gas emissions policy regimes develop around the world there seems to be little effort to take account of the actions of early movers like ourselves. This can place the early movers at a competitive disadvantage and act as a disincentive to other entities to step up with bold voluntary actions.

In conclusion:

- We determined that enough is known about global climate change to provide a basis for concern and warrant prudent action on our part;
- We have set and achieved aggressive greenhouse gas emissions reduction goals that while costly to pursue, have created an overall cost savings for the company due to reduced energy use;
- Climate change is clearly both an environmental *and* economic challenge and must be addressed with both of these aspects in mind.

Thank you. I will be happy to answer any questions.

BIOGRAPHY FOR MACK MCFARLAND

Summary CV

Mack received a B.S. in chemistry from the University of Texas at Austin in 1970 and a Ph.D. in Chemical Physics from the University of Colorado in 1973. From 1974 through 1983, first as a Post-Doctoral Fellow at York University and then a research scientist at the NOAA Aeronomy Laboratory, Mack planned, conducted and interpreted field experiments designed to probe the cycles that control atmospheric ozone concentrations. These studies included measurements of gases and processes important to the global climate change issue. In late 1983 Mack joined the DuPont Company. His primary responsibilities have been in the areas of coordination of research programs and assessment and interpretation of scientific information on stratospheric ozone depletion and global climate change. During 1995 and 1996, Mack was on loan to the Atmosphere Unit of the United Nations Environment Programme and in 1997 he was on loan to the Intergovernmental Panel on Climate Change (IPCC) Working Group II Technical Support Unit. The value of his contributions to DuPont has been recognized through a C&P Flagship Award, Environmental Respect Awards, and Environmental Excellence Awards. In 1999, Mack was awarded an individual Climate Protection Award by the U.S. Environmental Protection Agency for his contributions in providing understandable, reliable information to decision-makers.

Education

Ph.D. in Chemical Physics, 1973, University of Colorado. Thesis title: Development of a Flow-drift Technique for Ion-molecule Kinetic Studies.

B.S. in Chemistry with Honors, Special Honors, 1970, University of Texas at Austin.

Publications

Co-author of over 40 scientific publications primarily in the areas of reaction kinetics and atmospheric measurements of trace gas concentrations.

Work Experience

March, 1998–present: Principal Scientist, Environmental Programs in DuPont Fluoroproducts, Wilmington, DE.

March, 1997–February, 1998: On loan (from DuPont) to the Intergovernmental Panel on Climate Change (IPCC), Working Group II (WG II), Technical Support Unit (TSU), Washington, D.C. Decision-makers rely on IPCC Assessment Reports as their primary source of scientific, technical and socio-economic information on global climate change. The TSUs play lead roles in the IPCC process by helping to assure that reports are complete, objective and policy relevant.

March, 1995–February, 1997: On loan (from DuPont) to the Atmosphere Unit of the United Nations Environment Programme (UNEP), Nairobi, Kenya. Responsibilities during this assignment included representing UNEP at international meetings, assisting in strategy development for the Atmosphere and other UNEP programs, and preparing policy relevant materials for publication.

December, 1983–February, 1995: Principal Consultant, Environmental Programs (most recent title) in DuPont Fluoroproducts (formerly Freon(r) Products), Wilmington, DE. Primary responsibilities included management of atmospheric science research programs; representing DuPont in scientific meetings and before regulatory bodies, the media and customers; facilitating the preparation of scientific assessments; and analysis and communication of information on stratospheric ozone depletion and global climate change for development and implementation of business strategies.

1975–1983: Scientist in the National Oceanic and Atmospheric Administration (NOAA) Aeronomy Laboratory (AL), Boulder, CO. While at York University (see below) and NOAA, Mack planned, conducted and interpreted field experiments designed to probe the cycles that control atmospheric ozone concentrations.

1974–1975: Post Doctoral Fellow at York University, Downsview, Ontario, Canada.

Since joining DuPont in 1983, Mack's primary responsibilities have been in the areas of coordination of research programs and assessment and interpretation of scientific information on stratospheric ozone depletion and global climate change. Coordination of research programs involved two types of activities, both aimed at a cooperative approach to research and assessment to provide policy relevant information: project management through representing DuPont on the industry sponsored research programs to determine potential environmental impacts of CFCs and their replacements; and influence of direction of government sponsored research programs to ensure that they were appropriately focused on providing sound information as a basis for decisions. Cooperative research efforts tend to build consensus around key policy relevant scientific information as opposed to isolated research programs that have led to "our science/their science" politicization of environmental issues in some other areas.

Mack has been involved as an author, contributor or reviewer of every major international assessment on stratospheric ozone depletion and global climate change. Most recently he was a Lead Author of the technology chapter of *Working Group III (Mitigation) of the IPCC Third Assessment Report* (TAR—the report released in 2001) and a Lead Author on the Appendix to that chapter: "Options to Reduce Global Warming Contributions from Substitutes for Ozone Depleting Substances." He was also a Lead Author of the *Technical Summary for the Working Group I TAR (The Scientific Basis)* as well as an Author of the draft *Summary for Policy-makers* that was ultimately accepted by the IPCC. In 1999 he was a member of the UNEP TEAP task force that prepared the report: "The Implications of the Montreal Protocol of the Inclusion of HFCs and PFCs in the Kyoto Protocol."

Interpretation and communication of scientific information based on these assessments has provided a basis for developing and implementing business strategies. Mack has given hundreds of presentations on the science of ozone depletion and climate change to DuPont management, DuPont's customers, media representatives, government representatives and scientists. The value of his contributions to DuPont has been recognized through a C&P Flagship Award, Environmental Respect Awards, and Environmental Excellence Awards. In 1999 Mack was awarded an individual Climate Protection Award by the U.S. Environmental Protection Agency for his contributions in providing understandable, reliable information to decision-makers.

Chairman BOEHLERT. Thank you very much, Dr. McFarland.

Mr. Meissen.

STATEMENT OF MR. RONALD E. MEISSEN, SENIOR DIRECTOR, ENGINEERING, ENVIRONMENT, HEALTH & SAFETY, BAXTER INTERNATIONAL, INC.

Mr. MEISSEN. Mr. Chairman and Members of the Committee, I would like to thank you for your leadership on this area of global climate change. I would also like to thank you for holding this hearing.

I am Ron Meissen, and I manage Baxter's climate initiatives. I also manage the reduction of Baxter's greenhouse gas emissions. I appreciate the opportunity that you have provided to us to describe the balance between environmental stewardship and business realities.

In my remarks today, I would like to share with you some of the examples of how Baxter is proactively addressing environmental issues by driving greater operating efficiencies, adopting new technologies, and collaborating through public and private partnerships.

Baxter is a global health care company based in Deerfield, Illinois that produces biotech, specialty pharmaceutical, and device products that are used in the treatment of a variety of complex medical conditions.

In the mid-1990s, Baxter began publicly reporting information regarding energy use, cost, and associated greenhouse gas emissions, and was the first company to publish an environmental financial statement to demonstrate the linkage between our activities and our bottom line. In 1997, we set a number of long-term, nine-year goals in environmental health and safety including a goal to reduce energy usage and associated greenhouse gas emissions by 30 percent per unit.

A key driver in our proactive initiatives has been the realization that sound environmental practices can provide a competitive advantage. By driving greater operating efficiencies by adopting new technologies and by sharing ideas and best practices, we have achieved a 35 percent per unit reduction in greenhouse gas emissions from 1996 to 2004, a 22 percent improvement in energy efficiency during the same period, and our environmental health and safety investments over the last six years have yielded a savings of $80 million in 2004. We estimate that our energy savings and cost avoidance alone in that year exceeded $9 million.

The benefits go far beyond cost avoidance and energy or raw material savings. Many of the initiatives that we have put in place and investments that we have made have yielded higher quality levels, greater production output, and flexibility in our operations, reduced waste, as well as improvements in workplace safety, which is very important to Baxter.

We have pioneered a Lean and Clean approach by applying Lean manufacturing disciplines to our environmental processes and environmental know-how to our manufacturing operations. You may be familiar with Lean manufacturing, which is a process designed to remove waste and improve quality and efficiency by reducing or eliminating non-value-added activities and materials.

At Baxter, we have integrated Clean expertise into our Lean manufacturing initiatives to not only prevent negative environmental consequences but also to identify opportunities for environmental improvement.

Over the past decade, Baxter has grown significantly, investing in important expansions and upgrades to our manufacturing base. The investments that we have made also provide great opportunities to implement environmental improvements. For example, in the process of expanding our facility in Bloomington, Indiana, we are using new technologies to reduce energy usage and associated greenhouse gas emissions.

I also can not speak positively enough about the benefits of collaboration through public and private partnerships, such as the U.S. EPA's Climate Leaders program and the Green Supplier Network.

Last year, Baxter led participation in the health care industry in the Green Suppliers Network program, which strives to integrate both Lean and Clean manufacturing principles into the operations of suppliers common to that particular industry. So far, seven Baxter suppliers have agreed to participate in the program in which the U.S. Department of Commerce's Manufacturing Extension Partnership and the U.S. EPA provide fronts for technical professionals to train suppliers in Lean and Clean manufacturing processes. These professionals conduct a review of the suppliers' operations and recommend areas for improvement. This program brings expertise to small- and medium-sized companies that would normally not be considered or it would be unaffordable to them.

We are a global company, and we must remain globally competitive. Our 67 manufacturing facilities are located in 28 countries, and we hold all to the same high levels of standards.

Accordingly, we must closely monitor the actions proposed and taken by other countries to address climate change. For example, one of our food manufacturing facilities in Ireland will be affected by the phase one of the EU Emissions Trading Directive, which establishes a mandatory carbon cap and trade system. Climate taxes are also being implemented in some countries, and we currently pay climate tax for the electricity that we use in the United Kingdom.

We believe we are well positioned to respond to these initiatives, because our experience has taught us that reasonable improvements in energy conservation and emissions reductions are possible without huge investment, that investments in technology and improvements in manufacturing processes can bring both environmental and other benefits, including quality improvements, reduced raw material costs, and improved workplace safety, that companies that have been forward-looking on this issue are in a better position to compete on a global basis.

In summary, we believe that it is possible to responsibly address environmental issues and specifically climate change in a manner that provides economic benefit and is of a competitive advantage to our company.

Thank you for this opportunity to share with you our experiences and perspectives.

[The prepared statement of Mr. Meissen follows:]

PREPARED STATEMENT OF RONALD E. MEISSEN

Mr. Chairman and Members of the Committee, I would like to thank you for this opportunity to testify today on climate change and related activity within the business community, particularly at my company, Baxter International Inc.

I speak to you today both as a representative of one company that has been recognized as being at the leading edge of corporate environmental stewardship and as a practicing expert in the field. My name is Ron Meissen, and I serve as Senior Director of Environment, Health and Safety Engineering at Baxter. In addition to my professional interest in the subject of climate change and sustainability, I have a strong personal interest in this subject as well—I am currently pursuing my Ph.D. at the University of Wisconsin in Madison in sustainable development. The focus of my dissertation research, which I am hoping to complete in the next year, is the development and application of a strategic business model to reduce energy related greenhouse gas emissions.

In my role at Baxter, I coordinate the company's safety, occupational health, industrial hygiene and environmental engineering professionals as they lead their respective functions for the company and provide their expertise to Baxter's facilities and employees throughout the world. I also oversee Baxter's initiatives related to climate change and greenhouse gas emissions reductions.

Baxter International Inc. is a global health care company based in Deerfield, Illinois that assists health care professionals and their patients with treatment of complex medical conditions including hemophilia, immune disorders, kidney disease, cancer, trauma and other conditions. Baxter's 48,000 employees apply their expertise in medical devices, pharmaceuticals and biotechnology to help make a meaningful difference in patients' lives. In short, we strive to make a positive impact on the health and well-being of our local and global communities, and to conduct our operations in a manner that minimizes the use of natural resources and impact on the environment. Because of the life-saving nature of the products that we make, and the significant impact that we have on human health, Baxter has held environmental stewardship as a priority for more than two decades, and has been a pioneer in the areas of environmental financial reporting, management of environmental, safety and health data, and establishing, tracking progress against and reporting on specific environmental goals, including greenhouse gas emissions. We recognize that the health of the planet affects the health of the people who inhabit it. As a health care company, we understand this connection and work toward improving both.

I gave my first speech on global warming in 1989, to a group of my colleagues attending the company's annual Environmental Conference. Even then, prior to the more definitive scientific studies that have emerged over the last decade, some environmental professionals and enlightened organizations concluded that their emissions were having an impact on the atmosphere and environment, and began pursuing initiatives to reduce energy use, reduce emissions and eliminate the use of compounds and gases believed to contribute to the greenhouse effect. In the early 1990s, I became very interested in sustainable development, especially after the Earth Summit Conference in 1992, when essentially all the nations of the world adopted sustainable development as world policy.

In the mid-1990s, Baxter began tracking and publicly reporting detailed information regarding energy use, energy cost and associated greenhouse gas emissions from all of Baxter's facilities. Then, in 1997, Baxter set a number of long-term environmental, health and safety (EHS) goals, including a goal to reduce energy usage and associated greenhouse gas emissions by 30 percent, per unit of production activity, by 2005 from 1996 levels. Also in the late 1990s, the World Business Council on Sustainable Development (WBCSD) and the World Resources Institute (WRI) organized a group of experts and business leaders to develop the WBCSD/WRI GHG Protocol for calculating greenhouse gas emissions. I was honored to be a part of that group to develop what is now the global standard businesses and other organizations use to determine their greenhouse gas emissions.

Baxter has continued its leadership on this issue in the ensuing years, becoming one of the initial members of the Pew Center on Global Climate Change's Business Environment Leadership Council, a non-profit, non-partisan independent organization that is facilitating exchange of information and innovative solutions to address global climate change, a charter member of the U.S. EPA's Climate Leaders Program, a voluntary EPA industry-government partnership that encourages companies to develop long-term comprehensive climate change strategies, and a founding member of the Chicago Climate Exchange, the first voluntary pilot carbon trading platform in North America.

Our leadership and commitment to reducing our environmental footprint and advancing the health and welfare of our communities has been sustained over the years not just by good intentions. A key driver for these proactive initiatives over the years at Baxter has been the realization that sound environmental practices can contribute to and in some cases drive competitive advantage.

By *driving greater operating efficiencies,* by piloting and in many cases *adopting new technologies,* and by *sharing ideas and best practices* within the company and through collaborations and voluntary programs sponsored by the EPA and others, we have achieved among other things:

- A 35 percent reduction in greenhouse gas emissions from 1996 through 2004, on a per-unit-of-production value basis;
- A 22 percent improvement in energy efficiency from 1996 through 2004, on a per-unit-of-production value basis; and

- Savings and cost avoidance totaling several millions of dollars each year. In 2004 alone, we estimate our energy savings and cost avoidance exceeded $9 million.

And the benefits go far beyond just cost avoidance and energy or raw material savings. Many of the initiatives we have put in place in our facilities have also brought higher production throughput, higher quality levels, greater production flexibility and optimization of manufacturing assets, reduced scrap materials and waste, as well as improvements in workplace safety.

Given the nature of our products and the nature of our operations, the majority of Baxter's greenhouse gas emissions are carbon dioxide emissions related to energy usage. Therefore, the focus of our greenhouse gas management strategy is energy conservation—specifically, activities and initiatives that improve the energy efficiency of our facility and reduce our energy costs.

Driving Operating Efficiencies

At Baxter, we view EHS as an integrated part of our operations, not as a separate or supplemental function. We believe that world-class manufacturing requires excellence in design, process, purchasing, quality and EHS. Successful, world-class companies tap all of those areas of expertise in a seamless manner to reduce waste, drive efficiency and increase productivity.

By applying Lean manufacturing disciplines to our environmental processes, and environmental know-how to our manufacturing operations, we have driven both Lean and Clean concepts and tools through our organization. The results have been greater efficiencies and productivity in our manufacturing facilities, as well as reductions in raw material and energy use, and reduction in waste generation and emissions.

Lean manufacturing is a process designed to remove waste and improve quality and efficiency by continuously identifying, reducing and eliminating non-value-added activities, materials and other resources in the manufacturing process. Lean tools like value streams and process mapping help identify opportunities to reduce raw materials, wasted motion and scrap by standardizing processes and materials by pinpointing where waste is created. But, Lean manufacturing initiatives, when taken solely on their own, can sometimes have negative environmental consequences.

At Baxter, we have integrated our EHS expertise and professionals into Lean manufacturing initiatives to not only prevent negative environmental consequences, but also to identify opportunities for environmental improvement—we call this Lean *and* Clean. First, we apply environmental concepts such as waste, water use and emissions to such commonly used lean tools as value stream maps to incorporate environmental considerations into the improvement initiative. Secondly, we apply lean tools to EHS-focused processes as waste water treatment or safety incident investigations to make our EHS processes more efficient. And, we integrate our tradition pollution prevention techniques into Lean and Clean tools to provide a new way of systematically looking at waste reduction opportunities.

This enables plant personnel to see and think about their processes differently, which can and does inspire innovative solutions. In a number of our manufacturing facilities, projects are underway that use process mapping and other lean manufacturing techniques to reduce the amount of waste or scrap generated in production. By breaking down all of the steps in a specific manufacturing process and assessing the resource allocation in terms of materials, utilities and other "inputs" and "outputs" for each step, our plants are able to identify multiple opportunities to reduce both manufacturing costs and waste. And, since employees themselves generate the ideas, they have a vested interest in seeing the initiatives through to successful completion and are motivated to continue to suggest further improvements.

The American Society for Quality recently recognized our facility in Marion, North Carolina with its Gold Award for International Team Excellence for applying Lean tools to one area of the facility. Through value stream mapping, the team identified a number of opportunities to reconfigure production processes, which yielded increased product throughput, decreased the amount of manufacturing floor space required to get the work done, and reduced energy and heating, ventilation and air conditioning, or HVAC, requirements. As a result of these changes, the facility estimates it has saved in excess of $100,000 per year in utility costs. While $100,000 a year may not seem like a big number, when you consider that we have 67 manufacturing facilities alone, these kinds of projects and incremental savings quickly add up to much larger numbers and do make a difference.

Adopting New Technologies

Over the last decade, Baxter has grown significantly, investing in important expansions and upgrades to its manufacturing base. The capital investments that we have made to expand our manufacturing capacity, assure product quality and advance our product portfolio have also provided great opportunities for us to implement environmental improvement.

For example, we are moving away from sterilization methods that use ethylene oxide to methods that use e-beam sterilization. Baxter is different from most pharmaceutical companies, because we don't manufacture pills and tablets. Instead, most of our products are medications that are administered intravenously or injected, or are devices. The production process for these types of products typically requires much more extensive sterilization procedures, which can be labor and capital intensive. For decades, many of our products have been sterilized using ethylene oxide. In this process, finished product is moved along a conveyor belt into a special room or chamber. Then ethylene oxide gas is released into the room and product exposed to the gas for a certain length of time to render it sterile. The ethylene oxide, which is a toxic gas, is then evacuated from the room by means of vacuum pressure, which is an energy intensive process. Then the product is moved to another well-ventilated area for a period of time to allow for any remaining gas to be released from the product. All of the exhaust gases are required to be treated with a scrubber, also an energy intensive process.

Now, we are increasingly using alternative, more energy efficient methods of sterilization that also have considerably less environmental impact—technologies similar to those used to protect your own mail from anthrax and other contamination. With e-beam sterilization, we use high energy electrons to sterilize our products. These newer methods are significantly more energy efficient and do not have the same requirements for ventilation and treatment of exhaust gases.

Because of the sterilization processes we employ and the clean room environments we must maintain in our facilities in order to produce the highest quality of medical products, our HVAC requirements are very high, and energy intensive, in some cases representing 60 to 70 percent of the energy consumption for the facility. Accordingly, this is an important area of focus for us.

For example, we are currently in the process of expanding our facility in Bloomington, Indiana, and are employing new technology to replace clean rooms and thereby reduce our HVAC and lighting requirements. Through the use of isolators, special pre-assembled self-contained production and laboratory units, we are able to confine and more closely control the higher sterility, ventilation and lighting requirements of a clean room to significantly smaller space. Picture if you will a trailer sized unit, with equipment inside and the walls made up of windows. Depending on the particular application, work may done in the small area within the isolator, or employees may even work outside of the unit, with their hands and arms inserted into glove-like apparatus that extends from the window into the unit. Not only will this approach save a considerable amount in energy costs, less investment is required in HVAC and other infrastructure. And, the risk of employees possibly being exposed to chemicals used in the process is significantly lower.

Sharing Ideas and Best Practices

I cannot speak positively enough about the benefits of collaboration—the sharing of ideas, practical advice and best practices within our own organization and through such formal industry and agency collaborations as the EPA's Climate Leaders and Green Supplier Network programs.

These programs serve as valuable clearinghouses for sharing of best practices, real-world experience and multiple perspectives that really set a strong foundation for continuous environmental improvement across companies and industries. Most importantly, they are helping to address some of the most difficult environmental challenges we face today, and extending the progress that large companies like Baxter have made further into the supply chain—to the smaller and medium sized companies that are our suppliers.

Last year, Baxter spearheaded the participation of the health care industry in a public/private initiative called the Green Suppliers Network. The objective is to integrate both Lean and Clean manufacturing principles into the operations of suppliers common to a particular industry. While large companies like Baxter are able to tap the expertise that resides within the organization to drive improvement in operations and reduce their environmental impact, the reality is that few small or medium size companies have that expertise available to them internally. Over the years, we had tried to share our own expertise with select suppliers through conferences, audits, and meetings, but recognized that the impact that we could have was limited while the opportunity for improvement was significant. We learned of the Green Suppliers Network and the impact it was having in other industries, like the automotive industry, and we were immediately attracted to the program. Our Purchasing and Environment, Health and Safety departments have worked to aggressively promote the program with suppliers. So far, seven Baxter suppliers have agreed to participate in the program, in which the U.S. Department of Commerce's Manufacturing Extension Partnership (MEP) and the U.S. EPA provide funds for technical professionals to train suppliers in Lean and Clean manufacturing processes.

For a small fee, a participating supplier receives access to manufacturing consultants experienced in process improvement and waste reduction, including a week-long review of the supplier's operations, help in administering relevant training and expertise, and a full report detailing areas for improvement and change. Experts from EPA's state pollution prevention technical programs also lend their support. This program brings expertise and insight to these companies that would normally not be considered or would be unaffordable.

The first of our seven suppliers to participate already has implemented a number of changes and yielded impressive results, significantly reducing energy consumption and therefore cost, and significantly reducing hazardous waste generation and emissions—savings that have far exceeded the initial fee and modest capital investments required. The environmental and economic benefits realized have motivated this supplier to continue with other initiatives. We look forward to similar successes with the other suppliers that are participating.

While we highly value external collaborations such as these, we also recognize that some of the best ideas can and do come from within our own company. We have created a number of ways to share and leverage those ideas and expertise that resides within our global organizations, including global energy engineering conferences, training sessions and awards.

We held our last biannual global energy engineering conference in September 2004 in Austin, Texas, with 60 Baxter energy managers representing 44 facilities from 21 different countries attended the week long conference. The conference included training sessions dedicated to maximizing the performance of plant utility systems and sharing information on best demonstrated energy practices. At every biannual conference, each manufacturing facility is asked to identify three specific energy projects that its energy management team will commit to implement during the next two-year period. At the next energy conference, the locations report the results of their three key projects to all conference attendees. This open sharing of both successful energy projects and unforeseen challenges has been beneficial in strengthening individual expertise and broadening institutional technical knowledge. As part of the conference, we also present awards to the engineers and facilities that achieve outstanding performance in such areas as:

- Largest percentage of energy cost saved per unit of production
- Largest percentage of energy usage saved per unit of production
- Energy project that has the widest application throughout Baxter
- Most innovative cost saving project implemented at Baxter
- Largest percentage of energy saved of total facility energy cost in a non-manufacturing facility
- Special recognition for outstanding contribution to Baxter's energy program.

Our next energy conference is scheduled for the fall of 2006, and I am very excited to hear updates from the facilities on the three projects that they each committed to in 2004.

While we have achieved reductions in greenhouse gas emissions and improvements in energy efficiency over the years, we recognize that much more needs to be done. We are a very global company, with more than half of our sales and two-thirds of our employees located outside the United States. Our 67 manufacturing facilities are located in 28 countries, and no matter where a facility is located, all are held to the same high level of EHS policies, standards and metrics.

We are a global company and we must remain globally competitive. Accordingly, we must closely monitor actions proposed or taken by other countries to address climate change, such as implementing regional or national carbon cap or trade systems. One of our manufacturing facilities in Ireland will be affected by phase one of the EU Emissions Trading Directive, which establishes a mandatory carbon cap-and-trade scheme. Climate taxes also are being implemented in some countries. We currently pay climate taxes on our electricity use in the United Kingdom. Here in the United States, 132 mayors from across the country recently announced that they would voluntarily adopt the Kyoto Protocol reduction target for their cities. In 2001, Baxter developed its formal position on climate change, which states that we believe, "The Kyoto agreement represents a first step in the international process, but more must be done, both to implement the market-based mechanisms that were adopted in principle in Kyoto and to more fully involve all countries in the solution."

Fortunately, because of our foresight on this issue, because of the significant experience we have gained over the years in reducing our greenhouse gas emissions and energy use, and the experience we have gained through participation in the Chicago Climate Exchange's voluntary program for capping and trading greenhouse gas emissions, we expect to be well-positioned to respond to these and other emerging cap-and-trade initiatives.

Our EHS policy clearly states that we are committed to continuous improvement in environmental, health and safety performance. We strive to conserve resources and minimize or eliminate adverse EHS effects and risks that may be associated with our products, services and operations. Because we self-manufacture nearly 90 percent of the products that we sell, and because we have in place talented environmental professionals in all of our major facilities, we are able to more closely monitor our environmental impact, and implement appropriate changes.

While we recognize that we are in the minority of companies that voluntarily have taken action on this issue, we are encouraged by the lessons that our own experience has taught us:

- that reasonable improvements in energy conservation and emissions reductions are possible without huge investment;
- that investments in new technology and improvements in manufacturing process can bring significant benefits in quality, optimal use of manufacturing assets, reduced raw material costs, and improved workplace safety as well as reduced energy requirements and associated greenhouse gas emissions; and
- that companies that have been forward-looking on this issue are in the best position to build upon the momentum they have created and better compete on a global basis.

In summary, we believe that it is possible to responsibly address environmental issues in a manner that provides economic benefit and competitive advantage. Our experience has proven to us that the business case is indeed there for taking action to reduce impact on our climate and environment by decreasing energy consumption and lowering greenhouse gas emissions.

Thank you for this opportunity to share with you some of our experiences and perspectives on climate change.

BIOGRAPHY FOR RONALD E. MEISSEN

Ron Meissen manages worldwide Environment, Health and Safety (EHS) resources for Baxter International Inc. In this position, Mr. Meissen is responsible for providing EHS services to regional and facility team members through the coordination of Baxter's safety, occupational health, industrial hygiene and environmental engineering professionals.

Mr. Meissen joined Baxter in 1975 as a project control engineer and progressed through a variety of positions in energy management and environmental engineering. He has been actively engaged in the company's environmental program and reporting and co-founded the company's EHS sustainability team. For the past 10 years, he has managed Baxter's greenhouse gas and climate change initiatives and represents the company in outside climate groups, including the Chicago Climate Exchange, the Pew Center on Global Climate Change and the U.S. Environmental Protection Agency Climate Leaders Program.

Mr. Meissen has Bachelor of Science degree in civil engineering from the University of Wisconsin–Platteville, a Master of Science degree in civil engineering from the University of Illinois, and a masters of business administration from Lake Forest Graduate School of Management. He is currently pursuing his Ph.D. in sustainable development at the University of Wisconsin–Madison, where he is working on his dissertation about the development of a strategic business model to reduce energy-related greenhouse gas emissions.

Chairman BOEHLERT. Thank you, Mr. Meissen.

Dr. Hobbs.

STATEMENT OF DR. ROBERT H. HOBBS, DIRECTOR OF OPERATIONS, UNITED TECHNOLOGIES RESEARCH CENTER, UNITED TECHNOLOGIES CORPORATION

Dr. HOBBS. Good morning, Mr. Chairman and Members of the Committee. I am Bob Hobbs, Director of Operations at the United Technology Research Center, the research and development arm of United Technologies Corporation. United Technologies, based in Hartford, Connecticut, is a diversified company that provides high technology products and services to the aerospace and commercial building industries worldwide. UTC's products include Otis elevators and escalators, Carrier air conditioning systems, UTC Fire & Security products and services, UTC Power fuel cells, Pratt & Whitney aircraft engines and space propulsion systems, Hamilton Sundstrand aerospace systems, and Sikorsky helicopters.

UTC is a $38 billion company, the 39th largest in the United States. Our shareholder return since 1992 is more than three times that of either the S&P 500 index or the Dow 30 Industrials. UTC is proud of its record of providing shareholder value within the confines of very good corporate citizenship.

UTC is pursuing its climate change goals directly by reducing greenhouse gas emissions produced by UTC operations and indirectly by developing and manufacturing products that use less energy and emit smaller amounts of greenhouse gases.

In 1997, UTC resolved to reduce its global energy consumption by 25 percent by 2007. We exceeded that target halfway through the 10-year period and so increased the goal to a 40 percent reduction, which we met last year, two years early. Since joining the Environmental Protection Agency Climate Leaders in 2001, we have reduced our greenhouse gas emissions by 74,000 metric tons as a result of our energy efficiency goals. In roughly the same time period, our revenues increased by $9.5 billion, demonstrating that environmental quality and economic growth can indeed go hand-in-hand. UTC's environmental performance and achievements recently earned us one of the EPA's 2005 Climate Protection Awards.

Why is UTC taking a leadership role to address climate change?

The short answer is that our own corporate policy demands it. UTC's environmental health and safety policy requires that we "conserve natural resources in the design, manufacture, and disposal of products and delivery of service."

To quote our Chairman, George David, "We don't choose between responsibility and profitability. We pursue both with discipline and focus." Our vision of corporate responsibility and global sustainability places environmental performance right alongside financial results. We believe that setting goals for reduced energy consumption, which translates into lower greenhouse gas emissions, has already improved our bottom line performance by reducing production costs and allowing us to be more competitive.

Environmental leadership doesn't merely enhance our corporate reputation, it offers our customers world-class quality and products while increasing efficiency and reducing waste, making them better stewards of the environment as well.

By creating products that use less energy and help lower greenhouse gases that contribute to climate change, we can differentiate our products in an increasingly environmentally-conscious global marketplace.

UTC has an expansive and diverse portfolio of energy-efficient and environmentally-friendly products, but let me talk briefly about one.

UTC Power has developed the industry's first integrated micro-turbine and double-effect absorption chiller system, the PureComfort 240M. The system converts more than 80 percent of its fuel input to efficient electric cooling and heating output. I started to say 90, because we see 90 percent fuel efficiency in our laboratories. They quote 80 in their literature. We expect it to reduce carbon dioxide emissions by 40 percent and nitrogen oxide emissions by 90 percent over those of the average central fossil fuel generation plant. In May, the A&P grocery chain installed a PureComfort 240M in its Mount Kisco, New York store, citing the technology as one of the company's commitments to "make more efficient use of energy and to protect the environment by minimizing emissions."

New corporate climate policies have proven to be complementary to good business policies, allowing UTC to understand, manage, track, and minimize our greenhouse gas emissions and energy use while simultaneously adding business value.

Thank you, Mr. Chairman, for giving us the opportunity today to share with you and members of the Committee some of the specifics of our commitment to reducing greenhouse gases throughout our operation and across all our product lines. If you would like further information regarding our environmental success story, we have copies of the UTC 2004 corporate responsibility report available here or on our website.

[The prepared statement of Dr. Hobbs follows:]

PREPARED STATEMENT OF ROBERT H. HOBBS

Good morning, Mr. Chairman and Members of the Committee. I am Bob Hobbs, Director of Operations at the United Technologies Research Center, the research and development arm of United Technologies Corporation (UTC). United Technologies, based in Hartford, Connecticut, is a diversified company that provides high technology products and services to the aerospace and commercial building industries worldwide. UTC's products include Otis elevators, escalators and people movers; Carrier heating and air conditioning systems; UTC Fire & Security fire safety and security products and services; UTC Power fuel cells; Pratt & Whitney aircraft engines; Hamilton Sundstrand aerospace systems; and Sikorsky helicopters.

UTC & Corporate Responsibility

UTC is a $38 billion company, the 39th largest in the United States. Our total shareholder return since 1992 is close to 1000 percent and is more than three times that of either the S&P 500 index or the Dow 30 Industrials. UTC is proud of its record of solid corporate citizenship. We've been included in the Dow Jones Sustainability World Indexes since it began in 1999 and have been rated AAA by Innovest Strategic Value Advisors. We were also named one of the world's 100 most sustainable companies at this year's World Economic Forum in Davos by Corporate Knights and were the only aerospace company included. UTC's success is rooted in clarity of organization and total alignment among management about what we want to accomplish. For UTC, that is shareholder value within the confines of very good corporate citizenship. We don't choose between one or the other, we pursue both with discipline and focus.

Shareholder value comes in part from research and development. UTC spends approximately $2.8 billion annually, 90 percent of that in the United States, to develop tomorrow's technologies. United Technologies Research Center (UTRC) works with each UTC business to make certain their products and services are the most innovative and technologically advanced in the world. UTRC is an incubator for UTC products, researching energy and environmental innovations to assist UTC in developing, and then building, new products for the next generation. Whether its research on hydrogen production and storage technologies, inventing ways to heat and cool more efficiently or improving jet engine design and efficiency, UTRC provides valuable technical experience to further UTC's pursuit of better environmental quality in its products.

UTC Voluntary Commitment

UTC is constantly working to reduce the environmental footprint of our worldwide facilities and operations. We are accomplishing this objective directly by reducing greenhouse gas emissions produced by UTC operations and indirectly by developing and manufacturing products that use less energy and emit smaller amounts of greenhouse gases. We are driving pollutants in the manufacturing process down to their lowest achievable levels and reducing our energy consumption so less pollution is produced in the satisfaction of our energy needs. UTC quantifies environmental goals, measures progress and reports that progress to our Board of Directors, employees and community.

In 1997, UTC resolved to reduce its global energy consumption by 25 percent (normalized for revenues) from 1997 levels by 2007. Once we exceeded that target, we increased the goal to a 40 percent reduction in our energy use worldwide, and we are already meeting that ambitious goal. Even as we revised the goal upward, we kept the timetable firm and still achieved the enhanced goal two years ahead of schedule. Since joining the Environmental Protection Agency (EPA) Climate Leaders in 2001, we have reduced our greenhouse gas emissions by 74,000 metric tons as a result of our energy efficiency goals. In roughly the same time period, our revenues increased by $9.5 billion, demonstrating that environmental quality and economic growth can indeed go hand-in-hand. UTC's environmental performance and achievements recently earned us one of the EPA's 2005 Climate Protection Awards.

Key Drivers in Reducing Greenhouse Gases

Why is UTC taking a leadership role to address climate change? The short answer is that our own corporate policy demands it. UTC's environmental, health and safety policy requires that we "conserve natural resources in the design, manufacture, use and disposal of products and delivery of service." We take this directive extremely seriously and have established internal environmental standards that both comply with the law and go beyond it when necessary to achieve the goals of this policy. We don't choose between responsibility and profitability; our corporate responsibility places environmental performance right alongside financial results.

We would not be where we are today if not for strong commitment of our Chairman, George David, senior managers and front-line employees in each of our business units. In a speech given in 1998 at the Earth Technologies Forum, Mr. David explained his personal motivation in committing the corporation to address the climate change issue by stating: "I have children and prospectively grandchildren and great grandchildren whose lives and livelihoods concern me." Mr. David again stressed UTC's commitment to sustainability in a 2003 speech to the Society for Organizational Learning in East Hartford, Connecticut. He defined UTC's approach to sustainability within the context of five general themes: energy efficiency of our products and service; environment, health and safety impacts in our own operations; productivity in its conventional sense (doing more with less); opportunities for employees to develop themselves; and legal compliance and high ethical standards.

Through close coordination among the operating businesses and corporate headquarters, UTC has brought together a tight network of experts to gather and analyze energy consumption data; provide technical assistance; develop benchmarks; and share best practices across the corporation. We have developed internal guidelines for use across the units in common energy applications such as lighting and compressed air. In addition to our energy efficiency goals, we are also on track to achieve a 60 percent reduction in air pollutants and non-recycled waste and a 40 percent reduction in water consumption by 2007 (all normalized for revenue). We've been able to achieve such dramatic progress due in part to our "Achieving Competitive Excellence" (ACE) program. ACE is the internal UTC discipline intended to simplify procedures, raise efficiency and ensure world-class quality in products and processes while supporting our environmental commitments. "Continuous improvement" in our operations is the key element of ACE.

Climate change is a growing dynamic in the global marketplace. We believe that setting goals for reduced energy consumption, which translates into lower greenhouse gas emissions, has already improved our bottom line performance by reducing production costs and allowing us to be more competitive. Lower energy costs and improvements in manufacturing processes are leaving us with more resources to devote to developing new and innovative products that address climate change and other environmental and energy problems. We are also keeping ahead of the curve on potential future climate change regulations by investing in greenhouse gas reductions now. We hope and trust that policy-makers will recognize these early commitments to the climate change solution.

Energy Efficiency, Greenhouse Gases and UTC Products

Genuine corporate responsibility requires that we make environmental considerations priorities in new product development and investment decisions. Environmental leadership doesn't merely enhance our corporate reputation; it offers our customers world-class quality in products while increasing efficiency and reducing waste—making them better stewards of the environment as well. UTC continuously explores ways to increase efficiency and reduce greenhouse gas emissions through the products it develops.

By creating products that use less energy and help lower greenhouse gases that contribute to climate change, we can differentiate our products in an increasingly environmentally conscious global marketplace. Because the energy savings from the use of our products present our greatest contribution to the reduction of greenhouse gases, I'd like to give you a snapshot of UTC's expansive and diverse portfolio of energy-efficient and environmentally friendly products.

UTC Power/Fuel Cells

Our UTC Power division is a full-service provider of clean power solutions and is the leading developer and producer of fuel cells for on-site power, transportation and space applications. UTC Fuel Cells (UTCFC) is a business unit of UTC Power and manufactures the PureCell™ 200 power system, which provides 200 kilowatts of electricity and up to 925,000 btu/hr of heat for combined heat and power applications. Each PureCell™ 200 avoids the production of 1,100 tons of carbon dioxide emissions annually, which is why UTC Power earned one of the EPA's Climate Protection Awards in 2000. Last month, the PureCell™ 200 fuel cell fleet achieved a major milestone, providing one billion kilowatt hours of energy production, or enough to power 91,000 homes for a year. We've already deployed a total of 275 units world wide, including 26 in New York to date, avoiding 102 million pounds of carbon dioxide emissions in the Chairman's home state alone.

In addition to its demonstrated environmental and energy efficiency accomplishments, the PureCell™ 200 is earning a reputation for reliability as well. A UTC Power fuel cell kept the Central Park police station operating during New York City's famous power outage in 2003, and just last month, Russia's leading oil and gas pipeline engineering company, Orgenergogaz, was able to keep operating during a blackout in southern Moscow because of the PureCell™ 200. We're keeping lights on from New York to Moscow and will expand our reach in 2007 when UTC Power plans to introduce an enhanced version of the PureCell™ 200 with twice the life span of its existing product.

UTC Power has also developed the industry's first integrated microturbine and double-effect absorption chiller system, the PureComfort™ 240M. The system converts more than 80 percent of its fuel input to efficient electric, cooling and heating output. We expect it to reduce carbon dioxide emissions by 40 percent and nitrogen oxide emissions by 90 percent over those of the average central fossil fuel generation plant. This is equal to the benefits of planting 150 acres of trees and taking 250 cars off the road, respectively, during the same time period. In May, the A&P grocery chain, which operates 650 stores in 10 states, installed a PureComfort™ 240M system in its Mount Kisco, NY store, citing the technology as one of the company's commitments to "make more efficient use of energy and to protect the environment by minimizing emissions."

Waste heat represents an untapped energy resource. According to the U.S. Department of Energy's May 2003 Thermally Activated Technologies Roadmap, total energy loss in the form of waste heat in the United States is equal to the amount of energy annually consumed by the U.S. transportation sector or by the entire Japanese economy. UTC Power, in partnership with Carrier Corporation, another UTC business unit, developed the PureCycle™ 200 power system to turn waste heat into electricity, providing a zero-emission alternative to traditional power sources. In addition to the environmental benefits, the PureCycle™ 200 offers high reliability, low maintenance and cost savings through the reduced fuel use.

In addition to its portfolio of climate-friendly on-site power solutions, UTCFC is also developing zero emission, energy efficient fuel cells for transportation applications with environmental and energy security benefits. We've deployed zero emission fuel cell buses in Washington, DC, California, Madrid and Turin. Last year, AC Transit logged over 8,000 miles operating a Thor 30' hydrogen fuel cell, hybrid-electric bus developed by ISE Corporation and UTC Fuel Cells. This bus was deployed in the Oakland, California area and achieved double the fuel economy of a 30-foot diesel bus. This year, we are delivering power plants for four fuel cell buses that will be operated in California by AC Transit and SunLine Transit.

UTCFC is currently working with major automobile manufacturers, including Nissan, Hyundai-KIA and BMW, and the U.S. Department of Energy (DOE) on development and demonstration programs for automobiles. We are teamed with Chevron and Hyundai-KIA as part of DOE's Hydrogen Learning Demonstration Program and will be deploying a fleet of 32 zero-emission Hyundai-KIA Tucson sport utility vehicles and Sportage cars as part of the initiative.

Carrier

Carrier Corporation is the world's leading manufacturer of heating, ventilating, refrigerating, and air conditioning systems and products. Carrier is at the forefront of its industry, developing systems with ever-more environmentally sound refrigerants and dramatically reducing the power requirements of their products. From the smallest window air conditioning units to the largest centrifugal chillers, Carrier heating and cooling equipment is distinguished by some of the highest energy efficiency ratings in the industry. Carrier participates in the EPA's Energy Star program to provide energy efficient products to residents and businesses. Carrier supports the goals of the Montreal Protocol to phase out use of certain substances that deplete the ozone layer, and in 1994, pioneered the worldwide phase-out of CFCs. Carrier is also helping lead a revolution in the way the air conditioning industry handles chlorine-containing refrigerants and is the only air conditioning manufacturer that provides chlorine-free refrigerants across its entire product line.

Not a company to rest on its laurels, Carrier is a leading advocate for a national energy policy with a strong commitment to conservation and efficiency improvement, including a consensus energy efficiency standard agreement for commercial packaged air conditioning products, refrigerants and freezers. Carrier was instrumental in moving the industry to a 13 SEER [Seasonal Energy Efficiency Ratio] standard, meaning that Carrier residential air conditioning systems shipped in the United States after January 2006 will be on average 30 percent more efficient than today's standard.

Pratt & Whitney

Pratt & Whitney is a world leader in the design, manufacture and support of aircraft engines, gas turbines and space propulsion systems. Through the development of better heat resistant coatings, more environmentally friendly processes, innovative servicing procedures, more efficient turbine blades and quieter, more fuel efficient engines, Pratt & Whitney has pioneered most major advances in both military and commercial aviation. And, the company's new Specialty Materials & Services business is redefining entire industries by applying environmental technologies in unique ways. For example, ElectroCore™ is a new, advanced power plant emissions control system under development that will control a variety of pollutants from coal-, wood- and other solid fuel-fired boilers, ushering in a new way to control multiple pollutants in power plants and manufacturing facilities.

Otis

Another UTC division, Otis, the world largest manufacturer of elevators, escalators and moving walkways, reexamined every aspect of the elevator—from design and installation to operation and maintenance—and created the Gen2 system that is up to 50 percent more efficient than conventional elevators. Innovative new regenerative technologies will reduce the net power requirements of new Otis elevators installed worldwide even further.

Forming Partnerships

UTC regularly forms partnerships with others to encourage greenhouse gas reductions and meet energy efficiency goals. As an EPA Climate Leaders partner, UTC pledged to reduce global greenhouse gas emissions by 16 percent per dollar of revenue from 2001 to 2007. As an EPA Energy Star member, we are helping Americans to save energy and avoid greenhouse gas emissions by providing energy efficient products in residential and commercial settings. UTC is a founding member of the Pew Center's Business Environmental Leadership Council, a group of companies committed to responding to climate change challenges, and the U.S. Green Building Council, a coalition of companies promoting the use of green building practices.

Earlier this year, Global Green USA awarded UTC the "Corporate Design Award" for our Sustainable Cities environmental grant and volunteer effort to advance environmentally responsible building systems in urban areas. UTC Power joined with the EPA as part of CHP Partners, a public-private partnership committed to providing clean, efficient power and thermal energy and reducing pollutants and greenhouse gases. On the state level, UTC is active with the Regional Greenhouse Gas Initiative, a multi-state effort to reduce carbon dioxide emissions, and Governor Rell's Connecticut Climate Change initiative.

UTC also frequently partners with suppliers to help them reach our standards. For example, Hamilton Sundstrand provides training for its suppliers to help them attain UTC environmental levels. And, Pratt & Whitney is a corporate sponsor of EPA's Strategic Goals Program under which large companies share with suppliers their best practices in environmental management systems, pollution prevention and waste minimization.

Conclusion

Good corporate climate policies have proven to be complementary to good business policies, allowing UTC to understand, manage, track and minimize our greenhouse gas emissions and energy use while simultaneously adding business value. Thank you, Mr. Chairman, for giving us the opportunity today to share with you and the Members of the Committee some of the specifics of our commitment to reducing greenhouse gases throughout our operations and across all our product lines. If you'd like further information regarding our environmental success story, we have copies of the UTC 2004 Corporate Responsibility Report available here and on our website at www.utc.com.

Biography for Robert H. Hobbs

Experience

United Technologies Research Center—1971–present

1997–	Director of Research Operations
1996–1997	Director, Chemical Science and Fluid Mechanics Dept.
1995–1996	Director, Mechatronics Dept.
1994–1995	Manager, Collaboration Technology
1994–1994	Manager, Network Technology
1978–1994	Senior Theoretical Physicist
1971–1978	Research Scientist

Applied theoretical modeling in the areas of: dynamical systems, quantum chemistry, acoustics, fiber-optics, electro-optics, lasers, semiconductors and diverse physical and chemical systems ranging from atoms and molecules to elevators and jet engines; and program management.

MIT DSR—Physics Instructor—1971

MIT Center for Theoretical Physics—Research Assistant—1968–1970

Johns Hopkins Univ. Applied Physics Laboratory—Summer 1963–1965

Research Analysis Corporation—Group Leader—Summer 1960–1962

Johns Hopkins Univ. Operations Research Office—Summer 1959

Educational Background

Massachusetts Institute of Technology, Ph.D. Theoretical Physics—1971

Massachusetts Institute of Technology, S.B. Physics—1964

Publications/Patents

38 papers, 1 issued patent

Hobby

Yacht Racing Administration—1968–present including:

- United States Junior Olympic Committee—1992–1996
- United States Sailing Association (National Governing Body of sailing in U.S.)
  - President, United States Sailing Foundation—2004–2000
  - Chairman, Olympic Sailing Committee—1996–2000
  - President—1991–1993, Vice President—1985–1991, Board of Directors—1979–1993
- Intercollegiate Yacht Racing Assoc. of NA (NGB of collegiate sailing in U.S.)
  - CEO—1979–1988

DISCUSSION

Chairman BOEHLERT. Thank you very much, Dr. Hobbs.

And Mr. Meissen, thank you for commending our leadership. Let me say to you, to all of you, we want to commend your leadership. It is music to our ears up here to hear from leading figures in the "real world" outside Washington, DC and the responsible manner in which you are dealing with this very important subject.

Let me ask you. When you are out leading the parade, you are also a target. What has been the reaction that you have had from your business colleagues? And are you winning any converts, or is it not in your enlightened self-interest to try to convert the unconverted?

Mr. Rogers, let me ask you.

Mr. ROGERS. Mr. Chairman, I served as a Chairman of the Environmental Policy Committee for our industry association EEI for four or five years, and what I have seen in our industry is a movement toward dealing with these issues in a straightforward manner. They are all in a little different place. Some of our companies have nuclear primarily, and it is easy for them to think about this issue and deal with it. Some like ourselves are predominantly coal. It is a different—we start in a different point. But if I look at the climate programs that existed during the 1990s in terms of greenhouse gas reductions, I look at what has happened over the last five or six years, our industry is really starting to step up and deal with this issue in a very responsible way. And I am proud to be part of an industry, and one that has such a direct impact on so many, because who doesn't use electricity. And I see people increasingly look at this issue in our industry, and I think that is a good thing.

Chairman BOEHLERT. Thank you for that. Thank you for your leadership. I hope that there is some followership.

Dr. McFarland.

Dr. MCFARLAND. Yes, I agree that there is an increasing trend of industries stepping forward to deal with this issue in a prudent manner and take action. You see this initially with global companies that are having to operate in a carbon-constrained world in other regions. About half of our business and 40 percent of our operations are outside the United States, and we are operating in carbon-constrained regimes. And there are other global companies that are having to do the same. So it is—you know, as I said, it is a social, economic, and environmental reality for many companies.

Chairman BOEHLERT. Mr. Meissen.

Mr. MEISSEN. I do agree with you. Some people struggle with this concept of climate change. It is happening in distant places. It is going to happen in the future. But at Baxter, we focus on improving efficiencies, environmental stewardship. We put it in terms of being more efficient, effective, cost-effective. It makes us more competitive. And that is—by focusing on our energy management program, which is—most of our energy greenhouse gas emissions are associated with that. By driving on that, pushing on that, we are able to also reduce greenhouse gas emissions.

Chairman BOEHLERT. Dr. Hobbs.

Dr. HOBBS. Mr. Chairman, I believe our Chairman, George David, has been both visible and vocal on the issues of environmental protection and sustainability globally. I am very proud of the stand he has taken in these issues. UTC also partners with others, including EPA Climate Leaders, Pew Climate Center, and closer to home, the Connecticut Climate Change Group. So we are working with our other industry people to try to both understand and share practices.

Chairman BOEHLERT. Well, you know, there are some doubters out there. We are still doing our leveled best to try to convince the doubters that they shouldn't be so skeptical.

But Mr. Rogers, in your testimony, you had some interesting commentary, and I would like you to repeat it a little bit and ask the others to comment. Suppose we are wrong. What is the worst case if we are wrong?

Mr. ROGERS. If we are wrong, what it means is we have developed technologies that are more environmentally-friendly. What is wrong with that?

Chairman BOEHLERT. That is exactly right.

Mr. ROGERS. And we help our customers. Particularly if you are a power supplier, you help your customers use energy more wisely. What is wrong with that? And as I see it, we are moving directionally. I see it with SO_X, NO_X, mercury, and I see it with carbon. We are moving more and more to almost, not quite, because I don't think the cost-benefit test can be met, but we are moving in a direction of minimizing our emissions from all operations across this country. I think that that is a standard that we are moving on around the world. Now there is a place where it doesn't make sense to reduce further, but the reality is I think most global companies, both companies that are looking at what is going on around the world and are looking at the science are saying, "We need to deal with this issue. We need to be responsible about this issue."

And I remember, Mr. Chairman, a senior partner of mine when I practiced law here in Washington, Bob Strauss. And Strauss used to say, "When you see a parade form on an issue in Washington, you have two choices: you can throw your body in front of it and let them walk over you, or you can jump in front of the parade and pretend it is yours."

Chairman BOEHLERT. Very fortunately, he is still providing leadership in a whole wide range of areas to this day.

Dr. McFarland, do you have a comment?

Dr. MCFARLAND. Yes, I agree entirely that this makes sense anyway from a wide range—for a wide range of issues. With global economic growth, we must learn to use our resources, natural resources, more effectively. Saving energy makes sense, economic sense, especially when you see rising energy prices, energy security issues. So even if we are wrong about climate change, which I believe that we are not, and our company believes we are not, then the actions that we have taken make sense.

Chairman BOEHLERT. Well, as you pointed out in your testimony, the scientific case continues to be strengthened every day.

Dr. MCFARLAND. Yes.

Chairman BOEHLERT. The scientific consensus is clearly there. You understand it. You have outlined to us the benefits to your individual companies and to society. I love Mr. Rogers, and I wish he would speak some time, but we won't have him do it now, his grandkids theory. We were discussing that yesterday. And the test that he applies in many of his decisions: "How is this going to impact on my grandkids?" Very important.

Mr. Meissen.

Mr. MEISSEN. Well, I don't see a downside. I only see an upside. I see an upside to becoming more energy efficient, more—reducing costs, becoming more competitive. I see an upside working with our many suppliers, and by working with them on the Lean and Clean principles that I mentioned, they also become more competitive. And also, which is very important for Baxter and other companies that have many suppliers, they are more reliable. And they are going to be in business longer and be there to deliver the products and services that they provide our company. And I also think that there is no downside, just an upside in acting responsibly for the company. And I believe our customers, shareholders, stakeholders expect us to do that.

Chairman BOEHLERT. Thank you very much.

And Dr. Hobbs?

Dr. HOBBS. Taking the actions that we have at UTC are not only protecting the environment, but they are saving us money and making us more effective in creating better products for us, so all of that is good. Furthermore, I hope that we don't have to have the trash pile up in front of our house before we realize that we should produce less waste. That is really all we are talking about.

Chairman BOEHLERT. So it is a win-win situation.

Dr. HOBBS. Absolutely.

Chairman BOEHLERT. Thank you all very much.

My time has expired.

Mr. Gordon.

Mr. GORDON. Thank you, Mr. Chairman.

So oftentimes, we have a bad news panel. This is nice to have a good news panel today. Dr. McFarland, I think you hit a good note when you reminded all of us that we should not penalize early movers. That needs to be echoed so that as this process goes forward that we reward and not penalize.

And Mr. Rogers, you were very impressive in laying out the logic of your case.

But what I would like to do is turn to the international folks here first.

As we all know, the Kyoto protocol has been ratified by the requisite number of countries. What I would like to better understand is what you are going to be required to do internationally that you are not going to be doing here, what is the cost of that in terms of competitiveness, and what would be necessary to get you to the Kyoto levels. So I will—maybe we will just do it in reverse order here.

Dr. HOBBS. Mr. Gordon, UTC is a global company. We make more of our revenue outside the United States than inside the United States, or at least have more employees outside the United States. We have been taking our environmental actions globally right from the beginning. The kinds of energy reductions and——

Mr. GORDON. But if I could——

Dr. HOBBS. I didn't talk about, like, air emission reductions.

Mr. GORDON. Well, excuse me. I don't mean to be discourteous, but we have got a limited time here. More specifically, what are you going to be doing internationally—what are you going to be required to do internationally that you are not going to be doing here and how is that——

Dr. HOBBS. Well, what I was about to say is that we are not going to do anything internationally, because we are already—we believe we are already doing it.

Mr. GORDON. And are you doing the same——

Dr. HOBBS. We are doing the same thing in the United States.

Mr. GORDON.—domestically? So it has no impact.

Dr. HOBBS. I believe that is the case.

Mr. GORDON. Thank you.

And what about DuPont?

Dr. MCFARLAND. I think it is the same case for DuPont. We view this as a global issue. We are taking actions. We do have plants in Europe, for example, that are under the cap and trade, but the energy efficiency put us in—well positioned right now. The question is going forward. But to date, it—there is no——

Mr. GORDON. So you think domestically you will be meeting the Kyoto standards?

Dr. MCFARLAND. We reset our goals and we looked at energy efficiency improvements. It is being done globally.

Mr. GORDON. But do you expect that here, domestically, you will reach the Kyoto standards?

Dr. MCFARLAND. Yes.

Mr. GORDON. Okay. And what about Baxter? I am not trying to criticize. I am just trying to better understand here.

Mr. MEISSEN. We are working to reduce our greenhouse gas emissions. To meet the Kyoto standard may require some additional efforts than we currently have. We have been preparing for a carbon cap and——

Mr. GORDON. Okay. When you say that, do you mean internationally or domestically?

Mr. MEISSEN. Both.

Mr. GORDON. Okay.

Mr. MEISSEN. Both. We are in—we realize that the cap-and-trade schemes are emerging around the world, and it is taking place in Europe. And in anticipating that, we became a founding member of the Chicago Climate Exchange, which is a carbon cap and trade organization in Chicago, which I might talk about later, but—as a member company. And there, we are gaining experience in trading. We are gaining experience in making our greenhouse gas emissions database more robust. And we are gaining institutional knowledge in how that operates so that we can better respond to these cap and trade systems as they emerge.

Mr. GORDON. So do you expect to meet the international Kyoto standards?

Mr. MEISSEN. We expect to meet the emissions limits for those facilities that are affected.

Mr. GORDON. Internationally?

Mr. MEISSEN. Right.

Mr. GORDON. Indeed. What more will be needed here in this country for you to accomplish that?

Mr. MEISSEN. I believe that as we go forward into the future, we are going to be adopting more state-of-the-art technologies, more efficient utility systems. We are going to——

Mr. GORDON. Well, is it the cost? I mean, are you concerned about losing a competitive advantage to do that?

Mr. MEISSEN. No. I—we are taking—our approach is a global approach, just like these other gentlemen. And we—by driving down—we are seeing the benefits of being more efficient in seeing and realizing those benefits, it is spurring us on to achieve more.

Mr. GORDON. Mr. Rogers wrote—go ahead, sir.

Mr. ROGERS. Congressman, let me caution a little bit on Kyoto, if I may.

Mr. GORDON. I am not trying to—I am not either advocating or——

Mr. ROGERS. No.

Mr. GORDON. I just want to know where we are to get a benchmark.

Mr. ROGERS. But let me kind of make an important point, if I may.

If you look at—Kyoto goes back to 1990 levels.

Mr. GORDON. Right.

Mr. ROGERS. I think it is impossible, particularly for the power industry, to go back to 1990 levels, given how much our economy has grown over the last 15 years. If you put a stake in the ground around 2000, it is a more prudent approach, given where we are today across this country in the growth of the demand for electricity. As I think about going forward, the prudent way forward is to think more about slowing down the rate of emissions and then starting to reduce the emissions level. And that is a strategy that matches up with concerns by environmentalists who talk about the carbon debt, and also matches up extremely well with a—from a cost-benefit standpoint.

And finally, I would suggest that Kyoto is such a politically-charged word. We are much better off, as we think about reducing carbon going forward, to come up with a son or daughter of Kyoto rather than that.

Mr. GORDON. Well, let me ask you this. There are other countries that have adopted Ktoto. I mean, they may game it or not. But what is going to happen to those power companies in the other countries? Are they to go back to 1990? I know that, as you pointed out, they probably have more of a nuclear base that might make it easier, but are they going to make the 1990 baseline or are they just going to game it or give up or what is going to happen?

Mr. ROGERS. I had the opportunity yesterday to have lunch with Prime Minister Blair, and we talked about the United Kingdom. The United Kingdom is an interesting situation, because they are meeting their targets and why are they meeting their targets in the generation? Because they had a lot of coal. What has happened is, starting in the 1990s, and really with Thatcher, what they have done is shut down their coal plants and really converted to gas fire generation in a large movement. That has been responsible for a lot of their change. They have been able to take natural gas out of the North Sea, bring it into the United Kingdom, and use it. If you go to a country like France, they already have 75 to 80 percent of their generation in nuclear, so no problem. The countries who will have the difficulty will be Germany. Germany is—there the government has cut a deal with the Green Party to effectively shut down nuclear by 2025. I don't see how they are able to hit a Kyoto target in 2012 if they are facing a shut down of nuclear units in subsequent years.

The following point on this is it is not clear yet if they will hit the Kyoto targets, which are really 2012 targets, and are other countries. Some of the countries have got a head start, and the United Kingdom would be an example of that because of the conversion from coal to gas that happened in the 1990s.

Mr. GORDON. So what does that mean for our competitive position?

Mr. ROGERS. The troubling competitive issue is if they start to try to say that U.S. companies are subsidized because they are not——

Mr. GORDON. You inferred a trade problem. So are you foreseeing that there could be, again, whatever trade allegations brought against us and penalties on the international scale?

Mr. ROGERS. I could see the EU and countries and companies in the EU starting to use that as an argument that U.S. countries are subsidized because they don't have to comply with Kyoto, as a consequence, their products are cheaper. I think that is a possibility. We haven't seen that yet, but I think that is a possibility.

Mr. GORDON. I wish we could talk more, but my time is up.

Chairman BOEHLERT. Dr. McFarland, did you want to respond to Mr. Gordon? Okay. Fine.

Mr. Bonner.

Mr. BONNER. Thank you, Mr. Chairman.

Many people back in our Districts have—who have seen corporations move overseas in a global economy have asked questions of us over the years what are we doing to stop these job losses. You have got companies that go to India or China or places in Europe or Central or South America, and the belief is that they don't have the same minimum wage standards that we have. They don't have the same environmental protection laws that we have. For those of you who have companies in or plants in other countries, how do our environmental laws and what we are doing compare with the plant operations that you have got in China, or in India, or in Europe, or in other parts of the world? Are we putting our U.S. companies at a disadvantage in terms of being able to stay on the continent and provide jobs to American workers? It is an open question.

Dr. MCFARLAND. You know, I would be happy to provide more information, because this is somewhat outside my area of expertise. But speaking for DuPont strictly, we have one environmental standard around the world. And wherever we put a plant, it is the same standard. So you know, that is not an issue for us.

Dr. HOBBS. For UTC, it is much the same. Our—we endeavor to hold everyone that works for UTC to the same standards of environmental performance, and by the way, the same ethical performance. And we provide things like education evenly all over the globe. We don't set wage standards in all of the places that we have factories, but to the extent that we are using our rules, we have global standards.

Mr. BONNER. And let me just add to Dr. McFarland since he has the plant in my District, we are grateful for the jobs that DuPont provides in south Alabama and consider you all very good, outstanding corporate citizens.

Mr. Rogers, I would like to go to a question that comes from one of the comments you made earlier in your statement, and that is that states are not—and I want to get your quote right, increasingly taking on added roles in their monitoring and regulation on greenhouse emissions. In your judgment, since there are 50 states and obviously 50 different standards, is that an added hardship or is that something that your company welcomes in terms of the added emphasis that state governments are applying?

Mr. ROGERS. I think it is an additional hardship from the standpoint—I mean, you create this patchwork of different regulations in different states, and it—one of the—from a national policy standpoint, we ought to have environmental policies that apply across all of our country in every state, and we—and it should be a national policy, not state. I think it would make it very difficult for companies to operate in this country, particularly in the power industry. If you have one rule in Alabama, you have got another rule in Georgia, another rule in the Carolinas. The question is how—what does that mean when power flows between states. And so to have the states weighing in with specific rules that are different than the EPA, I believe, would be a problem.

Mr. BONNER. Thank you, Mr. Chairman.

Chairman BOEHLERT. Thank you very much.

Mr. Carnahan.

Mr. CARNAHAN. Thank you, Mr. Chairman.

I want to compliment all of the panel on the work that you are doing —your leadership in this important environmental area.

I wanted to get some additional comment from each of you quickly, because I guess, Dr. McFarland, you had expressed concern about being put at a competitive disadvantage, and Mr. Meissen had indicated that he believed they were actually achieving some competitive advantage from some of the activities and developments. And I wanted to see if there is really a difference of opinion here or get your additional comment about that.

Dr. MCFARLAND. I don't see a difference of opinion on that. What we are—you know, what Mr. Meissen is talking about is in the current climate. And we, too, are saving money by our energy efficiency goals. However, if some sort of regime is set up where you are set to a standard that is based on historical performance, then the companies that have moved early have already picked their low-hanging fruit. They have done the things that they can do most economically. So if it is set on a prior performance standard, those that have moved are going to have to spend more to meet a reduction target, given reduction target, as compared to those who have not taken action.

So the difference is Mr. Meissen is talking about in the current climate. And we, too, have saved money in the current climate, but we are talking about in a regulatory, carbon-constrained regime where you are set to a standard that is based on some prior performance.

Chairman BOEHLERT. Just let me interrupt here, and I will not take this out of your time.

I want to point out that you should be credited and not penalized for your early, positive, constructive action, and that is our objective.

The gentleman is——

Mr. CARNAHAN. Thank you, Mr. Chairman.

Mr. Meissen, did you have any additional comment?

Mr. MEISSEN. Okay. Thanks a lot.

I think many companies expect that they would be credited for the initial activities that they have done. Their participation in the voluntary programs, such as U.S. EPA Climate Leaders program, the different registries in different states. I do believe that it is a challenge to have different regulations in different states, and a uniform framework and a uniform time frame, I think, will be beneficial for companies. They would provide companies flexibility in planning, especially capital planning cycles, which are multi-year cycles, and if there is a requirement to invest in maybe expensive core generation systems, it has great savings also, then they can work that into their strategic planning cycle and capital cycle.

Mr. CARNAHAN. I guess I want to also close with a quick question to get your opinion about what you believe would be some of the best things we could do from the public policy perspective to incentivize and encourage companies to continue with some of these cutting-edge actions. Really, any of the panel.

Dr. MCFARLAND. Well, it—to provide some assurance, regulatory assurance, that those who have—are taking forward—or are stepping forward with action are credited for those actions going forward.

Mr. ROGERS. I think another thing that the Committee could do is continue to take a holistic review of the R&D programs the government now funds and look at ways to jump-start some of these programs and where the focus is on the D part of the programs and also more toward the deployment and not just the development. And I think that would be a movement in the right direction.

Mr. CARNAHAN. Thank you, Mr. Chairman.

Chairman BOEHLERT. The Committee is proud of the leadership provided in advancing clean coal technology, and I would imagine, Mr. Rogers, you would be a cheerleader in that arena.

Mr. ROGERS. Yes, sir.

Chairman BOEHLERT. Thank you very much.

The distinguished Vice Chairman of the Committee, Mr. Gutknecht.

Mr. GUTKNECHT. Well, thank you very much, Mr. Chairman. And let me thank you, Chairman, for bringing this distinguished panel here today.

I want to compliment all of you and your companies for what you are doing. And I happen to agree that, long-term, this makes good sense. It makes good business sense, it makes good environmental sense, and so I just want to congratulate all of you and the companies that you represent, because the testimony here has been excellent, and I agree with the basic point.

But I do want to pursue something that Mr. Bonner from Alabama raised. And I think it is—I wasn't completely satisfied with the responses that we had. One of the reasons that the Kyoto protocols received a rather chilly reception up here on Capitol Hill, I think, was because it exempted some of the developing countries, and in particular, China and India. And there is growing concern in all kinds of businesses that I talk to on a regular basis in my District, and I suspect my District is no different than the Districts of most of my colleagues here on this side of the panel, and that is that we were going to impose fairly strict standards on American enterprises but not on those in developing countries, like China and India. I wonder if you could give us a little more response to that. And how serious is that problem? And long-term, you know, where do we go from here?

Mr. ROGERS. Congressman, let me suggest that you can not have an effective climate program without having both China and India as part of it.

The question really is raised, well, what do we do as we work to make them part of it. I think it has to be the industrial countries of the world, and clearly China and India, given how fast they are growing, the number of power plants they are building, the number of factories they are building. So the question is how do you get the timing right on that. We could, as a country—it was good judgment not to go back to 1990 levels at this point. But good judgment also tells you that we need to work to start to reduce the rate of emissions in preparation, and but we have to work hard to make sure internationally we bring those two countries along. If you could bring those two countries, then over time, you would bring other developing countries along, but they clearly have to be part of this to get a good result.

Mr. GUTKNECHT. Anybody else?

Does it place—particularly small manufacturers. I think it is easier if you are a big player and you have access to lots of capital and, more importantly, you have a strong science and technology base to your company anyway. I think it is relatively—it is easier for companies like yours, with all due respect, than it is if you were a smaller company that is building widgets in north Mankato, Minnesota that—you know, they can't do that kind of thing. And that is where I think a lot of the fear was.

Anyway, that is not really a question. I would just yield back my time. And again, thank you for what you do.

Chairman BOEHLERT. Mr. Lipinski.

Mr. LIPINSKI. Thank you, Mr. Chairman.

I would like to, as my colleagues have done, applaud everyone on the panel here for what your companies have done to improve the environment.

Now the question that I have, the first question comes from what Dr. McFarland said, he had talked about he doesn't want companies to be penalized, those who have picked the low-hanging fruit, to be penalized if there are some regulations put out that they are penalized as compared to other companies who still have the low-hanging out there. And I think we certainly all agree about that. But my question is, and we will start with Dr. McFarland, and I want to hear from everyone on the panel, how far have you gone now in picking all of the low-hanging fruit. Are you close to the end now of reductions? You have gotten the low-hanging fruit, and we all know once it gets tougher, then there is much less economic incentives and other incentives to make further reductions. Is this it? Are you close to the end of what is going to be easy to do? And what incentive is there to do any more?

Dr. MCFARLAND. Well, clearly we have picked the lowest-hanging fruit, but technology is not static. We are continuing to drive toward lower emissions and improving our performance on these. It is difficult to answer, because the way we make the decisions is to provide marginal cost curves for what projects we can undertake to achieve, you know, the best greenhouse gas emission reductions, and those marginal cost curves change yearly with advances in technology. So I am not trying to avoid your question, it is just a difficult question with the technology changing. We could continue to focus on making project—process—progress to reducing our emissions.

Mr. LIPINSKI. Are there—right now, and this is for Dr. McFarland and all of you, are there—do you have items right now that are in the works in the plans to do more reductions?

Dr. MCFARLAND. Yes.

Mr. LIPINSKI. Mr. Rogers.

Mr. ROGERS. I would approach the question by saying we are in the business of supplying electricity, and we have to have the capability to meet whatever demand is placed on us in the future, and we operate in an area where there is growing demand for electricity, so we have to build more generation. So our ability to do that, if we build gas-fired plants, is $\frac{2}{3}$ the carbon emission of a coal plant. Gas prices today are $5 to $7, and the economics of that are questionable. And the—a broader question of our country, do we really want to have our power generation increasingly dependent, ultimately, on foreign sources of natural gas.

We are also looking at an integrating coal gasification facility. That would allow us to reduce our emissions even further, if we can build that and it makes economic sense. We are currently, as I mentioned before, working with GE and Bechtel trying to negotiate the building of a facility like that. And that would be a $1 billion investment. So we continue to look at investments and the environmental footprint of the investment is very critical to how—what decision we make.

Mr. LIPINSKI. Mr. Meissen.

Mr. MEISSEN. Yes. Most of Baxter's greenhouse gas emissions are associated with the use of energy. And because of that, Baxter has a very active energy management program. We have a network of energy managers in our largest facilities. We hold energy conferences, a global energy conference every two years. And we are doing energy audits, energy reviews of all of our major facilities on a frequent basis. And when we do these reviews, we do find opportunities. The projects, because of the dynamics of our organizations and many other companies like us, the manufacturing processes are changing, the fuel costs are changing, the opportunities are coming before us that we find. People say, "Well, we have picked all our low-hanging fruit," and I believe that—my experience at Baxter is that the tree keeps growing, the fruit keeps coming down lower, and every year we can go around and pick some more fruit. And so it is a continuous process of being more efficient and looking for projects. And we always have a bank of projects that we are working on and additional projects that we can work before us.

Mr. LIPINSKI. Dr. Hobbs.

Dr. HOBBS. Mr. Lipinski, UTC is coming to the end of the first decade of its environmental goals, and we are developing our goals for the next decade. They will continue to say we will improve in greenhouse gas emissions and reductions in energy usage. But we are looking more actively now at other parts of the value chain for new areas that we can make the impact. So we are looking at our partners and suppliers. How can we partner with them to make sure they are doing the same things we are? But we are looking for additional places to harvest low-hanging fruit as we go forward.

Mr. LIPINSKI. Thank you, Mr. Chairman.

Chairman BOEHLERT. To follow up on Mr. Lipinski's question, are there federal technology development or demonstration programs that have or could make a difference? I guess what he is looking for, and so am I, and I am sure all of us, is sort of guidance. What more can we do? So are there federal technology development programs that have made a difference, or, if they were more adequately funded, could make a significant difference?

Mr. Rogers.

Mr. ROGERS. I am delighted with that question, because I think back—on the project we are trying to create today on coal gasification, I think back to the early 1990s. And we were the beneficiary of a grant from the Department of Energy to build a coal gasification facility, one of only two that were built in the United States in the early 1990s. And we built it in Indiana, Wabash River Plant. And we used the Dow technology there. And we took the gas that came out of that unit and generated electricity. Here we are today, more than a decade later, working on a coal gas plant that is going to be closer to being what I call a commercial project versus demonstration. I think it is going to be very critical to have additional funding for carbon sequestration projects and carbon capture projects in these coal gas, because the economics of coal gas is very close to pulverized coal, depending on your assumptions about how carbon constrained we are in the future. The thing that really needs to be funded on these coal gas projects is really the funding of the carbon sequestration. And I think that would be very important in order to allow further development of the—because as you know, in technology, it is not the first generation, often not the second, but it is generally the third, fourth, and fifth technology, or generations in these technologies where it becomes very cost-effective. We need more money to experiment with carbon sequestration.

Chairman BOEHLERT. Does anyone else care to comment on that?

Dr. HOBBS. Mr. Chairman, I personally am from our research center, and so we have been very pleased to have help from the government on occasions to help us develop new products more rapidly that wouldn't come along as quickly without your help. One of our projects we are working on recently is basically an air conditioner running backwards. An air conditioner, normally you put in electricity and you get out cold air. We said, "Suppose you put in hot air. Can you get out electricity?" So we took a Carrier air conditioner, take a thermal waste heat source and get hundreds of kilowatts of electricity out of it. In partnership with the Department of Energy, we are able to try this in some field tests, for instance, at some geothermal sites in Alaska we are hoping for later in the year. There is important opportunity to try some things quickly that we wouldn't be able to do on our own and maybe bring some new products to market that make really good use of waste energy. Huge amount of waste energy. If we could harvest a lot more of that to reduce the generation requirements in this country, that would be really a neat opportunity.

Chairman BOEHLERT. Okay. And I would appreciate after this hearing, we will probably correspond with each of you, one, to thank you for your outstanding testimony, and two, maybe to ask some additional questions. And I would appreciate it if you would give some thought to that question, specific question, what more do you think, short of writing a blank check for all research, and that is obviously not going to happen, but what more do you think, specifically, we should do in terms of the Congress in providing funding for the demonstration programs that offer some real promise? And so we will follow through on that.

Ms. Biggert.

Ms. BIGGERT. Thank you, Mr. Chairman.

My first question is for Mr. Meissen.

I understand, and it was in your testimony, that there are a number of companies in the Chicago area that have formed the Chicago Climate Exchange, the first voluntary pilot carbon-trading platform. Can you tell me what is its purpose and something about your participation in that exchange?

Mr. MEISSEN. Okay. Yes. Thank you, Representative.

Approximately two years ago, the Chicago Climate Exchange was formed. This is the first multi-sector, multi-national carbon trading scheme performed in—actually in existence in the United States. It was formed initially by 14 companies. Baxter was one. Currently, there are over 90 members in different—members in different categories of membership.

The purpose of the exchange is to demonstrate that a carbon cap and trade scheme can work, to demonstrate the procedures, demonstrate that a metric ton of carbon, there could be a cost assigned to that in a trading scheme. And for Baxter, we found that very beneficial to us, because we are learning what that is all about. We are developing institutional knowledge on how it works. And that helps prepare us to address carbon cap and trade schemes as they evolve around the world.

Ms. BIGGERT. And this is the first? There haven't been any others throughout the country? Have people contacted you on how to form this or anything? Is this——

Mr. MEISSEN. Oh, yes. We have gotten a lot of good recognition for this. They have asked us about our participation in it. We have also been asked to speak on that in a number of forums.

Ms. BIGGERT. How do the energy requirements of manufacturing at Baxter differ from some of the other companies and industries that might be involved?

Mr. MEISSEN. One of the major differences with energy usage for Baxter that is a manufacturer of health care products is that we have to manufacture them in clean rooms under sterile conditions. And so our clean rooms and production operations relating to them are very energy-intensive. But we focus a lot of effort on making those more efficient. And we recently were going to a concept called isolators where instead of building a large clean room, we are building a small self-contained production unit where the basic production takes place, and those units are much more effective and provide higher levels of quality. It assures quality and also reduces energy costs.

Ms. BIGGERT. Okay. Thank you.

And Mr. Rogers, you mentioned a merger with Duke Power. And I understand that that company has nuclear facilities.

Mr. ROGERS. Yes, ma'am, they do, indeed. And actually, one of the reasons why we thought combining with them was a good thing for us, we were the largest non-nuclear generator in the United States, primarily coal and gas, and by combining with Duke, who is a recognized leader in the operation of nuclear, it gives us the capability to use that technology, because we don't—there are no silver bullets for the future, and we don't know what technology is going to be the right technology, because we don't know what the rules will be yet with respect to environmental requirements. And there might be a day where nuclear again is important to our country. I sense that it might well be.

Ms. BIGGERT. So I know that even the Administration has just come out with talking about how we haven't built a nuclear facility in years and years and years and that there is some talk about wanting to further that. Would your company then be in a position to maybe want to build another reactor?

Mr. ROGERS. It is my understanding that Duke has announced that they would be very interested in building another nuclear facility. However, it is almost impossible for them to contemplate that unless there is some resolution on the issue of storage of spent fuel, and the Yucca Mountain issue has been a major forever issue in our industry that is yet to be completely resolved. I think it would be very difficult for anybody in this country to build a nuclear unit in the face of no resolution of that spent fuel issue.

Ms. BIGGERT. Thank you. And we will be having a hearing on that soon.

Dr. Hobbs, you were talking about the waste heat energy. What are the obstacles that stand in the way of making this waste heat productive?

The kind of product that we are looking at works very well now if there is high-grade waste heat. And the research efforts we are going to today, particularly, are looking at lower-grade waste heat, heat that is not as hot when it starts. This includes all things from solar sources, for instance, solar collectors, to, as I say, geothermal sites and other sorts of sites. And the technology we are working on is how to use this lower-temperature heat effectively, and can you make the whole process work. It is exciting science right now.

Ms. BIGGERT. Are there any other market barriers?

Dr. HOBBS. I have still got to make the product work before I worry about marketing.

Ms. BIGGERT. Well, thanks for all you are doing, and thank you all.

Chairman BOEHLERT. Thank you, Ms. Biggert.

Ms. Woolsey.

Ms. WOOLSEY. Thank you, Mr. Chairman.

I would like to piggy-back on the last question you brought up to the panel, because you actually stole my question, so I am going to just take it and go further with it.

It is clear that it would make a big difference if products and services that would help you with these new technologies were already available in the marketplace and that they were available, affordable, and efficient and did what you needed them to do.

So I am asking you a couple of things. I mean, I am so impressed, Dr. Hobbs, that you actually develop your own products for your solutions. One, if those products were already available on the market, would you just purchase that solution and those services, and two, are you able to recoup your costs by turning that into a sellable product yourselves?

Dr. HOBBS. I hope if somebody else had it we might buy the company. We partner with all sorts of people for solutions. And in fact, the place that my research center particularly is working now is on integrated solutions. We are looking at more than simple components but at whole systems and how you can take multiple things and put them together to gain efficiency and lower total cost and reduce greenhouse gases and so forth in the process. And so having other people—parts of systems that belong to other people is perfectly fine. The more things that we have to play with, the more opportunities there are.

Ms. WOOLSEY. Right. Any of you that would like to respond about what in your own industries you would take advantage of if it were available in the marketplace, and also with the idea that I believe green technology is the next future industry of the United States if we will wake up and get behind it. So what does the Federal Government need to do to help that industry go forward?

Dr. McFarland, you had a——

Dr. MCFARLAND. Yes. You bring up another issue. What you heard about today, primarily, are the actions that industry is taking to reduce its own emissions. And you have heard the other panel members, and we as well, provide products to increase the efficiency of our end users. If you look at how carbon emissions are spread across the economy, assigning the carbon emissions that—from Mr. Rogers' sites and other utilities' sites, to the end user, about ⅓ of the emissions come from industry. About ⅓ come from buildings. And about ⅓ come from transportation. It is not exactly that. I could get you better numbers on that. You can find them in the reports.

We have got to engage all of the sectors of the economy. This is a global issue, as has been pointed out before. We need to engage all countries. But we also need to engage all sectors of the economy. And what Dr. Hobbs is talking about is a better way to convert energy and more efficiently use the resources, but you have got to have that pool. The industry is generally very cost-sensitive, and in some cases, more cost-sensitive than other sectors of the society. So we look at energy already as a—on the bottom line.

Projects that we are talking about here today I know go beyond what we would—what would be normal business, because they would not normally make the investment hurdle. But again, you heard from people here that are looking at energy as part of the bottom line.

Ms. WOOLSEY. Thank you.

Anybody else want to comment?

Thank you, Mr. Chairman.

Chairman BOEHLERT. Mr. Sodrel.

Mr. SODREL. Thank you, Mr. Chairman.

It is great to have a couple Hoosiers here. In fact, I have bought some of your electricity, Mr. Rogers, as little as possible.

Mr. ROGERS. Well, thank you for whatever you bought. We need the money.

Mr. SODREL. In my other life, I was in the transportation business, and we found that reducing our energy use was very cost-effective, but there is that 90/10 rule that people talk about: you get 90 percent of the benefit by 10 percent of the money. When we had trucks getting four miles to the gallon, it wasn't very difficult to get five. And when you got five, it wasn't very difficult to get six. What we found was that the latest technology in trucks costs more money to acquire, costs more money to maintain, and burns more fuel. So it is very difficult to get the user excited about going out and acquiring the asset. So I—you know, we talked a lot about the Kyoto protocols and how that affects our business. And I appreciate the fact that American-based industries that are operating in foreign countries will apply our standards to that operation. That doesn't mean that our domiciled in that country will do likewise, which puts us at a cost disadvantage.

I guess my question is, Mr. Meissen was talking about, you know, efforts in his plant, how close are we to getting to the end here? I mean, I always tell people, in our business, we can save 100 percent of our energy and create no environmental problems if we just lay off 600 people and they don't come to work today. You know, then we could save it all. So it is a balance between creating jobs and doing it with the minimal impact on the environment. And my question is how close do you think you are to the end where it becomes almost prohibitively expensive to cut emissions any further?

Mr. MEISSEN. Well, Representative, what we have seen at Baxter over the last 10 years is we have been able to accomplish an incremental improvement in energy efficiency and an incremental improvement or reduction in energy costs. And I don't see the end in the next decade or—I mean, I see incremental improvements continuing to increase, because every once in a while, there is a quantum shift, there is a new technology. We can go 10 percent all of a sudden in a certain area. I think it is difficult to anticipate where that end might be, but I think it is a number of years out for Baxter.

Mr. ROGERS. I would respond to that by saying the cost-benefit curve continues to move, and we really shouldn't, sort of, have a preordained spot for it in the future, because as you look at technologies, I look at the combined cycle plants, gas-fired plants have been developed by GE and how much their efficiency has been improved over the last decade. I look at coal gasification and how much we have brought the costs down and we are going to have the ability to do it even in a cheaper way going forward. We participated and are joint owner of a coal generation facility at the Texas City plant with BP where basically the same concept of capturing the heat and fully utilizing it within the system has created great efficiencies in terms of the utilization of natural gas.

So I think our country is on a road, and if we have clear standards or goal lines with respect to emissions levels, I think we have the capability in this country to use our ingenuity and our ability to develop technological solutions. I think there is no end to what we can achieve.

I had the good fortune in my life to have Neil Armstrong on our Board of Directors, which always meant that I started every conversation "one small step." But I think if we had in this country a kind of a man-to-the-moon type commitment with respect to technology and certain lines of where we need to be in the future in terms of emissions level, I think this country has got the capability to get it done.

Mr. SODREL. Just a follow up.

Because all of you have worked very hard on emissions and reducing your emissions, would you work any harder, would you be any more successful if we passed regulations that moved you faster than available technology can take you? I mean, is our new law going to help you become any more efficient than the existing laws?

Mr. ROGERS. Some of my friends in the industry would say, "Now you have gone from preaching to meddling," if you require us to do something that we don't have the capability to do or there is not the technology to do. But I believe that we need to be very sophisticated in the way we think about this, because sometimes if you put a stake in the ground, you go—you are forced and you work hard and you make it. There might be times where you can't make it, and we need to have regulations that are flexible enough that—and understand that to get the balance right on a stake-in-the-ground, we are going to make it, plus some flexibility if it doesn't work out that way. That is where we have got to have very creative legislation and regulators that really understand what the goals are and how best to get there, but at the same time not creating something that is just impossible.

Mr. SODREL. Would anybody else like to respond to that one?

Dr. HOBBS. Let me just add two or three words. I think that if there is additional legislation, flexibility in the approaches that companies have to approaching it is the key issue. If—you know, to Mr. Rogers' point, it is the ability to use different technologies and bring different things to the table that will be so important for continuing to make these strides. So if there is legislation, it has to be crafted in a way that it doesn't inhibit our ingenuity and flexibility.

Ms. BIGGERT. [Presiding.] The gentleman's time has expired.

The gentleman from Texas, Mr. Green, is recognized for five minutes.

Mr. GREEN. Thank you.

And I would like to thank the Chairman and the Ranking Member. I suppose I am especially appreciative of the Ranking Member for allowing me the opportunity to occupy this space. It is a lot bigger when you get here than it appears to be from the far end of the table.

I do want to acknowledge, as others have, that we have an outstanding group of experts here today. And I have been more than impressed with what you have said. I have been inspired. And Mr. Rogers, just to pick on you, I want you to know that your comments most recently made about what we are capable of doing, those are truly inspirational comments. Probably, had we been in another venue, someone would have applauded what you said. I think you demonstrated to us by way of your articulations that if we have the will, we can find the way. And that is what we are trying to gather now: the will to get this done, because Americans have always had the ability to find the way once we have applied the will.

I would like to just mention China for a moment, if I may, because having visited China, you really don't have to be an expert to see that there really is a problem there. It is quite visible. It is almost intuitively obvious to the most casual of observers. And given that it is now a problem, given that they are placing more cars on the road, given that they are attracting businesses from all over the world, given that they are constructing more buildings and industries, if it is a problem now, it surely is going to become a major problem in the future. And the question that we have to grapple with is how do we get them to comply to come on board if we are not on board. And I am saying that with as much sincerity as I can, because I am interested in having you, if you can, to the extent that you can, give some intelligence with reference to how do we get this done, which has to be done, without having done it ourselves. Mr. Rogers, perhaps you can continue to inspire me.

Mr. ROGERS. That is a very tough question.

I believe very strongly that we have to bring China and India on board, not necessarily all of the other developing countries at this time. But it is really a question of leadership. And you are right in your point that it is pretty hard to preach something when you are not doing it yourself. But I think the question that we have to ask ourselves is can we put a stake in the ground on this issue that moves us in that direction but, more importantly, allows companies in our country, like the ones here, and other companies, like GE, who can develop the technologies that they can subsequently sell into China and India creates a market for their products but they are products that allow them to create energy in a more efficient way or to reduce emissions, whether it is SO_X, NO_X, mercury, or CO_2. And I think all of those are problems in China and India.

And so my judgment is that we are going to have to lead on this. I don't think leadership translates into Kyoto. I think it is something less than that, because I don't think our country can do it for now. But I do think we can do something. And we need to do it and say we will go to this place, and if India and China are not on board at that place, then maybe we don't go any further. So we have—I think, at the end of the day, we are going to have to go first in order to bring them along with us.

And quite frankly, I am impressed with what Prime Minister Blair is doing. He is taking the G–8 in a couple of months and basically going to make this issue a primary issue. And he believes that bringing both India and China on board is critical to our success on this issue.

Mr. GREEN. I welcome any additional comments, Mr. Chairman, if time permits. If not, I will yield back.

Chairman BOEHLERT. Time does permit. And incidentally, if we were in a different venue, you had said you would stand up and applaud. You can stand up and applaud right here. This venue is—but I don't want you guys to think, quite frankly, that this is all going to be a cakewalk as you go forward. You understand that. Maybe absent today are some of the most critical of our colleagues in terms of this whole issue, and I am really sorry that they have conflicts and can't be here, because I would like them to hear what you are saying. And what you are saying is you are not just altruistic in doing what you are doing, providing leadership, and you are not just goodhearted citizens. There is an enlightened self-interest in doing what you are doing, and it is good for everybody.

So you have got more time, Mr. Green.

Mr. GREEN. Thank you, Mr. Chairman.

If another panel member would care to give a response. Yes, sir.

Mr. MEISSEN. Well, I can't speak to what other industries and companies are doing, but given the nature of our products and services and our manufacturing operations around the world, we operate—we have the same standards around the world, and these are the same standards on quality, but also in environmental health and safety policies but also on energy conservation, water conservation, and other resource conservation. We have a number of facilities in China and a few in India that are doing an excellent job on managing resources and operating in a very cost-effective manner. Actually, a few best practices are coming. So I think that it first starts with the company. And in our case, we can't influence maybe what other companies or larger organizations can do, but we can influence what we do. We can set our policies. We can set the direction we want to go. We can set our strategic focus. We see the carbon cap and trade schemes emerging around the world, and that is why we got involved in the Chicago Climate Exchange. The emissions of all of the members of the Chicago Climate Exchange equal over ½ the emissions of Great Britain. And in the first year of our pilot program, we were able to reduce that eight percent on an absolute basis. And that is by finding the most cost-effective in the different facilities and the different organizations to implement a project that reduces carbon.

And so when you have a multi-sector, multi-national organization, you can find the lowest—I mean, the cost—incremental cost to reduce carbon can be determined, and therefore, you, cost-effectively, can reduce it for the whole group.

Mr. GREEN. Yes, sir. Dr. Hobbs.

Dr. HOBBS. Just one more quick thing.

Sometimes applauding what people are doing good is a good thing, too, so recently our Carrier division and the state Environmental Protection Agency of China established a China Ozone Protection Award. The program recognizes individuals and organizations promoting the use of non-ozone-depleting technologies. That is not greenhouse, but it is allied, and—but we are trying to project the same kind of responsible image to China that we do in the United States.

Mr. GREEN. Thank you, Mr. Chairman. I yield back.

Chairman BOEHLERT. Thank you, Mr. Green.

Chairman Inglis.

Mr. INGLIS. Thank you, Mr. Chairman. That enlightened self-interest you were talking about, Mr. Chairman, comes home with General Electric who makes those coal gasification turbines in Greenville, so we are very excited about that. And I think that it is something that proves the point that you are making, that industry with enlightened self-interest can do things that really can help the whole world. So that is exciting.

Also, Mr. Rogers, we are excited about Duke Power looking at a nuclear power plant. I think the best—one of the best sites they could look at is in South Carolina's Savannah River Site, particularly if they use that technology—use that opportunity—your new company uses that opportunity to create hydrogen as a byproduct out of that nuclear reactor that they would build. We know a lot about keeping hydrogen under pressure at Savannah River Site, because we have kept tritium under pressure for 30 years there, and so it would be a fabulous place for Duke Power to do this, to start moving us toward fixing what Dr. McFarland was talking about, at least ⅓ of that sector being transportation. If we can create hydrogen and move toward a hydrogen economy that could propel us in cars, it would be a fabulous thing. And we have got an opportunity with that next nuclear reactor. And I hope, Mr. Chairman, that that becomes an opportunity for us to work in a very bipartisan way, and also biophilosophical, if that is a word, way between conservationists and environmentalists. Conservationists are people who want to conserve things. Environmentalists are people who have, perhaps, a slightly different worldview or a different worldview than conservationists, but there is agreement, it seems to me, or potential for agreement on things like moving toward hydrogen, especially if you did it through nuclear.

So that is a little bit of preaching there about the opportunities that are available.

And the question—I would follow up in what Mr. Green was asking about. It seems to me that if we are to encourage China and India to do what we have now figured out to do because our technology has gotten us to the place where we can do it, if we can get them, in some way, to go with that technology right off the starting line rather than to retrofit later. I have got to assume it is far more expensive—and this is your experience. I have got to assume it is far more expensive to retrofit an investment you already have. If we could encourage them to somehow get involved in this new technology, like coal gasification turbines made by General Electric, to buy those first rather than build the quick and easy now, come back later and find it cost-prohibitive to go that—can—anybody want to comment on how you can encourage people to do that? Obviously, your companies are leaders in this.

Mr. ROGERS. I think it is really critical that when new power plants are built in China and India they use the best available technology. And you are right. I mean, as a company that in the Midwest we will have spent, over the last decade and looking forward to 2010, almost $4 billion on retrofits in terms of putting scrubbers on the back end of plants and putting SCRs to take NO_X out and take SO_2 out and to combine they take mercury out. It is smarter to do it on the front end. And when you build a power plant, whether you build it in China or you build it in the United States, you are building that plant to be there for 40 to 50 years. And that is why it is so important in this country, and that is why I am so much a pragmatist about this. I am—all across our country, power companies, over the next three to five years, are going to be making decisions about the next generation of power plants to build. We don't even know what the rules are on SO_X, NO_X, and mercury. We don't know what the rules are on carbon. But we all instinctively know that they are going to be tighter than they are today and that we will have carbon rules. And because we will, we are forced to look at nuclear more, look at coal gasification because those are lower-cost approaches to taking it out. If you looked at a coal plant today and you—and if this is the coal plant where the retrofits have been put on, probably only that much of the coal plant is where the power is generated. All of the rest is to clean up the air byproduct. If you look at a coal gasification facility, what you see is you could do it cheaper, take the SO_X, NO_X, and mercury out, on the front end, and so you don't have to build this huge facility on the back end of the power generation. And that is about as technical as I ever get.

But my point is that these decisions are 40- and 50-year decisions. And so to your point, if we can lead with our technology and to set—help them and do it ourselves, set guidelines and goal lines, I think we have the ability to make the right decisions, rather than make the wrong decision and have to fix it 15 years from now.

Mr. INGLIS. Anybody else want to comment about that?

Dr. MCFARLAND. On the issue of leadership and bringing the other countries, China and India, on board, it is also a matter of implementing those technologies here to bring the costs down. And also, there is a long-term issue here that we, to solve this issue, are going to have to have breakthrough technologies, and developing and providing the market signals to implement those technologies in the long run are going to be absolutely critical to solving this long-term global issue.

This isn't a sprint. It is a marathon. We have got to get started now. It is going to take decades to really, truly address this issue. You know, just to put it in perspective, to achieve the goals of the Framework Convention on Climate Change, which I like to talk about rather than the Kyoto protocol, some time in the next 75 to 150 years, global average per capita emissions of carbon must be one-tenth of what they are today in the United States and continuing to fall. The more you emit now, the less you can emit in the future. So it says you start now, you take incremental steps, and you prepare for the future.

Chairman BOEHLERT. Thank you.

The gentleman's time has expired.

To paraphrase an old adage, Dr. McFarland, a journey of decades starts with the first day of forward movement, and you guys are moving forward. Thank you.

Mr. Wu.

Mr. WU. I would like to commend the Chairman for his leadership on this issue and thank the panel, Mr. Rogers, Dr. McFarland, Mr. Meissen, Dr. Hobbs, for your private sector leadership and the enterprises which you represent, whether it is Cinergy or DuPont or United Technologies or Baxter. Thank you very much for providing that private sector leadership.

I don't have a question for you all so much as I have a comment about what is going on in the public sector on this issue. Now I am way past the age where I take newspaper stories at face value, but there is a front-page story in today's *New York Times* by Andrew Revkin. And anything that says that a former American Petroleum Institute official is now the Chief of Staff for the White House Council on Environmental Quality sort of gets me to read the rest of the article. And the rest of the article proved rather interesting, because it turns out that this attorney with an economics background has been editing science reports on climate. And here is an example of a paragraph, which he crossed out from a scientific report.

The paragraph would have read, and this is all crossed out, "Warming will also cause reductions in mountain glaciers and advance the timing of the melt of mountain snow peaks in polar regions. In turn, runoff rates will change, and flood potential will be altered in ways that are currently not well understood. There will be significant shifts in the seasonality of runoff that will have serious effects on native populations that rely on fishing and hunting for their livelihood. These changes will be further complicated by shifts in precipitation regimes and a possible intensification in increased frequency in extreme hydrologic events."

"Extreme hydrologic events" is what I think we, in the Northwest, call a flood. And this is all redacted from a scientific report. And it would be disturbing in and of itself were it not for the fact that in the story, it said that "critics admit that while all Administrations routinely vet government reports, scientific content in such reports should be reviewed by scientists," and that, further, "politicization by the White House has fed back directly into the science program in such a way as to undermine the credibility and integrity of scientific programs with a chilling effect and has created a sense of frustration among scientists." And there is a comment of the National Academy of Sciences that they warn that the Administration's procedures for vetting reports on climate could result in excessive political interference with science.

Now you all have provided terrific private sector leadership in this arena, and Mr. Chairman, you and others on this committee have provided leadership on this issue in terms of science. And I would submit that we have an oversight responsibility to make sure that the integrity of the scientific process is maintained no matter what the current political climate may be. There is always a limit to what we can do, whether that is technologic or political, but we must exert best efforts.

As you know, Mr. Chairman, on my side of the aisle, I have been a relative moderate on climate change issues. I have been more focused on backyard issues than global change issues, but I do find that a twisting of the scientific process is very disturbing to me, and I would like to submit this June 8 *New York Times* article into the record of the hearing and yield back the balance of my time.

[The information follows:]

BUSH AIDE EDITED CLIMATE REPORTS

Ex-Oil Lobbyist Softened Greenhouse Gas Links

By ANDREW C. REVKIN

A White House official who once led the oil industry's fight against limits on greenhouse gases has repeatedly edited government climate reports in ways that play down links between such emissions and global warming, according to internal documents.

In handwritten notes on drafts of several reports issued in 2002 and 2003, the official, Philip A. Cooney, removed or adjusted descriptions of climate research that government scientists and their supervisors, including some senior Bush administration officials, had already approved. In many cases, the changes appeared in the final reports.

The dozens of changes, while sometimes as subtle as the insertion of the phrase "significant and fundamental" before the word "uncertainties," tend to produce an air of doubt about findings that most climate experts say are robust.

Mr. Cooney is chief of staff for the White House Council on Environmental Quality, the office that helps devise and promote administration policies on environmental issues.

Before going to the White House in 2001, he was the "climate team leader" and a lobbyist at the American Petroleum Institute, the largest trade group representing the inter-

Continued on Page A16

In Editing Climate Reports, Bush Aide Softened Greenhouse Gas Links

Continued From Page A1

ests of the oil industry. A lawyer with a bachelor's degree in economics, he has no scientific training.

The documents were obtained by The New York Times from the Government Accountability Project, a nonprofit legal-assistance group for government whistle-blowers.

The project is representing Rick S. Piltz, who resigned in March as a senior associate in the office that coordinates government climate research. That office, now called the Climate Change Science Program, issued the documents that Mr. Cooney edited.

A White House spokeswoman, Michele St. Martin, said yesterday that Mr. Cooney would not be available to comment. "We don't put Phil Cooney on the record," Ms. St. Martin said. "He's not a cleared spokesman."

In one instance in an October 2002 draft of a regularly published summary of government climate research, "Our Changing Planet," Mr. Cooney amplified the sense of uncertainty by adding the word "extremely" to this sentence: "The attribution of the causes of biological and ecological changes to climate change or variability is extremely difficult."

In a section on the need for research into how warming might change water availability and flooding, he crossed out a paragraph describing the projected reduction of mountain glaciers and snowpack. His note in the margins explained that this was "straying from research strategy into speculative findings/musings."

Other White House officials said the changes made by Mr. Cooney were part of the normal interagency review that takes place on all documents related to global environmental change. Robert Hopkins, a spokesman for the White House Office of Science and Technology Policy, noted that one of the reports Mr. Cooney worked on, the administration's 10-year plan for climate research, was endorsed by the National Academy of Sciences. And Myron Ebell, who has long campaigned against limits on greenhouse gases as director of climate policy at the Competitive Enterprise Institute, a libertarian group, said such editing was necessary for "consistency" in meshing programs with policy.

But critics said that while all administrations routinely vetted government reports, scientific content in such reports should be reviewed by scientists. Climate experts and representatives of environmental groups, when shown examples of the revisions, said they illustrated the significant if largely invisible influence of Mr. Cooney and other White House officials with ties to energy industries that have long fought greenhouse-gas restrictions.

In a memorandum sent last week to the top officials dealing with climate change at a dozen agencies, Mr. Piltz said the White House editing and other actions threatened to taint the government's $1.8 billion-a-year effort to clarify the causes and consequences of climate change.

"Each administration has a policy position on climate change," Mr. Piltz wrote. "But I have not seen a situation like the one that has developed under this administration during the past four years, in which politicization by the White House has fed back directly into the science program in such a way as to undermine the credibility and integrity of the program."

A senior Environmental Protection Agency scientist who works on climate questions said the White House environmental council, where Mr. Cooney works, had offered valuable suggestions on reports from time to time. But the scientist, who spoke on the condition of anonymity because all agency employees are forbidden to speak with reporters without clearance, said the kinds of changes made by Mr. Cooney had damaged morale. "I have colleagues in other agencies who express the same view, that it has somewhat of a chilling effect and has created a sense of frustration," he said.

Efforts by the Bush administration to highlight uncertainties in science pointing to human-caused warming have put the United States at odds with other nations and with scientific groups at home.

Prime Minister Tony Blair of Britain, who met with President Bush at the White House yesterday, has been trying to persuade him to intensify United States efforts to curb greenhouse gases. Mr. Bush has called only for voluntary measures to slow growth in emissions through 2012.

Yesterday, saying their goal was to influence that meeting, the scientific academies of 11 countries, including those of the United States and Britain, released a joint letter saying, "The scientific understanding of climate change is now sufficiently clear to justify nations taking prompt action."

The American Petroleum Institute, where Mr. Cooney worked before going to the White House, has long taken a sharply different view. Starting with the negotiations leading to the Kyoto Protocol climate treaty in 1997, it has promoted the idea that lingering uncertainties in climate science justify delaying restrictions on emissions of carbon dioxide and other heat-trapping smokestack and tailpipe gases.

On learning of the White House revisions, representatives of some environmental groups said the effort to amplify uncertainties in the science was clearly intended to delay consideration of curbs on the gases, which remain an unavoidable byproduct of burning oil and coal.

"They've got three more years, and the only way to control this issue and do nothing about it is to muddy the science," said Eileen Claussen, the president of the Pew Center on Global Climate Change, a private group that has enlisted businesses in programs cutting emissions.

Mr. Cooney's alterations can cause clear shifts in meaning. For example, a sentence in the October 2002 draft of "Our Changing Planet" originally read, "Many scientific observations indicate that the Earth is undergoing a period of relatively rapid change." In a neat, compact hand, Mr. Cooney modified the sentence to read, "Many scientific observations point to the conclusion that the Earth may be undergoing a period of relatively rapid change."

A document showing a similar pattern of changes is the 2003 "Strategic Plan for the United States Climate Change Science Program," a thick report describing the reorganization of government climate research that was requested by Mr. Bush in his first speech on the issue, in June 2001. The document was reviewed by an expert panel assembled in 2003 by the National Academy of Sciences. The scientists largely endorsed the administration's research plan, but they warned that the administration's procedures for vetting reports on climate could result in excessive political interference with science.

An Editor in the White House

Handwritten revisions and comments by Philip A. Cooney, chief of staff for the White House Council on Environmental Quality, appear on two draft reports by the Climate Change Science Program and the Subcommittee on Global Change Research. Mr. Cooney's changes were incorporated into later versions of each document, shown below with revisions in bold.

"STRATEGIC PLAN FOR THE U.S. CLIMATE CHANGE SCIENCE PROGRAM," DRAFT TEXT, OCT. 2002

wetlands will expand in areas where meltwater resulting from deeper and longer thaw periods does not have a natural drainage path to the ocean.

Warming will also cause reductions in mountain glaciers and advance the timing of the melt of mountain snow packs in polar regions. In turn, runoff rates will change and flood potential will be altered in ways that are currently not well understood. There will be significant shifts in the seasonality of runoff that will have serious impacts on native populations that rely on fishing and hunting for their livelihood. These changes will be further complicated by shifts in precipitation regimes and a possible intensification and increased frequency of extreme hydrologic events. Reducing the uncertainties in current understanding of the relationships between climate change and Arctic hydrology is critical

PUBLIC REVIEW DRAFT, NOV. 2002

Warming **could** also **lead to changes in the water cycle in polar regions**. Reducing the uncertainties …

FINAL REPORT, JULY 2003

The paragraph does not appear in the final report.

"OUR CHANGING PLANET," DRAFT TEXT, OCT. 2002

the next, and perhaps even beyond.

The challenge for the USGCRP is to provide the best possible scientific basis for documenting, diagnosing, and projecting changes in the Earth's life-support systems, and the role for CCRI is to facilitate full use of this scientific information in policy and decisionmaking on response strategies for adaptation and mitigation at the international, national, and regional scales.

From "Discovery" to "Comparative Analysis"

Because of the scientific accomplishments of USGCRP and other research programs during the last decade, a period that could be termed a productive *"period of discovery and characterization,"* the CCRI, in coordination with the USGCRP, will move into a new *"period of comparative analysis of response strategies."* In this new phase of the climate science programs, information that compares the potential consequences of different responses to global changes, including climate change, will be developed in a form useful to national debate and decisionmaking. This

FINAL REPORT, 2003

The challenge for the USGCRP is to provide the best possible scientific basis for documenting, **understanding**, and projecting changes in the Earth's life-support systems, and the role for CCRI is to **reduce the significant remaining uncertainties associated with human-induced climate change and** facilitate full use of scientific information in policy and decisionmaking on **possible** response strategies for adaptation and mitigation.

The New York Times

Chairman BOEHLERT. Thank you.

From one relative moderate to another, the Chair now recognizes Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman. I would just observe that when I stopped reading the *New York Times,* I increased the amount of time I had available and reduced my anxiety level. That is offered in jest, by the way. I don't want a *New York Times* editorial about the know-nothing attitude in the Science Committee.

I had several questions I was going to ask. Many of them have been touched upon.

Let me summarize with a few comments and some additional questions.

First of all, on Mr. Green's question and the answers.

I certainly agree that China and India are the greatest problem in the near future, but I think the Kyoto treaty was fatally flawed by not setting up a timeline for every nation. And the reason for that was alluded to by Mr. Rogers, in your comment that energy investments tend to be very long-term investments. And if, for example, Uganda and Costa Rica knew that they were going to be subject to the treaty requirements in 2020, they would make far different investment decisions now than they would make if they knew they didn't have to worry about it until some time in the future, and they wouldn't have to make retroactive changes. So I really think every nation has to be—has to know it is going to affect them, because clearly in sunny climates, particularly central Africa, our good investments in solar energy over the long run might be much more productive than investments in burning coal.

That was just a comment.

But Mr. Rogers, also in your testimony, you seemed to suggest that restrictions on greenhouse gas emissions can result in leadership and technology and advanced competitiveness. I think that is a very important factor that we tend to overlook too often on the Congress, and I have been impressed with those countries that have adopted, including, at times, the United States, that have adopted advanced requirements. They have led to developments of entire new industries in environmental control and which immediately becomes an export business when other countries have dropped those same requirements. But it seems to me that is always forgotten, or else ignored, by those who say there is no climate change. We could—if in fact we are wrong in that, or they are wrong on it, we could be in the situation of having to import our environmental controls rather than being in the position of developing them, as Dr. Hobbs says, and exporting them. Does that make sense to you, or am I in La-La Land here?

Mr. ROGERS. No, I think you make a very good point. And at great risk, I am reminded of a series of articles that were in the *New York Times* over the last week talking about the innovation and the new technologies in Japan, because they are very focused on reducing their emissions of carbon and greenhouse gases. And it reminded me that, you know, there is an advantage to countries who know they are going to have to deal with this. It is an advantage of going to work, developing the technology, and solving the problem. And I believe that we might be left behind, because we don't have the same motivation here, although these companies are just such wonderful examples of people that are looking ahead. Because I think the reason that they are looking ahead is because they know eventually, or inevitably, that there are going to be requirements and that they will make money off of these technologies. And they see it as a trend that is occurring, and they are positioning themselves for it.

So I support your point very strongly.

Mr. EHLERS. It seems to me that our business community in the United States is, in many ways, ahead of both the political community and the general public on that issue, and that is particularly displayed by the folks represented here.

Two other quick points.

First of all, Dr. Hobbs, I—as a scientist, I have to take a little exception to the suggestion that you can just reverse an air conditioner and put in heat and get electricity out. I don't want people to think that they can buy this thing and just put a switch on it and flip it and run it backwards.

Dr. HOBBS. Yeah, you have to change a couple of valves, but it is not much worse—not much more than that.

Mr. EHLERS. Well, we will have to talk about that.

But your second point that you added later is the most important one. It is very much dependent on the quality of the heat you are working with. If you have high-energy content heat, it is very simple. If you have low-energy content, it is hard to beat the economics, and I hope we can. One thing we can't beat are the laws of thermodynamics, of course. That is our ultimate limitation.

Just quickly picking up on Mr. Sodrel's excellent question.

I think another factor that is involved in this is that as fuel prices increase, and this is not a short-term phenomenon, even though they may drop next year for a few years, but long-term, there are going to be sharp uptake as we deplete our fossil fuel, but particularly petroleum and natural gas resources. Many new approaches are going to become economically feasible, so that is another factor that says, you know, things that don't look feasible now, from an economic standpoint, will be feasible in 10 years, 15 years, and so let us get the ground work done.

And I can't let this pass without getting in a very strong statement saying that that is why it is absolutely important for the government to continue to support fundamental research so that you fellows can pick up the results of that and apply it in a very pragmatic way and solve these problems and make things more economically feasible. If we don't step up to the plate, as we should in the Congress and fund the fundamental research, it is going leave you folks high and dry in the future. If we do that, it is going to give you lots of opportunities for applied research technology development that is going to benefit not only you but the entire country.

As you said, it is better to preach than to meddle, and so I decided I should preach instead of meddle in your business.

So that is the end of my sermon, Mr. Chairman. Thank you very much.

Chairman BOEHLERT. Thank you, Pastor—I mean, Dr. Ehlers.

Listen, we have got truth in advertising. Dr. Ehlers is a very distinguished scientist in his own right. He is a fellow of the American

Physical Society and one of the strengths of this committee. And I thank you for your observations.

I am going to speak shortly. I am going to have a whole room full of lobbyists from the high-tech industries meeting on Capitol Hill. And part of my message to them is we want you to lobby us more, because we have to be strong advocates for more investment in fundamental research. We have to be strong advocates in more investment in K–12 science and math education. We are competing in the global marketplace, and we are not doing as well as we should.

And so—but part of the reason we are doing better than some people think is the panel before us and the companies you represent and the leadership you are providing in a very important, sensitive area.

So I thank you for being facilitators and resources for this committee. We will follow-up with some additional questions, as I indicated. In the meantime, have a good day.

This meeting is adjourned.

[Whereupon, at 12:05 p.m., the Committee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Mack McFarland, Environmental Manager, Fluorochemicals Business, E.I. DuPont De Nemours and Company

Q1. If you have any views on federal technology programs that you believe could help reduce greenhouse emissions with improved focus or additional funding, please provide them to the Committee.

A1. While many of DuPont's greenhouse gas reductions have involved non-CO_2 process gases, we recognize that energy related technologies will be the predominant source of GHG reductions. We therefore believe the following areas are important to pursue (not all of which lie in the Committee's purview).

- There are a range of energy efficiency and alternative energy provisions in the House and Senate energy bills currently in conference that we believe are beneficial, including from the Senate bill provisions 1521, 1522, 1529, 1527, 1524, 1506, 1508, 1501, 1507.
- As a general matter support for co-generation and other forms of distributed generation can help to make energy use more efficient.
- The Department of Energy's biofuels program, under which we are collaborating on an Integrated Corn Based Biorefinery, provides great promise to advance non-fossil fuels.
- There are a range of energy efficiency and renewable energy matters on which additional R&D can yield significant benefits. They include;
  - Continuing advances in low cost, distributed process energy instrumentation that can be installed without a shut-down. Concurrent advances in control room energy monitoring supervised by expert systems.
  - Continuing development to improve the reliability and efficiency and decrease the capital cost of: insulation and steam traps, topping cycles, recovery of waste b pressure generators, modern motors.
  - Long-term development of separation technologies that are an alternative to distillation.
  - Decreasing the capital cost for renewable energy equipment with particular attention to solar and large stationary CHP and fuel cells.
  - Significantly reducing the purity required for any fuel used in a fuel cell.
  - Addressing the large scale electrical energy storage problems (environmental footprint, durability and cost).
  - Improving the efficiency and reliability and reduce the cost for the transmission of electricity.
  - Decreasing the environmental impact of storage and production of all forms of biomass.

Appendix 2:

ADDITIONAL MATERIAL FOR THE RECORD

PREPARED STATEMENT OF TOM CATANIA
VICE PRESIDENT, GOVERNMENT RELATIONS
WHIRLPOOL CORPORATION

Whirlpool Corporation is the world's leading manufacturer and marketer of major home appliances with annual sales of over $13 billion, producing 42 million appliances per year, and employing 68,000 employees. We have 50 manufacturing and technology research centers around the globe. Whirlpool markets Whirlpool, KitchenAid, Brastemp, Bauknecht, Consul, and other major brand names to consumers in more than 170 countries. We have nine major manufacturing facilities in the United States. Of these, our plant in Clyde, Ohio is the world's largest clothes washer plant. Our plant in Marion, Ohio is the world's largest dryer plant and our plant in Findlay, Ohio is the world's largest dishwasher plant.

Whirlpool Corporation respectfully submits the following testimony together with the attached slides describing what we are doing to reduce greenhouse gas emissions. Some may still debate whether the science is definitive about the causes of global climate change or even whether it is, in fact, occurring. Despite any remaining uncertainty, though, Whirlpool Corporation believes prudence dictates that, when existing solutions are available to mitigate a company and its products' impact on the environment, they are worth pursuing especially where, as has been our experience, many of those solutions are not only a win for the environment and the consumer, but also for our employees and our shareholders.

Whirlpool Corporation is first and foremost a consumer and brand focused home appliance company. Our tens of thousands of shareholders and employees and tens of millions of consumers expect us to fulfill our commitments to them to the utmost of our collective ability, and they also assume that we can exceed their expectations while minimizing our impact on the environment. We take those expectations to heart. We have found that reducing the greenhouse gas emissions impact of our company and its products is quite compatible with what some see as a more narrow mission of being a profit-maximizing home appliance manufacturer and marketer.

Market-based Incentives and Public/Private Partnerships

We believe that GHG emissions reductions can be achieved most effectively and quickly through an appropriate balance of regulatory measures, market-based incentives, and public/private partnerships. Such incentives include a manufacturer's tax credit such as the one being debated in the current Energy Bill for super energy-efficient appliances. It could also include demand-side management incentives to consumers that encourage them to choose more energy efficient appliances. One example nearby was the state of Maryland's exemption of ENERGY STAR® appliances from state sales tax. This program saw a 21 percent increase in the sales of ENERGY STAR® appliances.

If the Appliance Manufacturer Tax Credit were passed by Congress this year in the Energy Bill, it would save over 200 trillion BTUs of energy, or the equivalent of taking 2.3 million cars off the road, or eliminating the need for 6 coal-fired power plants for a year. The bill would also reduce the amount of water necessary to wash clothes by 870 billion gallons or approximately the amount of water necessary to meet the needs of every household in a city the size of Phoenix, Arizona for two years.

If, for example, the state of Ohio were to pass a four-year, state sales tax exemption for consumers of ENERGY STAR® clothes washers, dishwashers, refrigerators, and dehumidifiers, the carbon savings would be 224,107 m/t. The CO_2 avoided would be 822,472 m/t; and consumers would have $261 million more to put back into the economy and pay for other products and services.

Public-private market transformation partnerships that have been successful include the ENERGY STAR® program implemented by the U.S. Environmental Protection Agency and the Department of Energy. This program is voluntary and yet has become competitively mandatory in the sense that, if a manufacturer does not participate in the program, the manufacturer risks losing market share. It is an excellent program that transforms consumer education into an opportunity for manufacturers to successfully market a more environmentally friendly product at a premium. Today, over 40 percent of the appliances in the ENERGY STAR® product categories meet or exceed the ENERGY STAR® levels.

If all new appliances sold in the United States were ENERGY STAR® qualified, the electricity saved in one year would be 3.4 billion kWh, the gas saved would be 109 million kWh, the carbon emissions avoided would be 2.4 million metric tons, and the savings in monthly electricity bills would be $618 million.

Voluntary Cap and Trade Program

If a voluntary cap and trade program offers true incentives for our industry to reduce GHGs, then such a program would be helpful, too. However, the current thoughts on cap and trade programs do not incentivize our industry to participate since the proposed programs do not credit our industry with savings from the life-cycle use of the product—the largest portion of GHG emissions reductions for appliance manufacturing. In 2000, the Energy Information Administration (EIA) reported that in 1999, 28 percent of all residential electricity consumption in the U.S. came from the use of white goods (refrigerators, dryers, freezers, clothes washers, cooking, and dishwashers). The UK Ecolabelling Board reported in 1992 that the cradle-to-grave assessment of the environmental impact of clothes washers was allocated such that less than 10 percent of the impact came from production, distribution, and disposal of the product. Whereas, *life-cycle use* of the product accounted for *over 90 percent* of the environmental impact. This shows that, if the government wants to motivate appliance manufacturers to participate in a meaningful cap and trade program, then it needs to provide credit for the power plant emissions reduced or avoided through the increased energy efficiency of our products.

We currently do not participate in the 1605b voluntary emissions reduction program because there is no clear benefit for our participation since our indirect emissions reductions would not be credited in the proposed final interim guidelines. They should be. Also, we are already reducing emissions voluntarily and so there is no incentive to become mired in a complex and burdensome emissions reporting program. Additionally, 1605b fails to recognize emissions reductions made before the 2003 reporting period.

Unilateral Reductions

Whirlpool Corporation has committed to reducing its GHG emissions globally by three percent during the period 1998 through 2008 despite a nearly 40 percent projected increase in production volumes. A description of this commitment is in the attached presentation. Whirlpool Corporation made this commitment because it is the right thing to do and it is a possible thing to do while still addressing our business objectives of producing consumer-demanded products, employing people, and generating profits. As national, regional, and global plans are developed to address climate change, care should be taken to analyze the overall climate impact of any particular measure. For example, banning the use of a particular greenhouse gas-emitting compound as a refrigerant or refrigerator wall insulation material, may be a net climate detriment if its impact in the product is to decrease its energy efficiency.

What Whirlpool has done and will continue to do

I am submitting a detailed presentation of what Whirlpool Corporation has done in the past to address GHG emissions, however, I will briefly cover a few of the highlights here.

Whirlpool has earned the ENERGY STAR® Partner of the Year award six times since 1999. Whirlpool has led in the crafting of all major appliance efficiency legislation since 1975 and in the crafting of every appliance efficiency standard since 1990.

The appliance industry as a whole has contributed significantly to energy efficiency and consumer savings over the years. Today's refrigerator uses 61 percent less energy than in 1983, saving the consumer $59/year vs. a 20-year old unit. Whirlpool's side-by-side refrigerators use 619 kWh/year, equal to a 75-watt light bulb. In 1980, as reported by the EIA in 2001, it took $87 per year to operate the average clothes washer and, in 2001, the cost dropped to only $25 a year for the highly efficient Whirlpool Duet.

Whirlpool was the first appliance manufacturer to announce in 2003 a global greenhouse gas emissions reduction target. Using 1998 annual total global emissions from product manufacturing, product lifetime energy use, and any emissions associated with product disposal as our baseline, Whirlpool will decrease our absolute total emissions by three percent by 2008. This reduction will occur despite a projected increase in unit sales by nearly 40 percent during that period. Such a reduction results in an annual savings of four million metric tons of carbon in absolute savings and fifteen million metric tons of carbon annually compared to our 1998 per unit rate of emissions. Fifteen million metric tons represents the elimination of 28 coal-fired power plants and the equivalent of 10 million fewer cars on the road.

This commitment is a global effort. This is something very important to recognize given that the Kyoto Protocol and a few other recent climate change proposals do not address climate change on a truly global basis. Our emissions per unit reductions from 1998 to 2008 are projected to be over 20 percent for production in Europe, India, and China and nearly 30 percent for production in the U.S. and Canada.

Closing

I appreciate the opportunity to provide comments on this important subject today. In summary, Whirlpool Corporation knows that it can contribute meaningfully to a reduction in greenhouse gas emissions without jeopardizing its leading global position in the industry. In fact, working on energy and water efficiency has helped us develop some of the products that are most profitable and loved by consumers. However, we believe this virtuous cycle is created through market-based mechanisms that encourage technological innovation, allow flexibility in global production, credit indirect emissions reductions that occur during the use of the product, and consistently support public-private partnerships that stimulate consumers into action. We look forward to working with you in the future on this important matter. Thank you.

Emissions Reduction in the Home Appliance Sector

Leading by Example, Encouraged by Market Forces

by Whirlpool Corporation
for the House Science Committee
Thomas F. Catania
VP, Government Relations

Outline

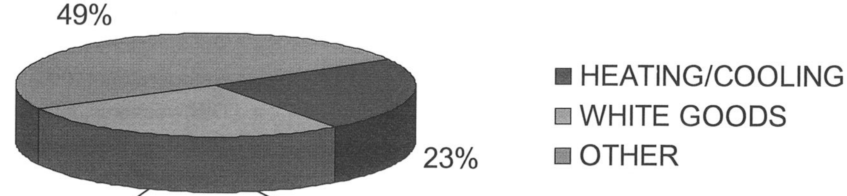
- History of Leadership in Energy Efficiency
- Energy Savings Story: Use of Product
- Individual Product Stories
- Greenhouse Gas Emissions Commitment
- Market-Based Transformational Programs

Whirlpool has a Long History of Leadership in Energy Efficiency

- Led in crafting Federal Trade Commission Energy Labeling Rules (1979)
- ENERGY STAR® Partner of the Year 6 times since 1999 (1999-2002, 2004-2005)
- First appliance manufacturer to announce a global greenhouse gas reduction target (Dec. 2003)
- Led in crafting all major appliance efficiency legislation:
  - » Energy Policy and Conservation Act (1975)
  - » National Energy Policy Conservation Act (1977)
  - » National Appliance Energy Conservation Act (1987)
- At forefront in multi-year lobbying for State and Federal ENERGY STAR Tax incentives
- Led in crafting every appliance efficiency standard:
  - » Refrigerators/Room Air Conditioners (1990)
  - » Refrigerators (1993)
  - » Dishwashers/Clothes Washers/Dryers (1994)
  - » Room Air Conditioners (2000)
  - » Refrigerators (2001)
  - » Soil-sensing Dishwashers (2003)
  - » Clothes Washers (2004 and 2007)
  - » Dehumidifiers (2007 and 2012, proposed)
- Super Efficient Refrigerator Program Winner (1992)
- Led in crafting Green Lights Program, an Environmental Protection Agency precursor to ENERGY STAR Program (1996)
- Recognized as leader in resource efficiency with over 100 international, national and state awards received since 1991

Residential Electricity Consumption

United States, 1999:



WHITE GOODS*

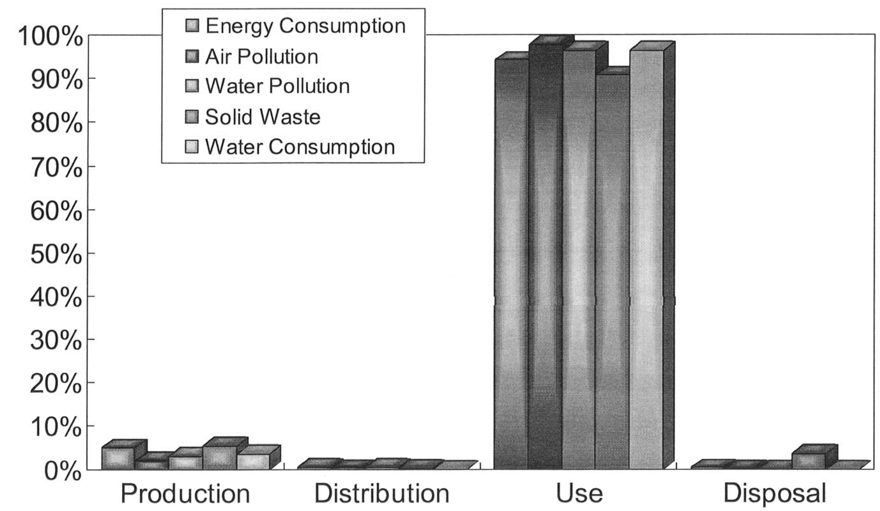
Refrigerator	**11%**	**Cooking**	**3%**
Clothes Dryer	**6%**	**Dishwasher**	**1%**
Freezer	**3%**		
Clothes Washer	**4%**		

* Factors in hot water use

Source: Energy Information Administration/Annual Energy *Outlook 2000*

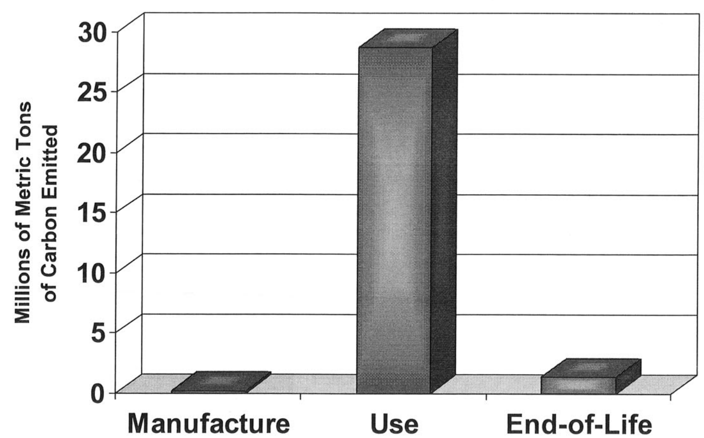
Cradle-to-Grave Assessment of Environmental Impact

Example: Clothes Washer



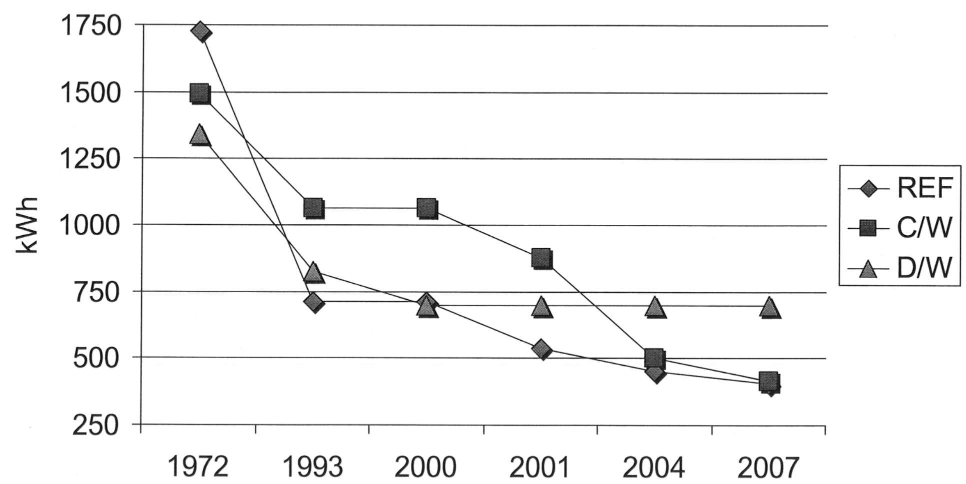
Source: "Ecolabelling Criteria for Washing Machines"
Proposal by the UK Ecolabelling Board, August 1992

Our Own Data Confirms the U.K. Study of Lifecycle Emissions Impact

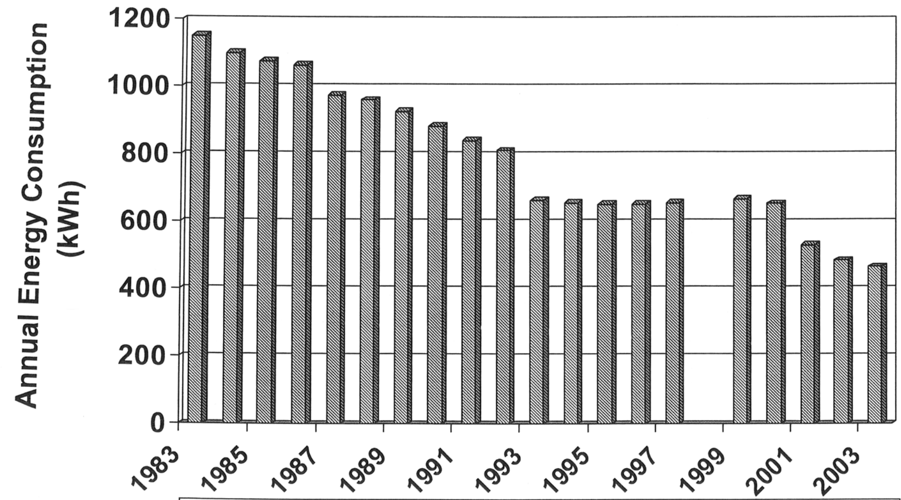


Home Appliance Energy Efficiency Improvements

Annual Average KilowattHour Usage:

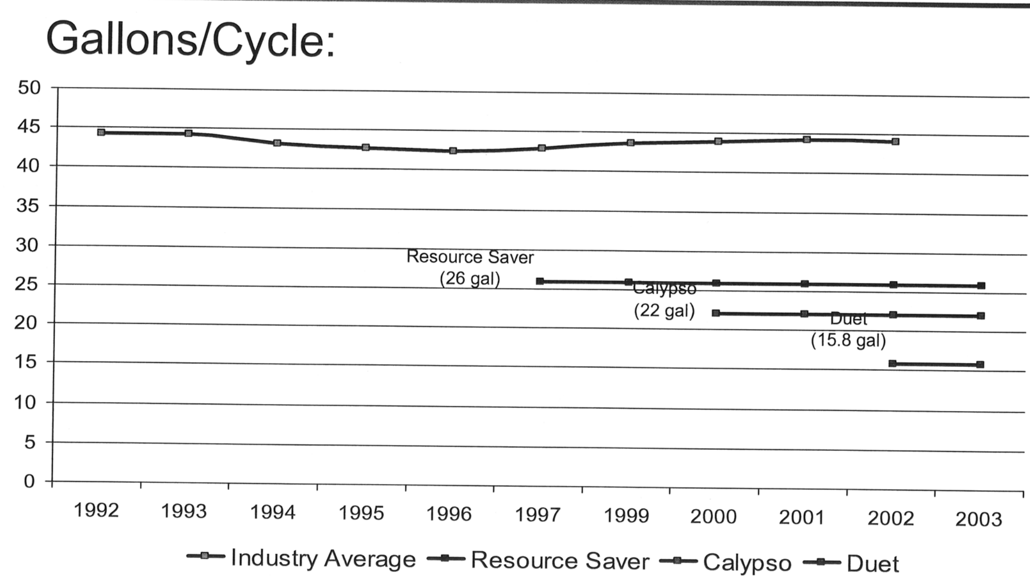


Consumer Benefits from Early Replacement--Refrigerator Example



Today's refrigerator uses 61% less energy, saving the consumer $59 / year vs 20-year old unit

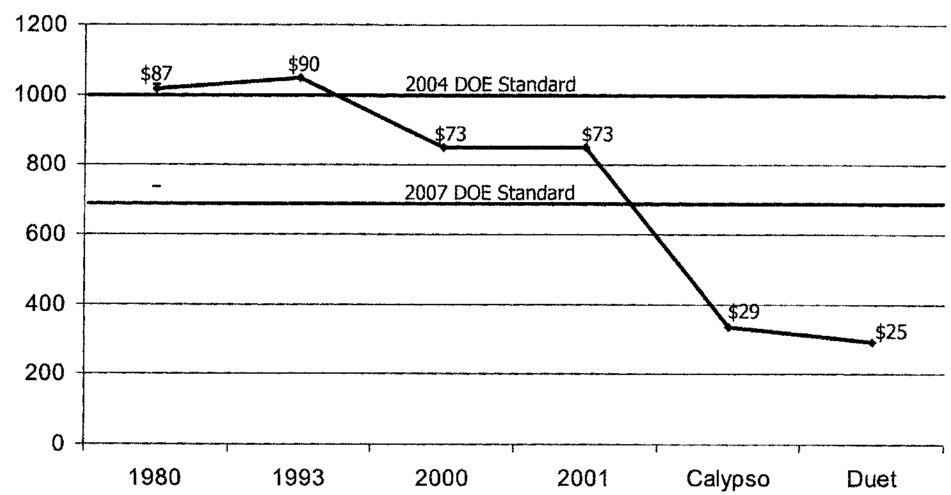
Clothes Washer Average Water Usage



Source: Whirlpool Corporation data and AHAM Industry data

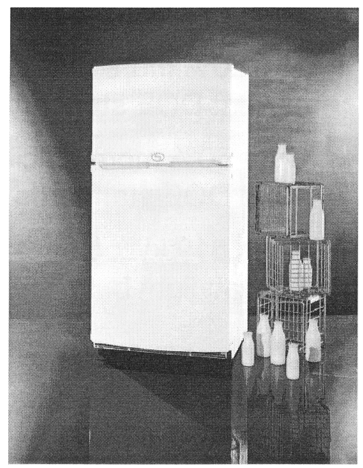
Clothes Washer Efficiency

Average Annual kilowatt-hour Usage and Cost to Operate*:



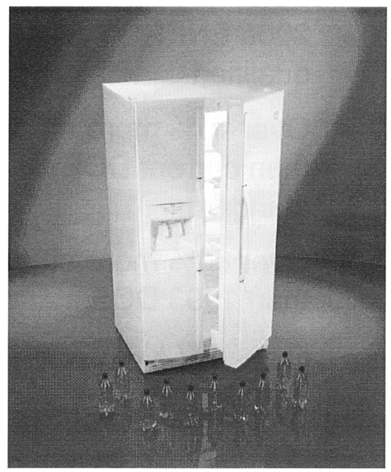
* Based on August, 2001 U.S. EIA reported average rate/kWh

TOP-MOUNT REFRIGERATORS



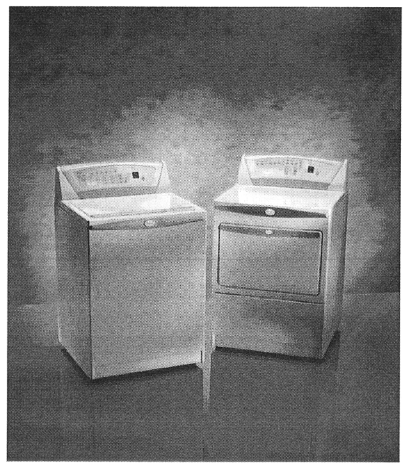
- 2005 ENERGY STAR® qualified
- Over 15% more efficient than current DOE standards
- Over 60% more efficient than 1993 DOE standards
- Uses 467 kWh/year

SIDE BY SIDE REFRIGERATORS



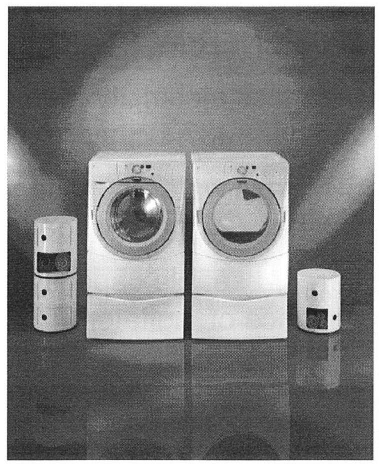
- 2005 ENERGY STAR® qualified
- 15 - 20% more efficient than current DOE standards
- Over 60% more efficient than 1993 DOE standards
- Uses 619 kWh/year - equal to a 75-watt light bulb

CALYPSO CLOTHES WASHER



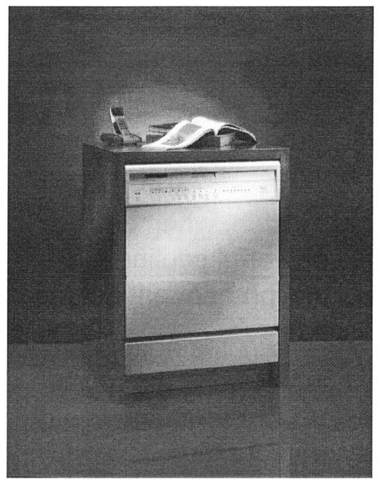
- 2005 ENERGY STAR® qualified
- 66% less electricity than standard washer - 337 kWh/yr
- 50% less water than standard washer - 22 gallons/load
- Larger useable capacity because of absence of agitator

DUET CLOTHES WASHER



- 2005 ENERGY STAR® qualified
- 68% less electricity than standard washer - 292 kWh/yr
- 67% less water than standard washer - 15.8 gallons/load
- 28% larger capacity than standard top-loading washer means fewer loads

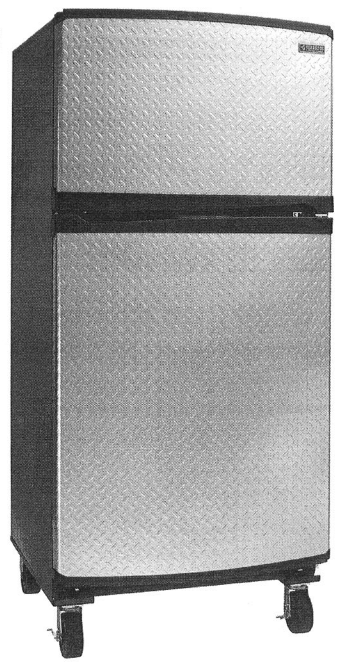
DISHWASHERS



- 2005 ENERGY STAR® qualified
- 27% less electricity than standard dishwasher - 53 kWh/yr
- 30% less water than standard dishwasher - 4.7 gallons/load

88

Gladiator™--Innovation Meets Efficiency

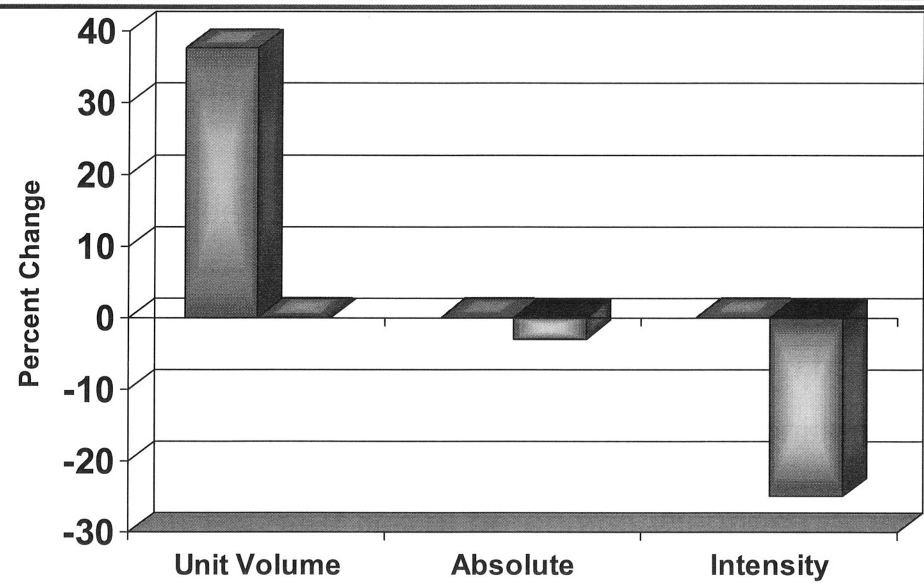


- 18 cu.ft. ENERGY STAR® Garage Refrigerator/Freezer…the only refrigerator designed to operate in the extreme garage environment
- Stays chilled inside, when it is freezing outside…even in very cold environments
- Stays cold inside, when it is hot outside…powerful cooling system operates in high heat environments
- Stays dry, when it is humid outside… special heater keeps the outside of the refrigerator from sweating in high humidity environments
- Rounded tread plate doors…sleek and rugged appearance

Whirlpool's Greenhouse Gas Emissions Commitment

- Using 1998 annual total global manufacturing, use and end-of-life emissions as our baseline...
- Whirlpool Corporation will decrease our absolute total emissions by 3% by 2008…
- Despite increasing our unit sales by nearly 40% during that period...
- Resulting in an annual savings of 4 million metric tons of carbon in absolute savings and 15 million metric tons of carbon annually compared to our 1998 per unit rate of emissions.

Global Carbon Emission Reduction Target: 1998 - 2008



What Does 15 Million Metric Tons Represent?

- 28 fewer coal-fired power plants required
- The equivalent of 10 million fewer cars on the highway

This is a Global Effort

Emissions per unit reductions from 1998 to 2008

- Europe, India, and China >20%
- US & Canada nearly 30%, but from a higher starting point
- Metric tons of Carbon over useful life of product

With global sales forecast to increase by nearly 40%, total Carbon emissions during the 10 years will be:

- Reduced over 40% from refrigerants and blowing agents
- Reduced nearly 10% from manufacturing operations
- Essentially unchanged emissions for utilities supplying our products

Success Stories from Around the Globe

- Ohio, USA
  - » The Findlay Division replaced Methyl Ethyl Ketone (MEK) with a less toxic chemical. The result was a 30% reduction in Volatile Organic Compound emissions and eliminating SARA reporting requirements
  - » Steps taken by the Marion Division reduced the solvent emissions, commonly called HAP's or Hazardous Air pollutants, by 60% according to company data
- Brazil
  - » Since 1994, appliances produced by the company have saved between 40% and 50% in energy consumption. Brazilian refrigeration industry voluntarily committed to reduce energy consumption by 50% from 1998 - 2002.
  - » Removal of CFC's by voiding hermetic system during equipment maintenance resulted in Ozone Group winning the Super Ecology 2002 Award
- India
  - » Through Whirlpool's Environmental Management System, Whirlpool India achieved savings of $10,400 in water and $63,000 in electrical and diesel conservation over a five-year period. The numbers only reflect the water and electricity usage in the factory and not consumer savings, which are far more substantial.

Significant Environmental Benefits Through Market-based Transformational Programs

Potential energy savings and environmental benefits if all new appliances sold in the U.S. were ENERGY STAR® qualified:

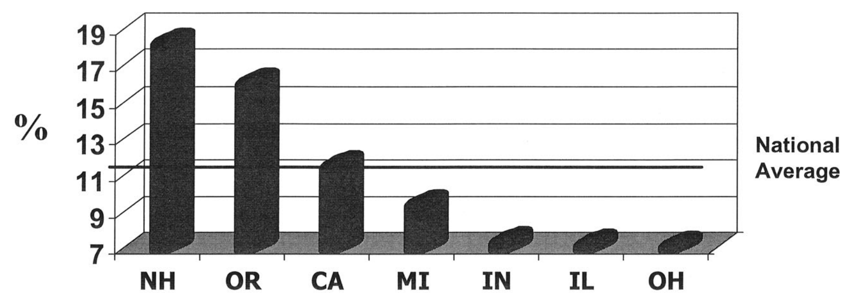
TYPE OF SAVINGS*	AFTER 1 YEAR	AFTER 5 YEARS	AFTER 10 YEARS	AFTER 15 YEARS
Electricity Saved (kilowatt hours)	3.4 billion	21 billion	41 billion	61 billion
Water Saved (gallons)	68 billion	418 billion	784 billion	1.2 trillion
Gas Saved (therms)	109 million	667 million	1.2 billion	1.9 billion
Savings on Monthly Electricity Bills	$ 618 million	$ 3.7 billion	$7.3 billion	$ 10.9 billion
Carbon Emissions Avoided (metric tons)	2.4 million	15.6 million	28.6 million	43.7 million
→ Equivalent to taking # of cars off roads	462,000 cars	3 million cars	5.5 million cars	8.4 million cars
Carbon Dioxide Avoided (metric tons)	2.1 million	13.2 million	25.3 million	38 million
Nitrogen Oxides Avoided (kilograms)	7.3 million	46 million	88 million	132 million
Sulfur Oxides Avoided (kilograms)	10.6 million	67 million	128 million	193 million

Market-oriented Policies and Measures Contained in U.S. Energy Bill...if passed

Appliance Manufacturer Tax Credit:

- The legislation will save over 200 trillion BTUs of energy or the equivalent of taking 2.3 million cars off the road or halt 6 coal-fired power plants for a year.
- The bill, by encouraging the manufacture of super-efficient washing machines, will reduce the amount of water necessary to wash clothes by 870 billion gallons or approximately the amount of water necessary to meet the needs of every household in a city the size of Phoenix, Arizona for two years.
- The credit is only earned if the level of production exceeds the average of the previous three years' production.

ENERGY STAR® WASHER MARKET PENETRATION 2000



- If every household in Ohio owned an ENERGY STAR® washer, each family would save 631 kWh, 10,333 gallons of water and $100 annually. As a state, that would equal 2.8 million megawatt-hours, 45.9 billion gallons of water and $444.5 million for consumers annually.
- If every U.S. household owned a high efficiency washer, we could save more than 1 trillion gallons of water and 58 million megawatt-hours of electricity annually.

A HYPOTHETICAL DEMAND-SIDE MANAGEMENT SOLUTION FOR OHIO

----Reduce energy demand by rewarding consumers who purchase super-efficient home appliances that meet or exceed EPA/DOE's demanding ENERGY STAR® standards.

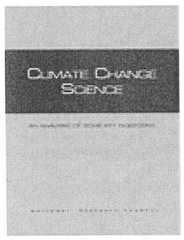
----Pass a four-year, state sales tax exemption for consumers of ENERGY STAR® clothes washers, dishwashers, refrigerators and dehumidifiers

Tax Exemption Benefits Consumers...

- Lets them contribute in visible, personal way to national energy conservation and environmental improvements
- Reduces their monthly electricity and water bills
  - » Replacement package of new Energy Star refrigerator, washer and dishwasher, made in Ohio, compared to standard prior products would save consumer in Toledo or Cleveland at least $300 per year in utility bills
- Lets them spend utility bill savings on other goods and services

Benefits to Ohio of hypothetical tax exemption

• Electricity/gas/water savings:	$261 million
• Carbon savings	224,107 m/t
• CO_2 avoided	822,472 m/t
• Columbus household lighting days	3.66 yrs.
• Total showers	1.035 billion
• Cars eliminated	181,160
• Miles not driven	2.0 billion



Climate Change Science: An Analysis of Some Key Questions

Committee on the Science of Climate Change, National Research Council

ISBN: 0-309-07574-2, 42 pages, 8.5 x 11, (2001)

CLIMATE CHANGE SCIENCE

AN ANALYSIS OF SOME KEY QUESTIONS

Committee on the Science of Climate Change

Division on Earth and Life Studies

National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.

NATIONAL ACADEMY PRESS 2101 Constitution Avenue, N.W. Washington, D.C. 20418

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

International Standard Book Number 0-309-07574-2

Additional copies of this report are available from:

National Academy Press
2101 Constitution Avenue, N.W.
Lockbox 285
Washington, D.C. 20055
(800) 624-6242
(202) 334-3313 (in the Washington metropolitan area)
http://www.nap.edu

Printed in the United States of America

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

COMMITTEE ON THE SCIENCE OF CLIMATE CHANGE

RALPH J. CICERONE *(Chair)*, University of California, Irvine
ERIC J. BARRON, Pennsylvania State University, University Park
ROBERT E. DICKINSON, Georgia Institute of Technology, Atlanta
INEZ Y. FUNG, University of California, Berkeley
JAMES E. HANSEN, NASA/Goddard Institute for Space Studies, New York, New York
THOMAS R. KARL, NOAA/National Climatic Data Center, Asheville, North Carolina
RICHARD S. LINDZEN, Massachusetts Institute of Technology, Cambridge
JAMES C. McWILLIAMS, University of California, Los Angeles
F. SHERWOOD ROWLAND, University of California, Irvine
EDWARD S. SARACHIK, University of Washington, Seattle
JOHN M. WALLACE, University of Washington, Seattle

Consultant

DANIEL L. ALBRITTON, NOAA/Aeronomy Laboratory, Boulder, Colorado

Staff

VAUGHAN C. TUREKIAN, Study Director
DIANE L. GUSTAFSON, Senior Project Assistant

Foreword

This study originated from a White House request to help inform the Administration's ongoing review of U.S. climate change policy. In particular, the written request (Appendix A) asked for the National Academies' "assistance in identifying the areas in the science of climate change where there are the greatest certainties and uncertainties," and "views on whether there are any substantive differences between the IPCC [Intergovernmental Panel on Climate Change] Reports and the IPCC summaries." In addition, based on discussions with the Administration, the following specific questions were incorporated into the statement of task for the study:

- *What is the range of natural variability in climate?*
- *Are concentrations of greenhouse gases and other emissions that contribute to climate change increasing at an accelerating rate, and are different greenhouse gases and other emissions increasing at different rates?*
- *How long does it take to reduce the buildup of greenhouse gases and other emissions that contribute to climate change?*
- *What other emissions are contributing factors to climate change (e.g., aerosols, CO, black carbon soot), and what is their relative contribution to climate change?*
- *Do different greenhouse gases and other emissions have different draw down periods?*
- *Are greenhouse gases causing climate change?*
- *Is climate change occurring? If so, how?*
- *Is human activity the cause of increased concentrations of greenhouse gases and other emissions that contribute to climate change?*
- *How much of the expected climate change is the consequence of climate feedback processes (e.g., water vapor, clouds, snow packs)?*
- *By how much will temperatures change over the next 100 years and where?*
- *What will be the consequences (e.g., extreme weather, health effects) of increases of various magnitudes?*
- *Has science determined whether there is a "safe" level of concentration of greenhouse gases?*
- *What are the substantive differences between the IPCC Reports and the Summaries?*
- *What are the specific areas of science that need to be studied further, in order of priority, to advance our understanding of climate change?*

The White House asked for a response "as soon as possible" but no later than early June—less than one month after submitting its formal request.

The National Academies has a mandate arising from its 1863 charter to respond to government requests when asked. In view of the critical nature of this issue, we agreed to undertake this study and to use our own funds to support it.

A distinguished committee with broad expertise and diverse perspectives on the scientific issues of climate change was therefore appointed through the National Academies' National Research Council (see Appendix B for biographical information on committee members). In early May, the committee held a conference call to discuss the specific questions and to prepare for its 2-day meeting (May 21-22, 2001) in Irvine, California. The committee reviewed the 14 questions and determined that they represent important issues in climate change science and could serve as a useful framework for addressing the two general questions from the White House.

For the task of comparing IPCC Reports and Summaries, the committee focused its review on the work of IPCC Working Group I, which dealt with many of the same detailed questions being asked above. The committee decided to address the questions in the context of a brief document that also could serve as a primer for policy makers on climate change science. To aid in the presentation, the questions have been organized into seven sections, with the questions addressed in each section listed in *italics* at the beginning of that section.

While traditional procedures for an independent NRC study, including review of the report by independent experts, were followed, it is important to note that tradeoffs were made in order to accommodate the rapid schedule. For example, the report does not provide extensive references to the scientific literature or marshal detailed evidence to support its "answers" to the questions. Rather, the report largely presents the consensus scientific views and judgments of committee members, based on the accumulated knowledge that these individuals have gained—both through their own scholarly efforts and through formal and informal interactions with the world's climate change science community.

The result is a report that, in my view, provides policy makers with a succinct and balanced overview of what science can currently say about the potential for future climate change, while outlining the uncertainties that remain in our scientific knowledge.

The report does not make policy recommendations regarding what to do about the potential of global warming. Thus, it does not estimate the potential economic and environmental costs, benefits, and uncertainties regarding various policy responses and future human behaviors. While beyond the charge presented to this committee, scientists and social scientists have the ability to provide assessments of this type as well. Both types of assessments can be helpful to policy makers, who frequently have to weigh tradeoffs and make decisions on important issues, despite the inevitable uncertainties in our scientific understanding concerning particular aspects. Science never has all the answers. But science does provide us with the best available guide to the future, and it is critical that our nation and the world base important policies on the best judgments that science can provide concerning the future consequences of present actions.

I would especially like to thank the members of this committee and its staff for an incredible effort in producing this important report in such a short period of time. They have sacrificed many personal commitments and worked long weekends to provide the nation with their considered judgments on this critical issue.

Bruce Alberts
President
National Academy of Sciences

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Betsy Ancker-Johnson, General Motors Corporation (retired), Austin, Texas
Wallace S. Broecker, Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York
David L. Dilcher, University of Florida, Gainesville
Thomas M. Donahue, University of Michigan, Ann Arbor
James R. Holton, University of Washington, Seattle
Jerry D. Mahlman, NOAA/Geophysical Fluid Dynamics Laboratory (retired), Princeton, New Jersey
Syukuro Manabe, Institute for Global Change Research, Yokohama City, Japan
Pamela A. Matson, Stanford University, California
William D. Nordhaus, Yale University, New Haven, Connecticut
Eugene M. Rasmusson, University of Maryland, College Park
Susan Solomon, NOAA/Aeronomy Laboratory, Boulder, Colorado
Andrew R. Solow, Woods Hole Oceanographic Institution, Massachusetts
Grace Wahba, University of Wisconsin, Madison

Although the reviewers listed above have provided constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Richard M. Goody (Harvard University) and Robert A. Frosch (Harvard University). Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

We would also like to thank the following individuals for their input regarding the IPCC process: John Christy, Haroon Kheshgi, Michael Mann, Jerry Meehl, Berrien Moore, Michael Oppenheimer, Joyce Penner, Ray Pierrehumbert, Michael Prather, Venkatachalam Ramaswamy, Ben Santer, Piers Sellers, Susan Solomon, Ron Stouffer, Kevin Trenberth, and Robert Watson.

Contents

Summary

Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability. Human-induced warming and associated sea level rises are expected to continue through the 21st century. Secondary effects are suggested by computer model simulations and basic physical reasoning. These include increases in rainfall rates and increased susceptibility of semi-arid regions to drought. The impacts of these changes will be critically dependent on the magnitude of the warming and the rate with which it occurs.

The mid-range model estimate of human induced global warming by the Intergovernmental Panel on Climate Change (IPCC) is based on the premise that the growth rate of climate forcing[1] agents such as carbon dioxide will accelerate. The predicted warming of 3°C (5.4°F) by the end of the 21st century is consistent with the assumptions about how clouds and atmospheric relative humidity will react to global warming. This estimate is also consistent with inferences about the sensitivity[2] of climate drawn from comparing the sizes of past temperature swings between ice ages and intervening warmer periods with the corresponding changes in the climate forcing. This predicted temperature increase is sensitive to assumptions concerning future concentrations of greenhouse gases and aerosols. Hence, national policy decisions made now and in the longer-term future will influence the extent of any damage suffered by vulnerable human populations and ecosystems later in this century. Because there is considerable uncertainty in current understanding of how the climate system varies naturally and reacts to emissions of greenhouse gases and aerosols, current estimates of the magnitude of future warming should be regarded as tentative and subject to future adjustments (either upward or downward).

Reducing the wide range of uncertainty inherent in current model predictions of global climate change will require major advances in understanding and modeling of both (1) the factors that determine atmospheric concentrations of greenhouse gases and aerosols, and (2) the so-called "feedbacks" that determine the sensitivity of the climate system to a prescribed increase in greenhouse gases. There also is a pressing need for a global observing system designed for monitoring climate.

The committee generally agrees with the assessment of human-caused climate change presented in the IPCC Working Group I (WGI) scientific report, but seeks here to articulate more clearly the level of confidence that can be ascribed to those assessments and the caveats that need to be attached to them. This articulation may be helpful to policy makers as they consider a variety of options for mitigation and/or adaptation. In the sections that follow, the committee provides brief responses to some of the key questions related to climate change science. More detailed responses to these questions are located in the main body of the text.

What is the range of natural variability in climate?

The range of natural climate variability is known to be quite large (in excess of several degrees Celsius) on local

[1]A climate forcing is defined as an imposed perturbation of Earth's energy balance. Climate forcing is typically measured in watts per square meter (W/m2).

[2]The sensitivity of the climate system to a prescribed forcing is commonly expressed in terms of the global mean temperature change that would be expected after a time sufficiently long for both the atmosphere and ocean to come to equilibrium with the change in climate forcing.

and regional spatial scales over periods as short as a decade. Precipitation also can vary widely. For example, there is evidence to suggest that droughts as severe as the "dust bowl" of the 1930s were much more common in the central United States during the 10th to 14th centuries than they have been in the more recent record. Mean temperature variations at local sites have exceeded 10°C (18°F) in association with the repeated glacial advances and retreats that occurred over the course of the past million years. It is more difficult to estimate the natural variability of global mean temperature because of the sparse spatial coverage of existing data and difficulties in inferring temperatures from various proxy data. Nonetheless, evidence suggests that global warming rates as large as 2°C (3.6°F) per millennium may have occurred during retreat of the glaciers following the most recent ice age.

Are concentrations of greenhouse gases and other emissions that contribute to climate change increasing at an accelerating rate, and are different greenhouse gases and other emissions increasing at different rates? Is human activity the cause of increased concentrations of greenhouse gases and other emissions that contribute to climate change?

The emissions of some greenhouse gases are increasing, but others are decreasing. In some cases the decreases are a result of policy decisions, while in other cases the reasons for the decreases are not well understood.

Of the greenhouse gases that are directly influenced by human activity, the most important are carbon dioxide, methane, ozone, nitrous oxide, and chlorofluorocarbons (CFCs). Aerosols released by human activities are also capable of influencing climate. (Table 1 lists the estimated climate forcing due to the presence of each of these "climate forcing agents" in the atmosphere.)

Concentrations of carbon dioxide (CO_2) extracted from ice cores drilled in Greenland and Antarctica have typically ranged from near 190 parts per million by volume (ppmv) during the ice ages to near 280 ppmv during the warmer "interglacial" periods like the present one that began around 10,000 years ago. Concentrations did not rise much above 280 ppmv until the Industrial Revolution. By 1958, when systematic atmospheric measurements began, they had reached 315 ppmv, and they are currently ~370 ppmv and rising at a rate of 1.5 ppmv per year (slightly higher than the rate during the early years of the 43-year record). Human activities are responsible for the increase. The primary source, fossil fuel burning, has released roughly twice as much carbon dioxide as would be required to account for the observed increase. Tropical deforestation also has contributed to carbon dioxide releases during the past few decades. The excess carbon dioxide has been taken up by the oceans and land biosphere.

Like carbon dioxide, methane (CH_4) is more abundant in Earth's atmosphere now than at any time during the 400,000 year long ice core record, which dates back over a number of glacial/interglacial cycles. Concentrations increased rather smoothly by about 1% per year from 1978, until about 1990. The rate of increase slowed and became more erratic during the 1990s. About two-thirds of the current emissions of methane are released by human activities such as rice growing, the raising of cattle, coal mining, use of land-fills, and natural gas handling, all of which have increased over the past 50 years.

A small fraction of the ozone (O_3) produced by natural processes in the stratosphere mixes into the lower atmosphere. This "tropospheric ozone" has been supplemented during the 20th century by additional ozone, created locally by the action of sunlight upon air polluted by exhausts from motor vehicles, emissions from fossil fuel burning power plants, and biomass burning.

Nitrous oxide (N_2O) is formed by many microbial reactions in soils and waters, including those acting on the increasing amounts of nitrogen-containing fertilizers. Some synthetic chemical processes that release nitrous oxide have also been identified. Its concentration has increased approximately 13% in the past 200 years.

Atmospheric concentrations of CFCs rose steadily following their first synthesis in 1928 and peaked in the early 1990s. Many other industrially useful fluorinated compounds (e.g., carbon tetrafluoride, CF_4, and sulfur hexafluoride, SF_6), have very long atmospheric lifetimes, which is of concern, even though their atmospheric concentrations have not yet produced large radiative forcings. Hydrofluorocarbons (HFCs), which are replacing CFCs, have a greenhouse effect, but it is much less pronounced because of their shorter atmospheric lifetimes. The sensitivity and generality of modern analytical systems make it quite unlikely that any currently significant greenhouse gases remain to be discovered.

What other emissions are contributing factors to climate change (e.g., aerosols, CO, black carbon soot), and what is their relative contribution to climate change?

Besides greenhouse gases, human activity also contributes to the atmospheric burden of aerosols, which include both sulfate particles and black carbon (soot). Both are unevenly distributed, owing to their short lifetimes in the atmosphere. Sulfate particles scatter solar radiation back to space, thereby offsetting the greenhouse effect to some degree. Recent "clean coal technologies" and use of low sulfur fuels have resulted in decreasing sulfate concentrations, especially in North America, reducing this offset. Black carbon aerosols are end-products of the incomplete combustion of fossil fuels and biomass burning (forest fires and land clearing). They impact radiation budgets both directly and indirectly; they are believed to contribute to global warming, although their relative importance is difficult to quantify at this point.

How long does it take to reduce the buildup of greenhouse gases and other emissions that contribute to climate change? Do different greenhouse gases and other emissions have different draw down periods?

TABLE 1 Removal Times and Climate Forcing Values for Specified Atmospheric Gases and Aerosols

Forcing Agent	Approximate Removal Times[3]	Climate Forcing (W/m^2) Up to the year 2000
Greenhouse Gases		
Carbon Dioxide	>100 years	1.3 to 1.5
Methane	10 years	0.5 to 0.7
Tropospheric Ozone	10-100 days	0.25 to 0.75
Nitrous Oxide	100 years	0.1 to 0.2
Perfluorocarbon Compounds (Including SF_6)	>1000 years	0.01
Fine Aerosols		
Sulfate	10 days	−0.3 to −1.0
Black Carbon	10 days	0.1 to 0.8

[3]A removal time of 100 years means that much, but not all, of the substance would be gone in 100 years. Typically, the amount remaining at the end of 100 years is 37%; after 200 years 14%; after 300 years 5%; after 400 years 2%.

Is climate change occurring? If so, how?

Weather station records and ship-based observations indicate that global mean surface air temperature warmed between about 0.4 and 0.8°C (0.7 and 1.5°F) during the 20th century. Although the magnitude of warming varies locally, the warming trend is spatially widespread and is consistent with an array of other evidence detailed in this report. The ocean, which represents the largest reservoir of heat in the climate system, has warmed by about 0.05°C (0.09°F) averaged over the layer extending from the surface down to 10,000 feet, since the 1950s.

The observed warming has not proceeded at a uniform rate. Virtually all the 20th century warming in global surface air temperature occurred between the early 1900s and the 1940s and during the past few decades. The troposphere warmed much more during the 1970s than during the two subsequent decades, whereas Earth's surface warmed more during the past two decades than during the 1970s. The causes of these irregularities and the disparities in the timing are not completely understood. One striking change of the past 35 years is the cooling of the stratosphere at altitudes of ~13 miles, which has tended to be concentrated in the wintertime polar cap region.

Are greenhouse gases causing climate change?

The IPCC's conclusion that most of the observed warming of the last 50 years is likely to have been due to the increase in greenhouse gas concentrations accurately reflects the current thinking of the scientific community on this issue. The stated degree of confidence in the IPCC assessment is higher today than it was 10, or even 5 years ago, but uncertainty remains because of (1) the level of natural variability inherent in the climate system on time scales of decades to centuries, (2) the questionable ability of models to accurately simulate natural variability on those long time scales, and (3) the degree of confidence that can be placed on reconstructions of global mean temperature over the past millennium based on proxy evidence. Despite the uncertainties, there is general agreement that the observed warming is real and particularly strong within the past 20 years. Whether it is consistent with the change that would be expected in response to human activities is dependent upon what assumptions one makes about the time history of atmospheric concentrations of the various forcing agents, particularly aerosols.

By how much will temperatures change over the next 100 years and where?

Climate change simulations for the period of 1990 to 2100 based on the IPCC emissions scenarios yield a globally-averaged surface temperature increase by the end of the century of 1.4 to 5.8°C (2.5 to 10.4°F) relative to 1990. The wide range of uncertainty in these estimates reflects both the different assumptions about future concentrations of greenhouse gases and aerosols in the various scenarios considered by the IPCC and the differing climate sensitivities of the various climate models used in the simulations. The range of climate sensitivities implied by these predictions is generally consistent with previously reported values.

The predicted warming is larger over higher latitudes than over low latitudes, especially during winter and spring, and larger over land than over sea. Rainfall rates and the frequency of heavy precipitation events are predicted to increase, particularly over the higher latitudes. Higher evaporation rates would accelerate the drying of soils following rain events, resulting in lower relative humidities and higher daytime temperatures, especially during the warm season. The likelihood that this effect could prove important is greatest in semi-arid regions, such as the U.S. Great Plains. These predictions in the IPCC report are consistent with current understanding of the processes that control local climate.

In addition to the IPCC scenarios for future increases in greenhouse gas concentrations, the committee considered a scenario based on an energy policy designed to keep climate change moderate in the next 50 years. This scenario takes into account not only the growth of carbon emissions, but also the changing concentrations of other greenhouse gases and aerosols.

Sufficient time has elapsed now to enable comparisons between observed trends in the concentrations of carbon dioxide and other greenhouse gases with the trends predicted in previous IPCC reports. The increase of global fossil fuel carbon dioxide emissions in the past decade has averaged 0.6% per year, which is somewhat below the range of IPCC scenarios, and the same is true for atmospheric methane concentrations. It is not known whether these slowdowns in growth rate will persist.

How much of the expected climate change is the consequence of climate feedback processes (e.g., water vapor, clouds, snow packs)?

The contribution of feedbacks to the climate change depends upon "climate sensitivity," as described in the report. If a central estimate of climate sensitivity is used, about 40% of the predicted warming is due to the direct effects of greenhouse gases and aerosols. The other 60% is caused by feedbacks. Water vapor feedback (the additional greenhouse effect accruing from increasing concentrations of atmospheric water vapor as the atmosphere warms) is the most important feedback in the models. Unless the relative humidity in the tropical middle and upper troposphere drops, this effect is expected to increase the temperature response to increases in human induced greenhouse gas concentrations by a factor of 1.6. The ice-albedo feedback (the reduction in the fraction of incoming solar radiation reflected back to space as snow and ice cover recede) also is believed to be important. Together, these two feedbacks amplify the simulated climate response to the greenhouse gas forcing by a factor of 2.5. In addition, changes in cloud cover, in the relative amounts of high versus low clouds, and in the mean and vertical distribution of relative humidity could either enhance or reduce the amplitude of the warming. Much of the difference in predictions of global warming by various climate models is attributable to the fact that each model represents these processes in its own particular way. These uncertainties will remain until a more fundamental understanding of the processes that control atmospheric relative humidity and clouds is achieved.

What will be the consequences (e.g., extreme weather, health effects) of increases of various magnitude?

In the near term, agriculture and forestry are likely to benefit from carbon dioxide fertilization and an increased water efficiency of some plants at higher atmospheric CO_2 concentrations. The optimal climate for crops may change, requiring significant regional adaptations. Some models project an increased tendency toward drought over semi-arid regions, such as the U.S. Great Plains. Hydrologic impacts could be significant over the western United States, where much of the water supply is dependent on the amount of snow pack and the timing of the spring runoff. Increased rainfall rates could impact pollution run-off and flood control. With higher sea level, coastal regions could be subject to increased wind and flood damage even if tropical storms do not change in intensity. A significant warming also could have far reaching implications for ecosystems. The costs and risks involved are difficult to quantify at this point and are, in any case, beyond the scope of this brief report.

Health outcomes in response to climate change are the subject of intense debate. Climate is one of a number of factors influencing the incidence of infectious disease. Cold-related stress would decline in a warmer climate, while heat stress and smog induced respiratory illnesses in major urban areas would increase, if no adaptation occurred. Over much of the United States, adverse health outcomes would likely be mitigated by a strong public health system, relatively high levels of public awareness, and a high standard of living.

Global warming could well have serious adverse societal and ecological impacts by the end of this century, especially if globally-averaged temperature increases approach the upper end of the IPCC projections. Even in the more conservative scenarios, the models project temperatures and sea levels that continue to increase well beyond the end of this century, suggesting that assessments that examine only the next 100 years may well underestimate the magnitude of the eventual impacts.

Has science determined whether there is a "safe" level of concentration of greenhouse gases?

The question of whether there exists a "safe" level of concentration of greenhouse gases cannot be answered directly because it would require a value judgment of what constitutes an acceptable risk to human welfare and ecosystems in various parts of the world, as well as a more quantitative assessment of the risks and costs associated with the various impacts of global warming. In general, however, risk increases with increases in both the rate and the magnitude of climate change.

What are the substantive differences between the IPCC Reports and the Summaries?

The committee finds that the full IPCC Working Group I (WGI) report is an admirable summary of research activities in climate science, and the full report is adequately summarized in the *Technical Summary*. The full WGI report and its *Technical Summary* are not specifically directed at policy. The *Summary for Policymakers* reflects less emphasis on communicating the basis for uncertainty and a stronger emphasis on areas of major concern associated with human-induced climate change. This change in emphasis appears to be the result of a summary process in which scientists work with policy makers on the document. Written responses from U.S. coordinating and lead scientific authors to the committee indicate, however, that (a) no changes were made without the consent of the convening lead authors (this group represents a fraction of the lead and contributing authors) and (b) most changes that did occur lacked significant impact.

It is critical that the IPCC process remain truly representative of the scientific community. The committee's concerns focus primarily on whether the process is likely to become less representative in the future because of the growing voluntary time commitment required to participate as a lead or coordinating author and the potential that the scientific process will be viewed as being too heavily influenced by governments which have specific postures with regard to treaties, emission controls, and other policy instruments. The United States should promote actions that improve the IPCC process while also ensuring that its strengths are maintained.

What are the specific areas of science that need to be studied further, in order of priority, to advance our understanding of climate change?

Making progress in reducing the large uncertainties in projections of future climate will require addressing a number of fundamental scientific questions relating to the buildup of greenhouses gases in the atmosphere and the behavior of the climate system. Issues that need to be addressed include (a) the future usage of fossil fuels, (b) the future emissions of methane, (c) the fraction of the future fossil-fuel carbon that will remain in the atmosphere and provide radiative forcing versus exchange with the oceans or net exchange with the land biosphere, (d) the feedbacks in the climate system that determine both the magnitude of the change and the rate of energy uptake by the oceans, which together determine the magnitude and time history of the temperature increases for a given radiative forcing, (e) details of the regional and local climate change consequent to an overall level of global climate change, (f) the nature and causes of the natural variability of climate and its interactions with forced changes, and (g) the direct and indirect effects of the changing distributions of aerosols. Maintaining a vigorous, ongoing program of basic research, funded and managed independently of the climate assessment activity, will be crucial for narrowing these uncertainties.

In addition, the research enterprise dealing with environmental change and the interactions of human society with the environment must be enhanced. This includes support of (a) interdisciplinary research that couples physical, chemical, biological, and human systems, (b) an improved capability of integrating scientific knowledge, including its uncertainty, into effective decision support systems, and (c) an ability to conduct research at the regional or sectoral level that promotes analysis of the response of human and natural systems to multiple stresses.

An effective strategy for advancing the understanding of climate change also will require (1) a global observing system in support of long-term climate monitoring and prediction, (2) concentration on large-scale modeling through increased, dedicated supercomputing and human resources, and (3) efforts to ensure that climate research is supported and managed to ensure innovation, effectiveness, and efficiency.

1

Climate, Climate Forcings, Climate Sensitivity, and Transient Climate Change

CLIMATE

Climate is the average state of the atmosphere and the underlying land or water, on time scales of seasons and longer. Climate is typically described by the statistics of a set of atmospheric and surface variables, such as temperature, precipitation, wind, humidity, cloudiness, soil moisture, sea surface temperature, and the concentration and thickness of sea ice. The statistics may be in terms of the long-term average, as well as other measures such as daily minimum temperature, length of the growing season, or frequency of floods. Although climate and climate change are usually presented in global mean terms, there may be large local and regional departures from these global means. These can either mitigate or exaggerate the impact of climate change in different parts of the world.

A number of factors contribute to climate and climate change, and it is useful to define the terms climate forcings, climate sensitivity, and transient climate change for discussion below.

CLIMATE FORCINGS

A climate forcing can be defined as an imposed perturbation of Earth's energy balance. Energy flows in from the sun, much of it in the visible wavelengths, and back out again as long-wave infrared (heat) radiation. An increase in the luminosity of the sun, for example, is a positive forcing that tends to make Earth warmer. A very large volcanic eruption, on the other hand, can increase the aerosols (fine particles) in the lower stratosphere (altitudes of 10-15 miles) that reflect sunlight to space and thus reduce the solar energy delivered to Earth's surface. These examples are natural forcings. Human-made forcings result from, for example, the gases and aerosols produced by fossil fuel burning, and alterations of Earth's surface from various changes in land use, such as the conversion of forests into agricultural land. Those gases that absorb infrared radiation, i.e., the "greenhouse" gases, tend to prevent this heat radiation from escaping to space, leading eventually to a warming of Earth's surface. The observations of human-induced forcings underlie the current concerns about climate change.

The common unit of measure for climatic forcing agents is the energy perturbation that they introduce into the climate system, measured in units of watts per square meter (W/m^2). The consequences from such forcings are often then expressed as the change in average global temperature, and the conversion factor from forcing to temperature change is the sensitivity of Earth's climate system. Although some forcings—volcanic plumes, for example—are not global in nature and temperature change may also not be uniform, comparisons of the strengths of individual forcings, over comparable areas, are useful for estimating the relative importance of the various processes that may cause climate change.

CLIMATE SENSITIVITY

The sensitivity of the climate system to a forcing is commonly expressed in terms of the global mean temperature change that would be expected after a time sufficiently long for both the atmosphere and ocean to come to equilibrium with the change in climate forcing. If there were no climate feedbacks, the response of Earth's mean temperature to a forcing of 4 W/m^2 (the forcing for a doubled atmospheric CO_2) would be an increase of about 1.2°C (about 2.2°F). However, the total climate change is affected not only by the immediate direct forcing, but also by climate "feedbacks" that come into play in response to the forcing. For example, a climate forcing that causes warming may melt some of the sea ice. This is a positive feedback because the darker ocean absorbs more sunlight than the sea ice it replaced. The responses of atmospheric water vapor amount and clouds probably generate the most important global climate feedbacks. The nature and magnitude of these hydrologic feedbacks give rise to the largest source of uncertainty about climate sensitivity, and they are an area of continuing research.

As just mentioned, a doubling of the concentration of carbon dioxide (from the pre-Industrial value of 280 parts per million) in the global atmosphere causes a forcing of 4 W/m^2. The central value of the climate sensitivity to this change is a global average temperature increase of 3°C (5.4°F), but with a range from 1.5°C to 4.5°C (2.7 to 8.1°F) (based on climate system models: see section 4). The central value of 3°C is an amplification by a factor of 2.5 over the direct effect of 1.2°C (2.2°F). Well-documented climate changes during the history of Earth, especially the changes between the last major ice age (20,000 years ago) and the current warm period, imply that the climate sensitivity is near the 3°C value. However, the true climate sensitivity remains uncertain, in part because it is difficult to model the effect of cloud feedback. In particular, the magnitude and even the sign of the feedback can differ according to the composition, thickness, and altitude of the clouds, and some studies have suggested a lesser climate sensitivity. On the other hand, evidence from paleoclimate variations indicates that climate sensitivity could be higher than the above range, although perhaps only on longer time scales.

TRANSIENT CLIMATE CHANGE

Climate fluctuates in the absence of any change in forcing, just as weather fluctuates from day to day. Climate also responds in a systematic way to climate forcings, but the response can be slow because the ocean requires time to warm (or cool) in response to the forcing. The response time depends upon the rapidity with which the ocean circulation transmits changes in surface temperature into the deep ocean. If the climate sensitivity is as high as the 3°C mid-range, then a few decades are required for just half of the full climate response to be realized, and at least several centuries for the full response.[1]

Such a long climate response time complicates the climate change issue for policy makers because it means that a discovered undesirable climate change is likely to require many decades to halt or reverse.

Increases in the temperature of the ocean that are initiated in the next few decades will continue to raise sea level by ocean thermal expansion over the next several centuries. Although society might conclude that it is practical to live with substantial climate change in the coming decades, it is also important to consider further consequences that may occur in later centuries. The climate sensitivity and the dynamics of large ice sheets become increasingly relevant on such longer time scales.

It is also possible that climate could undergo a sudden large change in response to accumulated climate forcing. The paleoclimate record contains examples of sudden large climate changes, at least on regional scales. Understanding these rapid changes is a current research challenge that is relevant to the analysis of possible anthropogenic climate effects.

[1]The time required for the full response to be realized depends, in part, on the rate of heat transfer from the ocean mixed layer to the deeper ocean. Slower transfer leads to shorter response times on Earth's surface.

2

Natural Climatic Variations

What is the range of natural variability in climate?

Climate is continually varying on time scales ranging from seasons to the lifetime of Earth. Natural climate changes can take place on short time scales as a result of the rapid alterations to forcings (as described in section 1). For example, the injection of large quantities of sulfur dioxide (SO_2), which changes to sulfuric acid droplets, and fine particulate material into the stratosphere (the region between 10 and 30 miles altitude where the temperature rises with increasing altitude) by major volcanic eruptions like that of Mt. Pinatubo in 1991 can cause intervals of cooler than average global temperatures. Climate variability also can be generated by processes operating within the climate system—the periodic rapid warming trend in the eastern Pacific Ocean known as El Niño being perhaps the best known example. Each of these different processes produces climate variability with its own characteristic spatial and seasonal signature. For example, El Niño typically brings heavy rainstorms to coastal Ecuador, Peru, and California and droughts to Indonesia and Northeast Brazil.

Over long time scales, outside the time period in which humans could have a substantive effect on global climate (e.g., prior to the Industrial Revolution), proxy data (information derived from the content of tree rings, cores from marine sediments, pollens, etc.) have been used to estimate the range of natural climate variability. An important recent addition to the collection of proxy evidence is ice cores obtained by international teams of scientists drilling through miles of ice in Antarctica and at the opposite end of the world in Greenland. The results can be used to make inferences about climate and atmospheric composition extending back as long as 400,000 years. These and other proxy data indicate that the range of natural climate variability is in excess of several degrees C on local and regional space scales over periods as short as a decade. Precipitation has also varied widely. For example, there is evidence to suggest that droughts as severe as the "dust bowl" of the 1930s were much more common in the central United States during the 10th to 14th centuries than they have been in the more recent record.

Temperature variations at local sites have exceeded 10°C (18°F) in association with the repeated glacial advances and retreats that occurred over the course of the past million years. It is more difficult to estimate the natural variability of global mean temperature because large areas of the world are not sampled and because of the large uncertainties inherent in temperatures inferred from proxy evidence. Nonetheless, evidence suggests that global warming rates as large as 2°C (3.6°F) per millennium may have occurred during the retreat of the glaciers following the most recent ice age.

3

Human Caused Forcings

Are concentrations of greenhouse gases and other emissions that contribute to climate change increasing at an accelerating rate, and are different greenhouse gases and other emissions increasing at different rates?

Is human activity the cause of increased concentrations of greenhouse gases and other emissions that contribute to climate change?

What other emissions are contributing factors to climate change (e.g., aerosols, CO, black carbon soot), and what is their relative contribution to climate change?

How long does it take to reduce the buildup of greenhouse gases and other emissions that contribute to climate change?

Do different greenhouse gases and other emissions have different draw down periods?

Are greenhouse gases causing climate change?

GREENHOUSE GASES

The most important greenhouse gases in Earth's atmosphere include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor (H_2O), ozone (O_3), and the chlorofluorocarbons (CFCs including CFC-12 (CCl_2F_2) and CFC-11 (CCl_3F)). In addition to reflecting sunlight, clouds are also a major greenhouse substance. Water vapor and cloud droplets are in fact the dominant atmospheric absorbers, and how these substances respond to climate forcings is a principal determinant of climate sensitivity, as discussed in Section 1. The CO_2, CH_4, N_2O and H_2O are both produced and utilized in many biological processes, although the major source of gaseous water is evaporation from the oceans. Ozone is created in the atmosphere by reactions initiated by sunlight. The CFCs are synthetic compounds developed and released into the atmosphere by humankind. In addition, sulfur hexafluoride (SF_6) and perfluorocarbon gases such as carbon tetrafluoride (CF_4) are very potent and nearly inert greenhouse gases with atmospheric lifetimes much longer than 1000 years.

The natural atmosphere contained many greenhouse gases whose atmospheric concentrations were determined by the sum of the ongoing geophysical, biological, and chemical reactions that produce and destroy them. The specific effects of humankind's activities before the industrial era were immersed in all of the natural dynamics and became noticeable only in the immediate vicinity, as with the smoke from small fires. The theoretical realization that human activities could have a global discernible effect on the atmosphere came during the 19th century, and the first conclusive measurements of atmospheric change were made during the last half of the 20th century. The first greenhouse gas demonstrated to be increasing in atmospheric concentration was carbon dioxide, formed as a major end product in the extraction of energy from the burning of the fossil fuels—coal, oil, and natural gas—as well as in the burning of biomass.

The common characteristics of greenhouse gases are (1) an ability to absorb terrestrial infrared radiation and (2) a presence in Earth's atmosphere. The most important greenhouse gases listed above all contain three or more atoms per molecule. Literally thousands of gases have been identified as being present in the atmosphere at some place and at some time, and all but a few have the ability to absorb terrestrial infrared radiation. However, the great majority of these chemical compounds, both natural[1] and anthropogenic, are removed in hours, days, or weeks, and do not accumulate in significant concentrations. Some can have an indirect greenhouse effect, as with carbon monoxide (CO).[2] If the average survival time for a gas in the atmosphere is a year or longer, then the winds have time to spread it throughout the lower atmosphere, and its absorption of terrestrial infrared radiation occurs at all latitudes and longitudes. All the listed greenhouse gases except ozone are released to the atmosphere at Earth's surface and are spread globally throughout the lower atmosphere.

The lifetime of CH_4 in the atmosphere is 10-12 years. Nitrous oxide and the CFCs have century-long lifetimes before they are destroyed in the stratosphere. Atmospheric CO_2 is not destroyed chemically, and its removal from the atmosphere takes place through multiple processes that transiently store the carbon in the land and ocean reservoirs, and ultimately as mineral deposits. A major removal process depends on the transfer of the carbon content of near-surface waters to the deep ocean, which has a century time scale, but final removal stretches out over hundreds of thousands of years. Reductions in the atmospheric concentrations of these gases following possible lowered emission rates in the future will stretch out over decades for methane, and centuries and longer for carbon dioxide and nitrous oxide.

Methane, nitrous oxide, and ozone all have natural sources, but they can also be introduced into the atmosphere by the activities of humankind. These supplementary sources have contributed to the increasing concentrations of these gases during the 20th century.

Carbon Dioxide

While all of the major greenhouse gases have both natural and anthropogenic atmospheric sources, the nature of these processes varies widely among them. Carbon dioxide is naturally absorbed and released by the terrestrial biosphere as well as by the oceans. Carbon dioxide is also formed by the burning of wood, coal, oil, and natural gas, and these activities have increased steadily during the last two centuries since the Industrial Revolution. That the burning of fossil fuels is a major cause of the CO_2 increase is evidenced by the concomitant decreases in the relative abundance of both the stable and radioactive carbon isotopes[3] and the decrease in atmospheric oxygen. Continuous high-precision measurements have been made of its atmospheric concentrations only since 1958, and by the year 2000 the concentrations had increased 17% from 315 parts per million by volume (ppmv) to 370 ppmv. While the year-to-year increase varies, the average annual increase of 1.5 ppmv/year over the past two decades is slightly greater than during the 1960s and 1970s. A marked seasonal oscillation of carbon dioxide concentration exists, especially in the northern hemisphere because of the extensive draw down of carbon dioxide every spring and summer as the green plants convert carbon dioxide into plant material, and the return in the rest of the year as decomposition exceeds photosynthesis. The seasonal effects are quite different north and south of the equator, with the variation much greater in the northern hemisphere where most of Earth's land surface and its vegetation and soils are found.

The atmospheric CO_2 increase over the past few decades is less than the input from human activities because a fraction of the added CO_2 is removed by oceanic and terrestrial processes. Until recently, the partitioning of the carbon sink between the land and sea has been highly uncertain, but recent high-precision measurements of the atmospheric oxygen:nitrogen (O_2:N_2) ratio have provided a crucial constraint: fossil fuel burning and terrestrial uptake processes have different O_2:CO_2 ratios, whereas the ocean CO_2 sink has no significant impact on atmospheric O_2. The atmospheric CO_2 increase for the 1990s was about half the CO_2 emission from fossil fuel combustion, with the oceans and land both serving as important repositories of the excess carbon, i.e., as carbon sinks.

Land gains and loses carbon by various processes: some natural-like photosynthesis and decomposition, some connected to land use and land management practices, and some responding to the increases of carbon dioxide or other nutrients necessary for plant growth. These gains or losses dominate the net land exchange of carbon dioxide with the atmosphere, but some riverine loss to oceans is also significant. Most quantifiable, as by forest and soil inventories, are the above- and below-ground carbon losses from land clearing and the gains in storage in trees from forest recovery and management. Changes in the frequency of forest fires, such as from fire suppression policies, and agricultural practices for soil conservation may modify the carbon stored by land. Climate variations, through their effects on plant growth and decomposition of soil detritus, also have large effects on terrestrial carbon fluxes and storage on a year-to-year basis. Land modifications, mainly in the middle latitudes of the northern hemisphere, may have been a net source of carbon dioxide to the atmosphere over much of the last century. However, quantitative estimates have only been possible over the last two decades, when forest clearing had shifted to the tropics. In the 1980s land became a small net sink for

[1]While the activities of mankind are part of the natural world, the convention exists in most discussions of the atmosphere that "natural processes" are those that would still exist without the presence of human beings; those processes that are significantly influenced by humans are called "anthropogenic".

[2]Both carbon monoxide and methane are removed from the atmosphere by chemical reaction with hydroxyl (OH). An increase in the carbon monoxide uses up hydroxyl, slowing methane removal and allowing its concentration and greenhouse effect to increase.

[3]Fossil fuels are of biological origin and are depleted in both the stable isotope ^{13}C and the radioactive isotope ^{14}C, which has a half-life of 5600 years.

carbon, that is, the various processes storing carbon globally exceeded the loss due to tropical deforestation, which by itself was estimated to add 10-40% as much carbon dioxide to the atmosphere as burning of fossil fuels. In the 1990s the net storage on land became much larger, nearly as large as the ocean uptake. How land contributes, by location and processes, to exchanges of carbon with the atmosphere is still highly uncertain, as is the possibility that the substantial net removal will continue to occur very far into the future.[4]

Methane

Methane is the major component of natural gas and it is also formed and released to the atmosphere by many biologic processes in low oxygen environments, such as those occurring in swamps, near the roots of rice plants, and the stomachs of cows. Such human activities as rice growing, the raising of cattle, coal mining, use of land-fills, and natural-gas handling have increased over the last 50 years, and direct and inadvertent emissions from these activities have been partially responsible for the increase in atmospheric methane. Its atmospheric concentration has been measured globally and continuously for only two decades, and the majority of the methane molecules are of recent biologic origin. The concentrations of methane increased rather smoothly from 1.52 ppmv in 1978 by about 1% per year until about 1990. The rate of increase slowed down to less than that rate during the 1990s, and also became more erratic; current values are around 1.77 ppmv. About two-thirds of the current emissions of methane are released by human activities. There is no definitive scientific basis for choosing among several possible explanations for these variations in the rates of change of global methane concentrations, making it very difficult to predict its future atmospheric concentrations.

Both carbon dioxide and methane were trapped long ago in air bubbles preserved in Greenland and Antarctic ice sheets. These ice sheets are surviving relics of the series of ice ages that Earth experienced over the past 400,000 years. Concentrations of carbon dioxide extracted from ice cores have typically ranged between 190 ppmv during the ice ages to near 280 ppmv during the warmer "interglacial" periods like the present one that began around 10,000 years ago. Concentrations did not rise much above 280 ppmv until the Industrial Revolution. The methane concentrations have also varied during this 400,000 year period, with lowest values of 0.30 ppmv in the coldest times of the ice ages and 0.70 ppmv in the warmest, until a steady rise began about 200 years ago toward the present concentrations. Both carbon dioxide and methane are more abundant in Earth's atmosphere now than at any time during the past 400,000 years.

Other Greenhouse Gases

Nitrous oxide is formed by many microbial reactions in soils and waters, including those processes acting on the increasing amounts of nitrogen-containing fertilizers. Some synthetic chemical processes that release nitrous oxide have also been identified. Its concentration remained about 0.27 ppmv for at least 1,000 years until two centuries ago, when the rise to the current 0.31 ppmv began.

Ozone is created mainly by the action of solar ultraviolet radiation on molecular oxygen in the upper atmosphere, and most of it remains in the stratosphere. However, a fraction of such ozone descends naturally into the lower atmosphere where additional chemical processes can both form and destroy it. This "tropospheric ozone" has been supplemented during the 20th century by additional ozone—an important component of photochemical smog—created by the action of sunlight upon pollutant molecules containing carbon and nitrogen. The most important of the latter include compounds such as ethylene (C_2H_4), carbon monoxide (CO), and nitric oxide released in the exhaust of fossil-fuel-powered motor vehicles and power plants and during combustion of biomass. The lifetime of ozone is short enough that the molecules do not mix throughout the lower atmosphere, but instead are found in broad plumes downwind from the cities of origin, which merge into regional effects, and into a latitude band of relatively high ozone extending from 30°N to 50°N that encircles Earth during Northern Hemisphere spring and summer. The presence of shorter-lived molecules, such as ozone, in the troposphere depends upon a steady supply of newly formed molecules, such as those created daily by traffic in the large cities of the world. The widespread practice of clearing forests and agricultural wastes ("biomass burning"), especially noticeable in the tropics and the Southern Hemisphere, contributes to tropospheric ozone.

The chlorofluorocarbons (CFCs) are different from the gases considered above in that they have no significant natural source but were synthesized for their technological utility. Essentially all of the major uses of the CFCs—as refrigerants, aerosol propellants, plastic foaming agents, cleaning solvents, and so on—result in their release, chemically unaltered, into the atmosphere. The atmospheric concentrations of the CFCs rose, slowly at first, from zero before first synthesis in 1928, and then more rapidly in the 1960s and 1970s with the development of a widening range of technological applications. The concentrations were rising in the 1980s at a rate of about 18 parts per trillion by volume (pptv) per year for CFC-12, 9 pptv/year for CFC-11, and 6 pptv/year for CFC-113 (CCl_2FCClF_2). Because these molecules were

[4]The variations and uncertainties in the land carbon balance are important not only in the contemporary carbon budget. While the terrestrial carbon reservoirs are small compared to the oceans, the possibility of destabilizing land ecosystems and releasing the stored carbon, e.g. from the tundra soils, has been hypothesized.

identified as agents causing the destruction of stratospheric ozone,[5] their production was banned in the industrial countries as of January 1996 under the terms of the 1992 revision of the Montreal Protocol, and further emissions have almost stopped. The atmospheric concentrations of CFC-11 and CFC-113 are now slowly decreasing, and that of CFC-12 has been essentially level for the past several years. However, because of the century-long lifetimes of these CFC molecules, appreciable atmospheric concentrations of each will survive well into the 22nd century.

Many other fluorinated compounds (such as carbon tetrafluoride, CF_4, and sulfur hexafluoride, SF_6), also have technological utility, and significant greenhouse gas capabilities. Their very long atmospheric lifetimes are a source of concern even though their atmospheric concentrations have not yet produced large radiative forcings. Members of the class of compounds called hydrofluorocarbons (HFCs) also have a greenhouse effect from the fluorine, but the hydrogen in the molecule allows reaction in the troposphere, reducing both its atmospheric lifetime and the possible greenhouse effect. The atmospheric concentrations of all these gases, which to date are only very minor greenhouse contributors, need to be continuously monitored to ensure that no major sources have developed. The sensitivity and generality of modern analytic systems make it unlikely that any additional greenhouse gas will be discovered that is already a significant contributor to the current total greenhouse effect.

AEROSOLS

Sulfate and carbon-bearing compounds associated with particles (i.e., carbonaceous aerosols) are two classes of aerosols that impact radiative balances, and therefore influence climate.

Black Carbon (soot)

The study of the role of black carbon in the atmosphere is relatively new. As a result it is characterized poorly as to its composition, emission source strengths, and influence on radiation. Black carbon is an end product of the incomplete combustion of fossil fuels and biomass, the latter resulting from both natural and human-influenced processes. Most of the black carbon is associated with fine particles (radius $<0.2\ \mu m$) that have global residence times of about one week. These lifetimes are considerably shorter than those of most greenhouse gases, and thus the spatial distribution of black carbon aerosol is highly variable, with the greatest concentrations near the production regions. Because of the scientific uncertainties associated with the sources and composition of carbonaceous aerosols, projections of future impacts on climate are difficult. However, the increased burning of fossil fuels and the increased burning of biomass for land clearing may result in increased black carbon concentration globally.

Sulfate

The precursor to sulfate is sulfur dioxide gas, which has two primary natural sources: emissions from marine biota and volcanic emissions. During periods of low volcanic activity, the primary source of sulfur dioxide in regions downwind from continents is the combustion of sulfur-rich coals; less is contributed by other fossil fuels. In oceanic regions far removed from continental regions, the biologic source should dominate. However, model analyses, accounting for the ubiquitous presence of ships, indicate that even in these remote regions combustion is a major source of the sulfur dioxide. Some of the sulfur dioxide attaches to sea-salt aerosol where it is oxidized to sulfate. The sea salt has a residence time in the atmosphere on the order of hours to days, and it is transported in the lower troposphere. Most sulfate aerosol is associated with small aerosols (radius $<1\ \mu m$) and is transported in the upper troposphere with an atmospheric lifetime on the order of one week. Recent "clean coal technologies" and the use of low sulfur fossil fuels have resulted in decreasing sulfate concentrations, especially in North America and regions downwind. Future atmospheric concentrations of sulfate aerosols will be determined by the extent of non-clean coal burning techniques, especially in developing nations.

CLIMATE FORCINGS IN THE INDUSTRIAL ERA

Figure 1 summarizes climate forcings that have been introduced during the period of industrial development, between 1750 and 2000, as estimated by the IPCC. Some of these forcings, mainly greenhouse gases, are known quite accurately, while others are poorly measured. A range of uncertainty has been estimated for each forcing, represented by an uncertainty bar or "whisker." However, these estimates are partly subjective, and it is possible that the true forcing falls outside the indicated range in some cases.

Greenhouse Gases

Carbon dioxide (CO_2) is probably the most important climate forcing agent today, causing an increased forcing of about 1.4 W/m^2. CO_2 climate forcing is likely to become more dominant in the future as fossil fuel use continues. If fossil fuels continue to be used at the current rate, the added

[5]Eighty-five percent of the mass of the atmosphere lies in the troposphere, the region between the surface and an altitude of about 10 miles. About 90% of Earth's ozone is found in the stratosphere, and the rest is in the troposphere.

FIGURE 1 The global mean radiative forcing of the climate system for the year 2000, relative to 1750, and the associated confidence levels with which they are known. (From IPCC, 2001; reprinted with permission of the Intergovernmental Panel on Climate Change.)

CO_2 forcing in 50 years will be about 1 W/m^2. If fossil fuel use increases by 1-1.5% per year for 50 years, the added CO_2 forcing instead will be about 2 W/m^2. These estimates account for the non-linearity caused by partial saturation in some greenhouse gas infrared absorption bands, yet they are only approximate because of uncertainty about how efficiently the ocean and terrestrial biosphere will sequester atmospheric CO_2. The estimates also presume that during the next 50 years humans will not, on a large scale, capture and sequester the CO_2 released during fossil-fuel burning.

Other greenhouse gases together cause a climate forcing approximately equal to that of CO_2. Any increase in CH_4 also indirectly causes further climate forcing by increasing stratospheric H_2O (about 7% of the CH_4 is oxidized in the upper atmosphere), as well as by increasing tropospheric O_3 through reactions involving OH and nitrogen oxides. The total climate forcing by CH_4 is at least a third as large as the CO_2 forcing, and it could be half as large as the CO_2 forcing when the indirect effects are included.

Methane is an example of a forcing whose growth could be slowed or even stopped entirely or reversed. The common scenarios for future climate change assume that methane will continue to increase. If instead its amount were to remain constant or decrease, the net climate forcing could be significantly reduced. The growth rate of atmospheric methane has slowed by more than half in the past two decades for reasons that are not well understood. With a better understanding of the sources and sinks of methane, it may be possible to encourage practices (for example, reduced leakage during fossil-fuel mining and transport, capture of land-fill emissions, and more efficient agricultural practices) that lead to a decrease in atmospheric methane and significantly reduce future climate change. The atmospheric lifetime of methane is of the order of a decade, therefore, unlike CO_2, emission changes will be reflected in changed forcing rather quickly.

Tropospheric ozone (ozone in the lower 5-10 miles of the atmosphere) has been estimated to cause a climate forcing of about 0.4 W/m^2. Some of this is linked to methane increases as discussed above, and attribution of the ozone forcing between chemical factors such as methane, carbon monoxide, and other factors is a challenging problem. One recent study, based in part on limited observations of ozone in the late 1800s, suggested that human-made ozone forcing could be as large as about 0.7-0.8 W/m^2. Surface level ozone is a major ingredient in air pollution with substantial impacts on human health and agricultural productivity. The potential human and economic gains from reduced ozone pollution and its importance as a climate forcing make it an attractive target for further study as well as possible actions that could lead to reduced ozone amounts or at least a halt in its further growth.

Aerosols

Climate forcing by anthropogenic aerosols is a large source of uncertainty about future climate change. On the basis of estimates of past climate forcings, it seems likely that aerosols, on a global average, have caused a negative climate forcing (cooling) that has tended to offset much of the positive forcing by greenhouse gases. Even though aerosol distributions tend to be regional in scale, the forced climate response is expected to occur on larger, even hemispheric and global, scales. The monitoring of aerosol properties has not been adequate to yield accurate knowledge of the aerosol climate influence.

Estimates of the current forcing by sulfates fall mainly in the range –0.3 to –1 W/m^2. However, the smaller values do not fully account for the fact that sulfate aerosols swell in size substantially in regions of high humidity. Thus, the sulfate forcing probably falls in the range –0.6 to –1 W/m^2. Further growth of sulfate aerosols is likely to be limited by concerns about their detrimental effects, especially acid rain, and it is possible that control of sulfur emissions from combustion will even cause the sulfate amount to decrease.

Black carbon (soot) aerosols absorb sunlight and, even though this can cause a local cooling of the surface in regions of heavy aerosol concentration, it warms the atmosphere and, for plausible atmospheric loadings, soot is expected to cause a global surface warming. IPCC reports have provided a best estimate for the soot forcing of 0.1-0.2 W/m^2, but with large uncertainty. One recent study that accounts for the larger absorption that soot can cause when it is mixed internally with other aerosols suggests that its direct forcing is at least 0.4 W/m^2. It also has been suggested that the indirect effects of black carbon—which include reducing low-level cloud cover (by heating of the layer), making clouds slightly "dirty" (darker), and lowering of the albedo of snow and sea ice—might double this forcing to 0.8 W/m^2. The conclusion is that the black carbon aerosol forcing is uncertain but may be substantial. Thus there is the possibility that decreasing black carbon emissions in the future could have a cooling effect that would at least partially compensate for the warming that might be caused by a decrease in sulfates.

Other aerosols are also significant. Organic carbon aerosols are produced naturally by vegetation and anthropogenically in the burning of fossil fuels and biomass. Organic carbon aerosols thus accompany and tend to be absorbed by soot aerosols, and they are believed to increase the toxicity of the aerosol mixture. It is expected that efforts to reduce emissions of black carbon would also reduce organic carbon emissions. Ammonium nitrate (not included in Figure 1) recently has been estimated to cause a forcing of –0.2 W/m^2.

Mineral dust, along with sea salt, sulfates, and organic aerosols, contributes a large fraction of the global aerosol mass. It is likely that human land-use activities have influenced the amount of mineral dust in the air, but trends are not well measured. Except for iron-rich soil, most mineral dust probably has a cooling effect, but this has not been determined well.

The greatest uncertainty about the aerosol climate forcing—indeed, the largest of all the uncertainties about global climate forcings—is probably the indirect effect of aerosols on clouds. Aerosols serve as condensation nuclei for cloud droplets. Thus, anthropogenic aerosols are believed to have two major effects on cloud properties: the increased number of nuclei results in a larger number of smaller cloud droplets, thus increasing the cloud brightness (the Twomey effect), and the smaller droplets tends to inhibit rainfall, thus increasing cloud lifetime and the average cloud cover on Earth. Both effects reduce the amount of sunlight absorbed by Earth and thus tend to cause global cooling. The existence of these effects has been verified in field studies, but it is extremely difficult to determine their global significance. Climate models that incorporate the aerosol-cloud physics suggest that these effects may produce a negative global forcing on the order of 1 W/m^2 or larger. The great uncertainty about this indirect aerosol climate forcing presents a severe handicap both for the interpretation of past climate change and for future assessments of climate changes.

Other Forcings

Other potentially important climate forcings include volcanic aerosols, anthropogenic land use, and solar variability. Stratospheric aerosols produced by large volcanoes that eject gas and dust to altitudes of 12 miles or higher can cause a climate forcing as large as several watts per square meter on global average. However, the aerosols fall out after a year or two, so unless there is an unusual series of eruptions, they do not contribute to long-term climate change.

Land-use changes, especially the removal or growth of vegetation, can cause substantial regional climate forcing. One effect that has been evaluated in global climate models is the influence of deforestation. Because forests are dark and tend to mask underlying snow, the replacement of forests by crops or grass yields a higher albedo surface and thus a cooling effect. This effect has been estimated to yield a global cooling tendency in the industrial era equivalent to a forcing of –0.2 W/m^2. Land use changes have been an important contributor to past changes of atmospheric carbon dioxide. However, the impacts of such changes on climate may be much more significant on regional scales than globally, and largely act through changes of the hydrologic cycle. Such impacts are currently poorly characterized because they depend on complex modeling details that are still actively being improved.

Solar irradiance, the amount of solar energy striking Earth, has been monitored accurately only since the late 1970s. However, indirect measures of solar activity suggest that there has been a positive trend of solar irradiance over the industrial era, providing a forcing estimated at about 0.3 W/m^2. Numerous possible indirect forcings associated with solar variability have been suggested. However, only one of these, ozone changes induced by solar ultraviolet irradiance variations, has convincing observational support. Some studies have estimated this indirect effect to enhance the direct solar forcing by 0.1 W/m^2, but this value remains highly uncertain. Although the net solar forcing appears small in comparison with the sum of all greenhouse gases, it is perhaps more appropriate to compare the solar forcing with the net anthropogenic forcing. Solar forcing is very uncertain, but almost certainly much smaller than the greenhouse gas forcing. It is not implausible that solar irradiance has been a significant driver of climate during part of the industrial era, as suggested by several modeling studies. However, solar forcing has been measured to be very small since 1980, and greenhouse gas forcing has certainly been much larger in the past two decades. In any case, future changes in solar irradiance and greenhouse gases require careful monitoring to evaluate their future balance. In the future, if greenhouse gases continue to increase rapidly while aerosol forcing moderates, solar forcing may be relatively less important. Even in that case, however, the difference between an increasing and decreasing irradiance could be significant and affect interpretation of climate change, so it is important that solar variations be accurately monitored.

4

Climate System Models

Climate system models are an important tool for interpreting observations and assessing hypothetical futures. They are mathematical computer-based expressions of the thermodynamics, fluid motions, chemical reactions, and radiative transfer of Earth climate that are as comprehensive as allowed by computational feasibility and by scientific understanding of their formulation. Their purpose is to calculate the evolving state of the global atmosphere, ocean, land surface, and sea ice in response to external forcings of both natural causes (such as solar and volcanic) and human causes (such as emissions and land uses), given geography and initial material compositions. Such models have been in use for several decades. They are continually improved to increase their comprehensiveness with respect to spatial resolution, temporal duration, biogeochemical complexity, and representation of important effects of processes that cannot practically be calculated on the global scale (such as clouds and turbulent mixing). Formulating, constructing, and using such models and analyzing, assessing, and interpreting their answers make climate system models large and expensive enterprises. For this reason, they are often associated, at least in part, with national laboratories. The rapid increase over recent decades in available computational speed and power offers opportunities for more elaborate, more realistic models, but requires regular upgrading of the basic computers to avoid obsolescence.

Climate models calculate outcomes after taking into account the great number of climate variables and the complex interactions inherent in the climate system. Their purpose is the creation of a synthetic reality that can be compared with the observed reality, subject to appropriate averaging of the measurements. Thus, such models can be evaluated through comparison with observations, provided that suitable observations exist. Furthermore, model solutions can be diagnosed to assess contributing causes of particular phenomena. Because climate is uncontrollable (albeit influenceable by humans), the models are the only available experimental laboratory for climate. They also are the appropriate high-end tool for forecasting hypothetical climates in the years and centuries ahead. However, climate models are imperfect. Their simulation skill is limited by uncertainties in their formulation, the limited size of their calculations, and the difficulty of interpreting their answers that exhibit almost as much complexity as in nature.

The current norm for a climate system model is to include a full suite of physical representations for air, water, land, and ice with a geographic resolution scale of typically about 250 km. Model solutions match the primary planetary-scale circulation, seasonal variability, and temperature structures with qualitative validity but still some remaining discrepancies. They show forced responses of the global-mean temperature that corresponds roughly with its measured history over the past century, though this requires model adjustments. They achieve a stable equilibrium over millennial intervals with free exchanges of heat, water, and stress across the land and water surfaces. They also exhibit plausible analogues for the dominant modes of intrinsic variability, such as the El Niño/Southern Oscillation (ENSO), although some important discrepancies still remain. At present, climate system models specify solar luminosity, atmospheric composition, and other agents of radiative forcing. A frontier for climate models is the incorporation of more complete biogeochemical cycles (for example, for carbon dioxide). The greater the sophistication and complexity of an atmospheric model, the greater the need for detailed multiple measurements, which test whether the model continues to mimic observational reality. Applications of climate models to past climate states encompass "snapshots" during particular millennia, but they do not yet provide for continuous evolution over longer intervals (transitions between ice ages).

5

Observed Climate Change During the Industrial Era

Is climate change occurring? If so, how?

Are the changes due to human activities?

THE OCCURRENCE OF CLIMATE CHANGE

A diverse array of evidence points to a warming of global surface air temperatures. Instrumental records from land stations and ships indicate that global mean surface air temperature warmed by about 0.4-0.8°C (0.7-1.5°F) during the 20th century. The warming trend is spatially widespread and is consistent with the global retreat of mountain glaciers, reduction in snow-cover extent, the earlier spring melting of ice on rivers and lakes, the accelerated rate of rise of sea level during the 20th century relative to the past few thousand years, and the increase in upper-air water vapor and rainfall rates over most regions. A lengthening of the growing season also has been documented in many areas, along with an earlier plant flowering season and earlier arrival and breeding of migratory birds. Some species of plants, insects, birds, and fish have shifted towards higher latitudes and higher elevations. The ocean, which represents the largest reservoir of heat in the climate system, has warmed by about 0.05°C (0.09°F) averaged over the layer extending from the surface down to 10,000 feet, since the 1950s.

Pronounced changes have occurred over high latitudes of the Northern Hemisphere. Analysis of recently declassified data from U.S. and Russian submarines indicates that sea ice in the central Arctic has thinned since the 1970s. Satellite data also indicate a 10-15% decrease in summer sea ice concentration over the Arctic as a whole, which is primarily due to the retreat of the ice over the Siberian sector. A decline of about 10% in spring and summer continental snow cover extent over the past few decades also has been observed. Some of these high latitude changes are believed to be as much or more a reflection of changes in wintertime wind patterns as a direct consequence of global warming per se. The rate of warming has not been uniform over the 20th century. Most of it occurred prior to 1940 and during the past few decades. The Northern Hemisphere as a whole experienced a slight cooling from 1946-75, and the cooling during that period was quite marked over the eastern United States. The cause of this hiatus in the warming is still under debate. The hiatus is evident in averages over both Northern and Southern Hemispheres, but it is more pronounced in the Northern Hemisphere. One possible cause of this feature is the buildup of sulfate aerosols due to the widespread burning of high sulfur coal during the middle of the century, followed by a decline indicated by surface sulfate deposition measurements. It is also possible that at least part of the rapid warming of the Northern Hemisphere during the first part of the 20th century and the subsequent cooling were of natural origin—a remote response to changes in the oceanic circulation at subarctic latitudes in the Atlantic sector, as evidenced by the large local temperature trends over this region. Suggestions that either variations in solar luminosity or the frequency of major volcanic emissions could have contributed to the irregular rate of warming during the 20th century cannot be excluded.

The IPCC report compares the warming of global mean temperature during the 20th century with the amplitude of climate variations over longer time intervals, making use of recent analyses of tree ring measurements from many different sites, data from the Greenland ice cores, and bore hole temperature measurements. On the basis of these analyses, they conclude that the 0.6°C (1.1°F) warming of the Northern Hemisphere during the 20th century is likely to have been the largest of any century in the past thousand years. This result is based on several analyses using a variety of proxy indicators, some with annual resolution and others with less resolved time resolution. The data become relatively sparse prior to 1600, and are subject to uncertainties related to spatial completeness and interpretation making the results somewhat equivocal, e.g., less than 90% confidence. Achieving greater certainty as to the magnitude of climate variations before that time will require more extensive data and analysis.

Although warming at Earth's surface has been quite pronounced during the past few decades, satellite measurements beginning in 1979 indicate relatively little warming of air temperature in the troposphere. The committee concurs with the findings of a recent National Research Council report,[1] which concluded that the observed difference between surface and tropospheric temperature trends during the past 20 years is probably real, as well as its cautionary statement to the effect that temperature trends based on such short periods of record, with arbitrary start and end points, are not necessarily indicative of the long-term behavior of the climate system. The finding that surface and troposphere temperature trends have been as different as observed over intervals as long as a decade or two is difficult to reconcile with our current understanding of the processes that control the vertical distribution of temperature in the atmosphere.

THE EFFECT OF HUMAN ACTIVITIES

Because of the large and still uncertain level of natural variability inherent in the climate record and the uncertainties in the time histories of the various forcing agents (and particularly aerosols), a causal linkage between the buildup of greenhouse gases in the atmosphere and the observed climate changes during the 20th century cannot be unequivocally established. The fact that the magnitude of the observed warming is large in comparison to natural variability as simulated in climate models is suggestive of such a linkage, but it does not constitute proof of one because the model simulations could be deficient in natural variability on the decadal to century time scale. The warming that has been estimated to have occurred in response to the buildup of greenhouse gases in the atmosphere is somewhat greater than the observed warming. At least some of this excess warming has been offset by the cooling effect of sulfate aerosols, and in any case one should not necessarily expect an exact correspondence because of the presence of natural variability.

The cooling trend in the stratosphere, evident in radiosonde data since the 1960s and confirmed by satellite observations starting in 1979, is so pronounced as to be difficult to explain on the basis of natural variability alone. This trend is believed to be partially a result of stratospheric ozone depletion and partially a result of the buildup of greenhouse gases, which warm the atmosphere at low levels but cool it at high levels. The circulation of the stratosphere has responded to the radiatively induced temperature changes in such a way as to concentrate the effects in high latitudes of the winter hemisphere, where cooling of up to 5°C (9°F) has been observed.

There have been significant changes in the atmospheric circulation during the past several decades: e.g., the transition in climate over the Pacific sector around 1976 that was analogous in some respects to a transition toward more "El Niño-like" conditions over much of the Pacific, and the more gradual strengthening of the wintertime westerlies over subpolar latitudes of both Northern and Southern Hemispheres. Such features bear watching, lest they be early indications of changes in the natural modes of atmospheric variability triggered by human induced climate change. To place them in context, however, it is worth keeping in mind that there were events of comparable significance earlier in the record, such as the 1930s dust bowl.

[1] *Reconciling Observations of Global Temperature Change*, 2000.

6

Future Climate Change

How much of the expected climate change is the consequence of climate feedback processes (e.g., water vapor, clouds, snow packs)?

By how much will temperatures change over the next 100 years and where?

What will be the consequences (e.g., extreme weather, health effects) of increases of various magnitude?

Has science determined whether there is a "safe" level of concentration of greenhouse gases?

ESTIMATING FUTURE CLIMATE CHANGE

Projecting future climate change first requires projecting the fossil-fuel and land-use sources of CO_2 and other gases and aerosols. How much of the carbon from future use of fossil fuels will be seen as increases in carbon dioxide in the atmosphere will depend on what fractions are taken up by land and the oceans. The exchanges with land occur on various time scales, out to centuries for soil decomposition in high latitudes, and they are sensitive to climate change. Their projection into the future is highly problematic.

Future climate change depends on the assumed scenario for future climate forcings, as well as upon climate sensitivity. The IPCC scenarios include a broad range of forcings. One scenario often used for climate model studies employs rapid growth rates such that annual greenhouse gas emissions continue to accelerate. This is a useful scenario, in part because it yields a reasonably large "signal/noise" in studies of the simulated climate response. More important, it provides a warning of the magnitude of climate change that may be possible if annual greenhouse gas emissions continue to increase. There are sufficient fossil fuels in the ground to supply such a scenario for well over a century.

IPCC scenarios cover a broad range of assumptions about future economic and technological development, including some that allow greenhouse gas emission reductions. However, there are large uncertainties in underlying assumptions about population growth, economic development, life style choices, technological change, and energy alternatives, so that it is useful to examine scenarios developed from multiple perspectives in considering strategies for dealing with climate change. For example, one proposed growth scenario[1] for the next 50 years notes that CO_2 emissions have grown by about 1% annually in the past 20 years and assumes a zero growth rate for CO_2 emissions until 2050 (that is, constant emissions). The scenario also focuses on forcings from non-CO_2 greenhouse gases such as methane, and assumes a zero growth rate for them (that is, atmospheric amounts in 2050 similar to those in 2000). Plausible assumptions for technological progress and human factors were proposed to achieve this trajectory for radiative forcing. This scenario leads to a predicted temperature increase of 0.75°C by 2050, approximately half of that resulting from more conventional assumptions. One rationale for focusing first on 2050 rather than 2100 is that it is more difficult to foresee the technological capabilities that may allow reduction of greenhouse gas emissions by 2100.

Scenarios for future greenhouse gas amounts, especially for CO_2 and CH_4, are a major source of uncertainty for projections of future climate. Successive IPCC assessments over the past decade each have developed a new set of scenarios

[1]Hansen, J., M. Sato, R. Ruedy, A. Lacis, and V. Oinas, Global warming in the twenty-first century: an alternative scenario, *Proceedings of the National Academy of Sciences*, 97: 9875-9880, 2000.

with little discussion of how well observed trends match with previous scenarios. The period of record is now long enough to make it useful to compare recent trends with the scenarios, and such studies will become all the more fruitful as years pass. The increase of global fossil fuel CO_2 emissions in the past decade, averaging 0.6% per year, has fallen below the IPCC scenarios. The growth of atmospheric CH_4 has fallen well below the IPCC scenarios. These slowdowns in growth rates could be short-term fluctuations that may be reversed. However, they emphasize the need to understand better the factors that influence current and future growth rates.

Global warming will not be spatially uniform, and it is expected to be accompanied by other climate changes. In areas and seasons in which there are large temperature changes, feedbacks may be much larger than their global values. An example of such regionally large effects is the ice-albedo feedback. Reduced snow cover and sea and lake ice will be important at high latitudes and higher elevations, especially during winter and spring. In the presence of the higher temperatures, atmospheric water vapor concentration and precipitation will also be higher. Determining the net ice-albedo feedback effect is complicated by its connections to other aspects of the hydrologic and energy cycles. Clouds may change to amplify or reduce its effect. Increased precipitation with warming at the margin of ice and snow may act to either reduce or amplify this effect, e.g., reducing the effect by increasing snow levels where it is below freezing. Changing vegetation cover likewise can introduce major modification.

An increase in the recycling rate of water in the hydrologic cycle is anticipated in response to higher global average temperatures. Higher evaporation rates will accelerate the drying of soils following rain events, thereby resulting in drier average conditions in some regions, especially during periods of dry weather during the warm season. The drier soils, with less water available for evapotranspiration, will warm more strongly during sunlight hours resulting in higher afternoon temperatures, faster evaporation, and an increase in the diurnal temperature range. The effect is likely to be greatest in semi-arid regions, such as the U.S. Great Plains. The faster recycling of water will lead to higher rainfall rates and an increase in the frequency of heavy precipitation events.

There is a possibility that global warming could change the behavior of one or more of the atmosphere's natural modes of variability such as ENSO or the so-called North Atlantic or Arctic Oscillation. Such changes could lead to complex changes in the present-day patterns of temperature and precipitation, including changes in the frequency of winter or tropical storms. Higher precipitation rates would favor increased intensity of tropical cyclones, which derive their energy from the heat that is released when water vapor condenses.

Temperatures are expected to increase more rapidly over land compared to oceans because of the ocean's higher heat capacity and because it can transfer more of the trapped heat to the atmosphere by evaporation. Over land, the warming has been—and is expected to continue to be—larger during nighttime than during daytime.

Consequences of Increased Climate Change of Various Magnitudes

The U.S. National Assessment of Climate Change Impacts, augmented by a recent NRC report on climate and health, provides a basis for summarizing the potential consequences of climate change.[2] The National Assessment directly addresses the importance of climate change of various magnitudes by considering climate scenarios from two well-regarded models (the Hadley model of the United Kingdom and the Canadian Climate Model). These two models have very different globally-averaged temperature increases (2.7 and 4.4°C (4.9 and 7.9°F), respectively) by the year 2100. A key conclusion from the National Assessment is that U.S. society is likely to be able to adapt to most of the climate change impacts on human systems, but these adaptations may come with substantial cost. The primary conclusions from these reports are summarized for agriculture and forestry, water, human health, and coastal regions.

In the near term, agriculture and forestry are likely to benefit from CO_2 fertilization effects and the increased water efficiency of many plants at higher atmospheric CO_2 concentrations. Many crop distributions will change, thus requiring significant regional adaptations. Given their resource base, the Assessment concludes that such changes will be costlier for small farmers than for large corporate farms. However, the combination of the geographic and climatic breadth of the United States, possibly augmented by advances in genetics, increases the nation's robustness to climate change. These conclusions depend on the climate scenario, with hotter and drier conditions increasing the potential for declines in both agriculture and forestry. In addition, the response of insects and plant diseases to warming is poorly understood. On the regional scale and in the longer term, there is much more uncertainty.

Increased tendency toward drought, as projected by some models, is an important concern in every region of the United States even though it is unlikely to be realized everywhere in the nation. Decreased snow pack and/or earlier season melting are expected in response to warming because the freeze line will be moving to higher elevations. The western part of

[2]Except where noted, this section is based on information provided in the U.S. National Assessment, U.S. Global Change Research Program, "Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change", 2001, Cambridge University Press, 612 pp.

the nation is highly dependent on the amount of snow pack and the timing of the runoff. The noted increased rainfall rates have implications for pollution run-off, flood control, and changes to plant and animal habitat. Any significant climate change is likely to result in increased costs because the nation's investment in water supply infrastructure is largely tuned to the current climate.

Health outcomes in response to climate change are the subject of intense debate. Climate change has the potential to influence the frequency and transmission of infectious disease, alter heat- and cold-related mortality and morbidity, and influence air and water quality. Climate change is just one of the factors that influence the frequency and transmission of infectious disease, and hence the assessments view such changes as highly uncertain.[3] This said, changes in the agents that transport infectious diseases (e.g., mosquitoes, ticks, rodents) are likely to occur with any significant change in precipitation and temperature. Increases in mean temperatures are expected to result in new record high temperatures and warm nights and an increase in the number of warm days compared to the present. Cold-related stress is likely to decline whereas heat stress in major urban areas is projected to increase if no adaptation occurs. The National Assessment ties increases in adverse air quality to higher temperatures and other air mass characteristics. However, much of the United States appears to be protected against many different adverse health outcomes related to climate change by a strong public health system, relatively high levels of public awareness, and a high standard of living. Children, the elderly, and the poor are considered to be the most vulnerable to adverse health outcomes. The understanding of the relationships between weather/climate and human health is in its infancy and therefore the health consequences of climate change are poorly understood. The costs, benefits, and availability of resources for adaptation are also uncertain.

Fifty-three percent of the U.S. population lives within the coastal regions, along with billions of dollars in associated infrastructure. Because of this, coastal areas are more vulnerable to increases in severe weather and sea level rise. Changes in storm frequency and intensity are one of the more uncertain elements of future climate change prediction. However, sea level rise increases the potential damage to coastal regions even under conditions of current storm intensities and can endanger coastal ecosystems if human systems or other barriers limit the opportunities for migration.

In contrast to human systems, the U.S. National Assessment makes a strong case that ecosystems are the most vulnerable to the projected rate and magnitude of climate change, in part because the available adaptation options are very limited. Significant climate change will cause disruptions to many U.S. ecosystems, including wetlands, forests, grasslands, rivers, and lakes. Ecosystems have inherent value, and also supply the country with a wide variety of ecosystem services.

The impacts of these climate changes will be significant, but their nature and intensity will depend strongly on the region and timing of occurrence. At a national level, the direct economic impacts are likely to be modest. However, on a regional basis the level and extent of both beneficial and harmful impacts will grow. Some economic sectors may be transformed substantially and there may be significant regional transitions associated with shifts in agriculture and forestry. Increasingly, climate change impacts will have to be placed in the context of other stresses associated with land use and a wide variety of pollutants. The possibility of abrupt or unexpected changes could pose greater challenges for adaptation.

Even the mid-range scenarios considered in the IPCC result in temperatures that continue to increase well beyond the end of this century, suggesting that assessments that examine only the next 100 years may well underestimate the magnitude of the eventual impacts. For example a sustained and progressive drying of the land surface, if it occurred, would eventually lead to desertification of regions that are now marginally arable, and any substantial melting or breaking up of the Greenland and Antarctic ice caps could cause widespread coastal inundation.[4]

"Safe" Level of Concentration of Greenhouse Gases

The potential for significant climate-induced impacts raises the question of whether there exists a "safe" level of greenhouse gas concentration. The word "safe" is ambiguous because it depends on both viewpoint and value judgment. This view changes dramatically if you are part of an Eskimo community dependent on sea ice for hunting, or an inhabitant of a coastal city, or a farm community. It depends on whether an industry is robust or sensitive to climate change. The viewpoint changes distinctly between countries with sufficient resources for adaptation and poorer nations. Value judgments become particularly important when assessing the potential impacts on natural ecosystems. The question can be approached from two perspectives. The first issue is whether there is a threshold in the concentration of greenhouse gases that, if exceeded, would cause dramatic or catastrophic changes to the Earth system. The second issue

[3] *Under the Weather: Climate, Ecosystems, and Infectious Disease*, 2001.

[4] Appreciable desertification on a regional scale could take place within a decade or two. Many centuries would be required for substantial melting of the ice sheets to occur and the likelihood of a breakup during this century is considered to be remote.

is whether the consequences of greenhouse warming, as a function of the concentration of greenhouse gases, are sufficiently well known that the scientific community can define "an acceptable concentration" based on an analysis of potential risks and damages. The first issue is best addressed by examining Earth's history. Guidance for the second issue can be derived from assessments of the impacts of climate change.

A variety of measurements demonstrate that CO_2 has varied substantially during Earth's history, reaching levels between three and nine times pre-industrial levels of carbon dioxide prior to 50 million years ago. During the periods of hypothesized high carbon dioxide concentrations, there are strong indicators of warmth (although many different factors have contributed to climate change during Earth's history). These indicators include warm deep-sea temperatures and abundant life within the Arctic Circle. There are also some records of abrupt warming (thousands of years) in Earth's history that may be related to atmospheric greenhouse concentrations, which caused significant perturbations to the Earth system. The global temperature increases determined for some of these warm periods exceed future projections from all climate models for the next century. These changes are associated with some extinctions, and both the periods of warmth and abrupt transitions are associated with the large-scale redistribution of species. However, a substantial biosphere is evident (i.e., no catastrophic impact tending toward wholesale extinctions) even with substantially higher CO_2 concentrations than those postulated to occur in response to human activities.

The course of future climate change will depend on the nature of the climate forcing (e.g., the rate and magnitude of changes in greenhouse gases, aerosols) and the sensitivity of the climate system. Therefore, determination of an acceptable concentration of greenhouse gases depends on the ability to determine the sensitivity of the climate system as well as knowledge of the full range of the other forcing factors, and an assessment of the risks and vulnerabilities. Climate models reflect a range of climate sensitivities even with the same emission scenario. For example, the consequences of climate change would be quite different for a globally-averaged warming of 1.1°C (2.0°F) or a 3.1°C (5.6°F) projected for the IPCC scenario in which CO_2 increases by 1% per year leading to a doubling from current levels in the next 70 years.

Both climate change and its consequences also are likely to have a strong regional character. The largest changes occur consistently in the regions of the middle to high latitudes. Whereas all models project global warming and global increases in precipitation, the sign of the precipitation projections varies among models for some regions.

The range of model sensitivities and the challenge of projecting the sign of the precipitation changes for some regions represent a substantial limitation in assessing climate impacts. Therefore, both the IPCC and the U.S. National Assessment of Climate Change Impacts assess potential climate impacts using approaches that are "scenario-driven." In other words, models with a range of climate sensitivities are used to assess the potential impacts on water, agriculture, human health, forestry, and the coastal zones, nationally and region by region. The differences among climate model projections are sufficiently large to limit the ability to define an "acceptable concentration" of atmospheric greenhouse gases. In addition, technological breakthroughs that could improve the capabilities to adapt are not known. Instead, the assessments provide a broader level of guidance:

- The nature of the potential impacts of climate change increases as a function of the sensitivity of the climate model. If globally-averaged temperature increases approach 3°C (5.4°F) in response to doubling of carbon dioxide, they are likely to have substantial impacts on human endeavors and on natural ecosystems.
- Given the fact that middle and high latitude regions appear to be more sensitive to climate change than other regions, significant impacts in these regions are likely to occur at lower levels of global warming.
- There could be significant regional impacts over the full range of IPCC model-based projections.
- Natural ecosystems are less able to adapt to change than are human systems.

In summary, critical factors in defining a "safe" concentration depend on the nature and level of societal vulnerability, the degree of risk aversion, ability and/or costs of adaptation and/or mitigation, and the valuation of ecosystems, as well as on the sensitivity of the Earth system to climate change.

7

Assessing Progress in Climate Science

What are the substantive differences between the IPCC Reports and the Summaries?

What are the specific areas of science that need to be studied further, in order of priority, to advance our understanding of climate change?

The committee was asked to address these two questions. The first involved evaluating the IPCC Working Group I report and summaries in order to identify how the summaries differ from the report. The second question involved characterizing areas of uncertainty in scientific knowledge concerning climate change, and identifying the research areas that will advance the understanding of climate change.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

The full text of the IPCC Third Assessment Report on *The Scientific Basis* represents a valuable effort by U.S. and international scientists in identifying and assessing much of the extensive research going on in climate science. The body of the WGI report is scientifically credible and is not unlike what would be produced by a comparable group of only U.S. scientists working with a similar set of emission scenarios, with perhaps some normal differences in scientific tone and emphasis.

However, because the IPCC reports are generally invoked as the authoritative basis for policy discussions on climate change, we should critically evaluate this effort so that we can offer suggestions for improvement. The goal is a stronger IPCC that will lead to better definitions of the nature of remaining problems, a clarity in expressing both robust conclusions and uncertainties, and thus aid achievement of the best possible policy decisions. We must also consider options for an improved process, given the enormous and growing investment required by individual scientists to produce this assessment. Three important issues directed to this goal are described below.

The IPCC Summary for Policy Makers

The IPCC WGI *Summary for Policymakers* (SPM) serves an obviously different purpose than the scientific working group reports. When one is condensing 1,000 pages into 20 pages with a different purpose in mind, we would expect the text to contain some modifications. After analysis, the committee finds that the conclusions presented in the SPM and the *Technical Summary* (TS) are consistent with the main body of the report. There are, however, differences. The primary differences reflect the manner in which uncertainties are communicated in the SPM. The SPM frequently uses terms (e.g., likely, very likely, unlikely) that convey levels of uncertainty; however, the text less frequently includes either their basis or caveats. This difference is perhaps understandable in terms of a process in which the SPM attempts to underline the major areas of concern associated with a human-induced climate change. However, a thorough understanding of the uncertainties is essential to the development of good policy decisions.

Climate projections will always be far from perfect. Confidence limits and probabilistic information, with their basis, should always be considered as an integral part of the information that climate scientists provide to policy and decision makers. Without them, the IPCC SPM could give an impression that the science of global warming is "settled," even though many uncertainties still remain. The emission scenarios used by the IPCC provide a good example. Human decisions will almost certainly alter emissions over the next century. Because we cannot predict either the course of human populations, technology, or societal transitions with any clarity, the actual greenhouse gas emissions could be either greater or less than the IPCC scenarios. Without an understanding of the sources and degree of uncertainty, decision makers could fail to define the best ways to deal with the serious issue of global warming.

Modification of the Scientific Text After Completion of the SPM

The SPM results from a discussion between the lead authors and government representatives (including also some non-governmental organizations and industry representatives). This discussion, combined with the requirement for consistency, results in some modifications of the text, all of which were carefully documented by the IPCC. This process has resulted in some concern that the scientific basis for the SPM might be altered. To assess this potential problem, the committee solicited written responses from U.S. coordinating lead authors and lead authors of IPCC chapters, reviewed the WGI draft report and summaries, and interviewed Dr. Daniel Albritton who served as a coordinating lead author for the IPCC WGI *Technical Summary*. Based on this analysis, the committee finds that no changes were made without the consent of the convening lead authors and that most changes that did occur lacked significant impact. However, some scientists may find fault with some of the technical details, especially if they appear to underestimate uncertainty. The SPM is accompanied by the more representative *Technical Summary* (TS). The SPM contains cross-references to the full text, which unfortunately is not accessible until a later date, but it does not cross-reference the accompanying TS.

The IPCC as Representative of the Science Community

The IPCC process demands a significant time commitment by members of the scientific community. As a result, many climate scientists in the United States and elsewhere choose not to participate at the level of a lead author even after being invited. Some take on less time-consuming roles as contributing authors or reviewers. Others choose not to participate. This may present a potential problem for the future. As the commitment to the assessment process continues to grow, this could create a form of self-selection for the participants. In such a case, the community of world climate scientists may develop cadres with particularly strong feelings about the outcome: some as favorable to the IPCC and its procedures and others negative about the use of the IPCC as a policy instrument. Alternative procedures are needed to ensure that participation in the work of the IPCC does not come at the expense of an individual's scientific career.

In addition, the preparation of the SPM involves both scientists and governmental representatives. Governmental representatives are more likely to be tied to specific government postures with regard to treaties, emission controls, and other policy instruments. If scientific participation in the future becomes less representative and governmental representatives are tied to specific postures, then there is a risk that future IPCC efforts will not be viewed as independent processes.

The United States should promote actions that improve the IPCC process while also ensuring that its strengths are maintained. The most valuable contribution U.S. scientists can make is to continually question basic assumptions and conclusions, promote clear and careful appraisal and presentation of the uncertainties about climate change as well as those areas in which science is leading to robust conclusions, and work toward a significant improvement in the ability to project the future. In the process, we will better define the nature of the problems and ensure that the best possible information is available for policy makers.

RESEARCH PRIORITIES

The underlying scientific issues that have been discussed in this report and the research priorities that they define have evolved over time. For this reason. many have been identified previously in NRC reports.[1]

Predictions of global climate change will require major advances in understanding and modeling of (1) the factors that determine atmospheric concentrations of greenhouse gases and aerosols and (2) the so called "feedbacks" that determine the sensitivity of the climate system to a prescribed increase in greenhouse gases. Specifically, this will involve reducing uncertainty regarding: (a) future usage of fossil fuels, (b) future emissions of methane, (c) the fraction of the future fossil fuel carbon that will remain in the atmosphere and provide radiative forcing versus exchange with the oceans or net exchange with the land biosphere, (d) the feedbacks in the climate system that determine both the magnitude of the change and the rate of energy uptake by the oceans. which together determine the magnitude and time history of the temperature increases for a given radiative forcing, (e) the details of the regional and local climate change consequent to an overall level of global climate change, (f) the nature and causes of the natural variability of climate and its interactions with forced changes, and (g) the direct and indirect effects of the changing distributions of aerosol. Because the total change in radiative forcing from

[1] *Decade-to-Century-Scale Climate Variability and Change: A Science Strategy*, 1998; *The Atmospheric Sciences Entering the Twenty-First Century*, 1998; *Adequacy of Climate Observing Systems*, 1999; *Global Environmental Change: Research Pathways for the Next Decade*, 1999; *Improving the Effectiveness of U.S. Climate Modeling*, 2001; *The Science of Regional and Global Change: Putting Knowledge to Work*, 2001.

other greenhouse gases over the last century has been nearly as large as that of carbon dioxide, their future evolution also must be addressed. At the heart of this is basic research, which allows for creative discoveries about those elements of the climate system that have not yet been identified, or studied.

Knowledge of the climate system and projections about the future climate are derived from fundamental physics and chemistry through models and observations of the atmosphere and the climate system. Climate models are built using the best scientific knowledge of the processes that operate within the climate system, which in turn are based on observations of these systems. A major limitation of these model forecasts for use around the world is the paucity of data available to evaluate the ability of coupled models to simulate important aspects of past climate. In addition, the observing system available today is a composite of observations that neither provide the information nor the continuity in the data needed to support measurements of climate variables. Therefore, above all, it is essential to ensure the existence of a long-term observing system that provides a more definitive observational foundation to evaluate decadal- to century-scale variability and change. This observing system must include observations of key state variables such as temperature, precipitation, humidity, pressure, clouds, sea ice and snow cover, sea level, sea-surface temperature, carbon fluxes and soil moisture. Additionally, more comprehensive regional measurements of greenhouse gases would provide critical information about their local and regional source strengths.

Climate observations and modeling are becoming increasingly important for a wide segment of society including water resource managers, public health officials, agribusinesses, energy providers, forest managers, insurance companies, and city planners. In order to address the consequences of climate change and better serve the nation's decision makers, the research enterprise dealing with environmental change and environment-society interactions must be enhanced. This includes support of (a) interdisciplinary research that couples physical, chemical, biological, and human systems, (b) improved capability of integrate scientific knowledge, including its uncertainty, into effective decision support systems, and (c) an ability to conduct research at the regional or sectoral level that promotes analysis of the response of human and natural systems to multiple stresses.

Climate research is presently overseen by the U.S. Global Change Research Program (USGCRP). A number of NRC reports[2] have concluded that this collection of agencies is hampered organizationally in its ability to address the major climate problems. The ability of the United States to assess future climate change is severely limited by the lack of a climate observing system, by inadequate computational resources, and by the general inability of government to focus resources on climate problems. Efforts are needed to ensure that U.S. efforts in climate research are supported and managed to ensure innovation, effectiveness, and efficiency. These issues have been addressed by NRC reports, but more examination is needed.

[2] *Global Environmental Change: Research Pathways for the Next Decade*, 1999; *Improving the Effectiveness of U.S. Climate Modeling*, 2001; *The Science of Regional and Global Change: Putting Knowledge to Work*, 2001

Appendixes

A

Letter from the White House

THE WHITE HOUSE
WASHINGTON

May 11, 2001

Dr. Bruce Alberts
National Academy of Sciences
2101 Constitution Avenue, NW
Washington, D.C. 20418

Dear Dr. Alberts:

The Administration is conducting a review of U.S. policy on climate change. We seek the Academy's assistance in identifying the areas in the science of climate change where there are the greatest certainties and uncertainties.

We would also like your views on whether there are any substantive differences between the IPCC Reports and the IPCC summaries.

We would appreciate a response as soon as possible.

Sincerely yours,

John M. Bridgeland
Deputy Assistant to the President
for Domestic Policy and
Director, Domestic Policy Council

Gary Edson
Deputy Assistant to the
President for International
Economic Affairs

B

Biographical Sketches of Committee Members and Staff

Dr. Ralph J. Cicerone *(Chair)* is the chancellor of the University of California at Irvine and the Daniel G. Aldrich Professor in the Department of Earth System Science and the Department of Chemistry. His areas of research include atmospheric chemistry; sources of gases that affect climate and the composition of the global atmosphere, especially methane and nitrous oxide; and the ozone layer and human influence on it. He is a member of the National Academy of Sciences. Dr. Cicerone received his Ph.D. from the University of Illinois.

Dr. Eric J. Barron is Director of the Earth and Mineral Sciences Environment Institute and Distinguished Professor of Geosciences at Pennsylvania State University. His specialty is paleoclimatology/paleoceanography. His research emphasizes global change, specifically numerical models of the climate system and the study of climate change throughout Earth's history. Dr. Barron is a fellow of the American Geophysical Union and the American Meteorological Society. He has served on several National Research Council committees, including, most recently, the Grand Challenges in the Environmental Sciences and the Task Group on Assessment of NASA Plans for Post-2000 Earth Observing Missions. He is currently the chair of the Board on Atmospheric Sciences and Climate. Dr. Barron received his Ph.D. from the University of Miami.

Dr. Robert E. Dickinson is a professor of dynamics and climate in the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. His research interests include the dynamics of atmospheric planetary waves, stratospheric dynamics, models of global structure and dynamics of terrestrial and planetary thermosphere, NLTE infrared radiative transfer in planetary mesopheres, global climate modeling and processes, the role of land processes in climate systems, the modeling role of vegetation in regional evapotranspiration, and the role of tropical forests in climate systems. Dr. Dickinson is a member of the National Academy of Sciences and the recipient of the Revelle medal of the American Geophysical Union (AGU) and the Rossby award of the American Meteorological Society. He is currently president-elect of the AGU. Dr. Dickinson received his Ph.D. from the Massachusetts Institute of Technology.

Dr. Inez Y. Fung is the Richard and Rhoda Goldman Distinguished Professor for the Physical Sciences, Director of the Center for Atmospheric Sciences, and a professor in the Department of Earth and Planetary Science and the Department of Environmental Sciences, Policy and Management at the University of California at Berkeley. Her research expertise is in large-scale numerical modeling of biogeochemical cycles and their interaction with climate. Her research also includes climate change, remote sensing of earth systems, investigations of atmosphere-ocean interactions, and atmosphere-biosphere interactions. She is a member of the National Academy of Sciences, a fellow of the American Geophysical Union and the American Meteorological Society, and a recipient of NASA's Exceptional Scientific Achievement Medal. Dr. Fung received her Sc.D. from the Massachusetts Institute of Technology.

Dr. James E. Hansen is head of the NASA Goddard Institute for Space Studies. His research interests include radiative transfer in planetary atmospheres, interpretation of remote sounding of planetary atmospheres, development of simplified climate models and three-dimensional global climate models, current climate trends from observational data, and projections of man's impact on climate. He is a member of the National Academy of Sciences and a fellow of the

American Geophysical Union. Dr. Hansen received his Ph.D. from the University of Iowa.

Mr. Thomas R. Karl is Director of the National Climatic Data Center of the National Oceanic and Atmospheric Administration. Before this he served as the senior scientist where his research interests included global climate change, extreme weather events, and trends in global and U.S. climate over the past 100 years. Mr. Karl is a fellow of the American Meteorological Society and the American Geophysical Union and served as the chair of the National Research Council's Climate Research Committee. He was a coordinating lead author for the IPCC Working Group I Third Assessment Report. Mr. Karl received his M.S. from the University of Wisconsin.

Dr. Richard S. Lindzen is the Alfred P. Sloan Professor of Meteorology in the Department of Earth, Atmospheric and Planetary Sciences at the Massachusetts Institute of Technology. His research interests include dynamic meteorology and climatology, specifically upper atmosphere dynamics, waves and instability, climate sensitivity, regional and interannual variability of weather, tropical meteorology, monsoons, mesoscale systems, clear air turbulence, climate dynamics, and general circulation. He is a member of the National Academy of Sciences and a fellow of the American Association for the Advancement of Science. He was a lead author for the IPCC Working Group I Third Assessment Report. Dr. Lindzen received his Ph.D. from Harvard University.

Dr. James C. McWilliams is the Slichter Professor of Earth Sciences in the Department of Atmospheric Sciences and the Institute for Geophysics and Planetary Physics at the University of California at Los Angeles. His research focuses on the fluid dynamics of Earth's oceans and atmosphere, both their theory and computational modeling. Particular subjects of interest include the maintenance of general circulations; climate dynamics; geostrophically and cyclo-strophically balanced dynamics in rotating, stratified fluids; vortex dynamics; the planetary boundary layers; planetary-scale thermohaline convection, the roles of coherent structures of turbulent flows in geophysical and astrophysical regimes; numerical methods; coastal ocean modeling and statistical estimation theory. He is a fellow of the American Geophysical Union and has served on the National Research Council's Climate Research Committee and Board on Atmospheric and Sciences. Dr. McWilliams received his Ph.D. from Harvard University.

Dr. F. Sherwood Rowland is the Donald Bren Research Professor of Chemistry and Earth System Science at the University of California at Irvine. His research interests include atmospheric chemistry (stratospheric ozone, trace compounds in the troposphere on a global basis); chemical kinetics, in particular, gas phase reactions of chlorine, fluorine, and hydrogen; and radiochemistry, specifically tracer studies with radioactive isotopes. Dr. Rowland is a member of the National Academy of Sciences where he currently serves as Foreign Secretary. He is also a member of the Institute of Medicine. He has received numerous awards including the Nobel Prize in Chemistry in 1995 and the Revelle medal of the American Geophysical Union. Dr. Rowland received his Ph.D. from the University of Chicago.

Dr. Edward S. Sarachik is a professor in the Department of Atmospheric Sciences and an adjunct professor in the School of Oceanography at the University of Washington. His research interests focus on large-scale atmosphere-ocean interactions, seasonal variations in the tropical oceans, the role of the ocean in climate change, and biogeochemical cycles in the global ocean. Dr. Sarachik is a fellow of the American Geophysical Union, the American Meteorological Society, and the American Association for the Advancement of Science. He has served on numerous National Research Council committees including the Climate Research Committee, the Tropical Ocean/Global Atmosphere (TOGA) Advisory Panel (chair), and the Panel on Improving U.S. Climate Modeling (chair). Dr. Sarachik received his Ph.D. from Brandeis University.

Dr. John M. Wallace is a professor of atmospheric sciences and co-director of the University of Washington Program on the Environment. From 1981-98 he served as director of the (University of Washington/NOAA) Joint Institute for the Study of the Atmosphere and the Ocean. His research specialties include the study of atmospheric general circulation, El Niño, and global climate. He is a member of the National Academy of Sciences; a fellow of the American Association for the Advancement of Science, the American Geophysical Union (AGU), and the American Meteorological Society (AMS); and the recipient of the Rossby medal of the AMS and Revelle medal of the AGU. Dr. Wallace received his Ph.D. from the Massachusetts Institute of Technology.

Dr. Vaughan C. Turekian *(Study Director)* is a Program Officer with the Board on Atmospheric Sciences and Climate. He received his B.S. from Yale University, where he specialized in Geology and Geophysics and International Studies. He received his Ph.D. in Environmental Sciences from the University of Virginia in 2000 where he used stable bulk and compound-specific isotope analyses to characterize the sources and processing of aerosols in marine air.