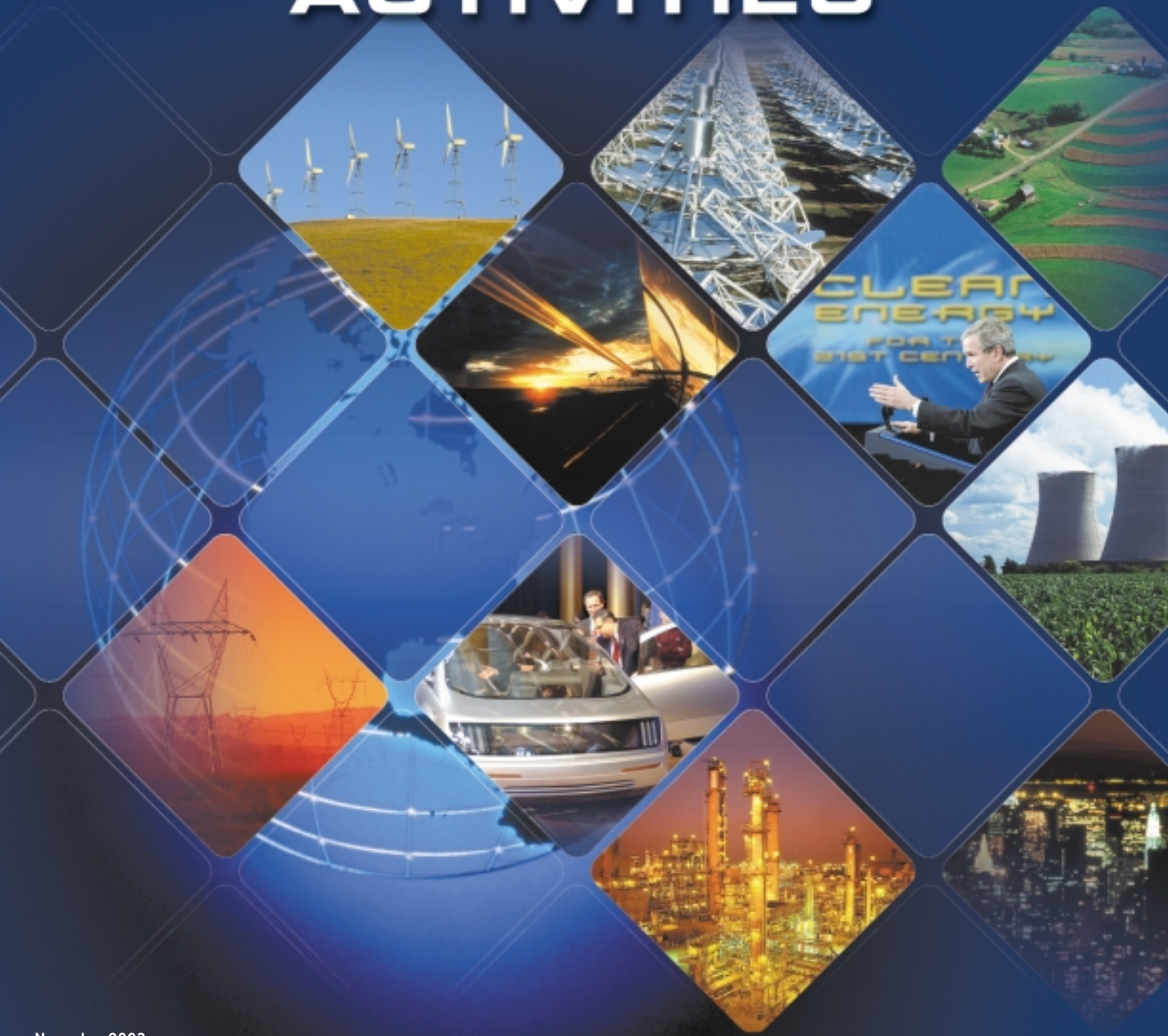
DOE/PI-0001

U.S. Climate Change Technology Program

RESEARCH AND CURRENT ACTIVITIES



November 2003

U.S. Climate Change Technology Program

U.S. Department of Energy (Lead-Agency)
U.S. Department of Agriculture
U.S. Department of Commerce, including
National Institute of Standards and Technology
U.S. Department of Defense
U.S. Department of Health and Human Services, including
National Institutes of Health
U.S. Department of Interior
U.S. Department of State, including
U.S. Agency for International Development
U.S. Department of Transportation
U.S. Environmental Protection Agency
National Aeronautics and Space Administration
National Science Foundation
Other Participating Research and Development Agencies

Executive Office of the President, including
Council on Environmental Quality
Office of Science and Technology Policy
Office of Management and Budget

November 2003

To the Reader:

We are pleased to present this report on *U.S. Climate Change Technology Program – Research and Current Activities*. The activities described herein highlight important Presidential initiatives and other important research, development and deployment activities. Within the overall Federal R&D portfolio, these activities are further complemented by an array of baseline R&D activities, catalogued in a companion report, *U.S. Climate Change Technology Program — Technology Options for the Near and Long Term*.

Collectively, these technology-related activities form an integral part of a comprehensive U.S. strategy on climate change that rests on three pillars — science, technology, and international cooperation. They also complement the recent Climate Change Science Program (CCSP) strategic plan, which represents an unprecedented effort to advance our knowledge of climate variability, the potential response of the climate system to growing greenhouse gas concentrations and their implications, and management options for natural environments. The scientific information developed under the CCSP will help us better define our technology challenges.

Early in his term, President Bush charged his Administration with identifying a new approach to climate change that is science-based, encourages scientific and technological breakthroughs, harnesses the power of markets, does not hamper economic growth, encourages global participation, and helps achieve the goal of stabilizing atmospheric concentrations of greenhouse gases. As research continues, there is a growing realization that existing technologies, even with substantial refinements, cannot meet the world's increasing demand for energy and achieve the eventual goal of stabilizing greenhouse gas concentrations in the atmosphere. Doing so will require developing low or zero-emission technologies that will fundamentally transform current energy systems.

To achieve this vision, the participating agencies of the U.S. Climate Change Technology Program are pursuing research in carbon sequestration, hydrogen, bioenergy, nuclear fission and fusion, and many other revolutionary technologies. These transformational technologies will put us on a path to stabilizing atmospheric greenhouse gas concentrations and also ensure secure, affordable, and clean energy to power economic growth worldwide.

Through scientific research, technological innovation, and international collaboration, we are working to ensure a bright energy and economic future for our Nation and a healthy planet for future generations. For more information on the U.S. Climate Change Technology Program, please visit our website at http://www.climatetechnology.gov/.

Spencer Abraham
Secretary of Energy
Chair, Committee on Climate Change Science and Technology Integration

Donald L. Evans
Secretary of Commerce
Vice Chair, Committee on Climate Change Science and Technology Integration

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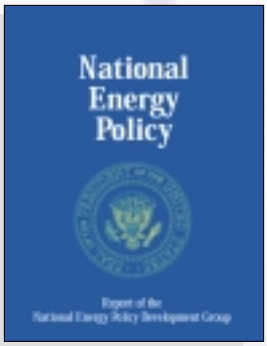
U.S. Climate Change Technology Program: Research and Current Activities

Table of Contents

Introduction

"America's the leader in technology and innovation. We all believe technology offers great promise to significantly reduce greenhouse gas emissions."

President George W. Bush
June 11, 2001



The National Energy Policy provides the Bush Administration's policy context for addressing climate change.

(http://www.whitehouse.gov/energy/NationalEnergy-Policy.pdf)

Global climate change is a major, long-term energy and environmental challenge that may require a fundamental change in the way we produce and use energy in the 21st century. President Bush is committed to taking bold action to galvanize an energy technology revolution that will provide the energy we need for sustained economic growth, while substantially reducing emissions of greenhouse gases (GHG).

This report, *U.S. Climate Change Technology Program: Research and Current Activities*, reflects the new approach to climate change the United States (U.S.) is taking under President Bush's leadership. The report highlights some of the Bush Administration's actions and profiles a number of promising, cutting-edge technologies found in today's robust U.S. climate change technology portfolio. A companion report, *Technology Options for the Near and Long Term*, provides a more complete list of the technologies in the portfolio.

Presidential Commitment and U.S. Approach

The U.S. is the undisputed global leader in technology and innovation. The U.S. has achieved this distinction due to its entrepreneurial spirit and unrivaled national investment in research and development (R&D). President Bush has great faith in American innovation and recognizes that targeted R&D investments are crucial to strengthening our ability to meet the climate change challenge. Accordingly, President Bush's approach to climate change – backed by unprecedented R&D investments in key areas - emphasizes both long and short-term technology solutions informed by vigorous scientific knowledge.

The May 2001 *National Energy Policy: Report of the National Energy Policy Development Group* provides the policy context for President Bush's climate change approach. The report outlines policies to enhance energy security while reducing GHG emissions and recommends aggressively developing alternative fuels and hydrogen, advancing carbon sequestration technologies, and promoting energy efficiency and renewable energy.

Based on the *National Energy Policy's* recommendations, President Bush announced in June 2001 his commitment to developing science-based climate change policy and targeting "breakthrough technologies." By stimulating American innovation with strong investments in key areas of the Federal R&D portfolio, President Bush is positioning the U.S. as a world leader in pursuit of energy technologies that can meet the climate change challenge. The approach is to focus and prioritize Federal investments, while ensuring that a balanced portfolio of technology options is pursued.

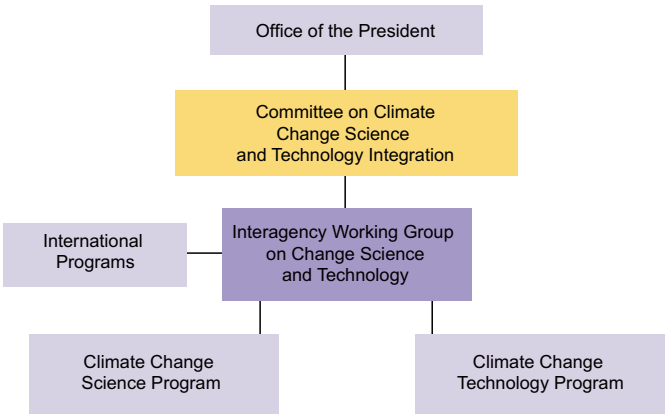
Selected Administration Actions to Date

President Bush committed the largest Federal budget for climate change activities in his FY 2004 proposed budget – more than $4 billion for climate change-related energy R&D, outreach activities, and targeted tax credits to encourage deployment of energy efficient and low-carbon energy technologies. Moreover, he launched a number of bold new climate change initiatives, enhanced international collaboration, and established the first Cabinet-level climate change management structure. Major Administration actions include:

Interagency Climate Change Initiatives: On June 11, 2001, President Bush initiated two complementary research efforts: a science-focused Climate Change Research Initiative (CCRI), and a technology-focused National Climate Change Technology Initiative (NCCTI). (http://www.whitehouse.gov/news/releases/2001/06/climatechange.pdf.). The NCCTI was chartered to:

- evaluate the current state of U.S. climate change technology R&D;
- provide guidance on strengthening research at universities and national labs;
- develop opportunities to enhance applied R&D partnerships;
- make recommendations for funding demonstration projects of cutting-edge technologies, and
- develop improved technologies for measuring and monitoring GHG emissions.

New Management Structure: In January 2002, President Bush established a new Cabinet-level management structure, the Committee on Climate Change Science and Technology Integration (CCCSTI), to guide and oversee his Administration's climate change activities. The President directed Energy Secretary Spencer Abraham and Commerce Secretary Donald Evans to lead the CCCSTI. The CCCSTI is chartered to provide recommendations to the President on climate change science and technology and address funding and implementation issues related to the Administration's climate change initiatives.



U.S. Climate Change Strategy: President Bush unveiled his Administration's new climate change approach on February 14, 2002. (http://www.whitehouse.gov/news/releases/2002/02/climatechange.html) The goal of the President's climate change strategy is to reduce U.S. greenhouse gas intensity -- how much we emit per unit of economic activity -- by 18 percent over the next 10 years. This will set the U.S. on a path to slow the growth of GHG emissions and, as science justifies, to stop and then reverse the growth of emissions. To reach this goal, several near-term actions were outlined including: improvements in the Federal GHG reduction registry; fuel economy increase for light trucks; tax incentives for renewable energy and hybrid and fuel-cell vehicles; Energy Star and encouraging voluntary actions by industry to reduce emissions. Key to achieving voluntary reductions are: Climate VISION (Voluntary Innovative Sector Initiatives: Opportunities Now), a multi-agency public-private partnership engaged with the major, energy-intensive sectors of the American economy to reduce emissions while sustaining strong economic growth, and Climate Leaders, a public-private partnership encouraging individual companies to develop long-term, comprehensive climate change strategies.

Interagency Working Group on Climate Change: In July 2002, the Secretaries of Agriculture, Commerce and Energy, and the Administrator of the Environmental Protection Agency (EPA), reported that the CCCSTI was operational and included a Deputy-level Interagency Working Group with direct oversight over two new multi-agency R&D coordination mechanisms:

- U.S. Climate Change Science Program (CCSP)
- U.S. Climate Change Technology Program (CCTP)

U.S. Climate Change Science Program (CCSP): The President established the U.S. Climate Change Science Program in 2002 as part of a new cabinet-level management structure to oversee public investments in climate change science. The new management structure also included the Climate Change Technology Program, which is summarized below. The CCSP incorporates the U.S. Global Change Research Program and the Climate Change Research Initiative established by the President in 2001. The Program coordinates and integrates scientific research on global change and climate change sponsored by 13 participating departments and agencies of the U.S. government. In July 2003, the CCSP released its strategic plan. (http://www.climatescience .gov/Library/stratplan2003/default.htm)

U.S. Climate Change Technology Program (CCTP): Working closely with the CCSP, the CCTP's goal is to accelerate the development and deployment of key technologies that may achieve substantial GHG emissions reductions and to promote voluntary reductions in GHG emissions. (CCTP's website is located at http://www.climatetechnology.gov.) The CCTP coordinates climate technology R&D activities across all of the relevant Federal agencies. The CCTP is currently:

- reviewing and making recommendations for identifying priorities of the Federal climate change technology R&D portfolio;
- conducting economic and technical analysis; and
- coordinating among and within Federal agencies.

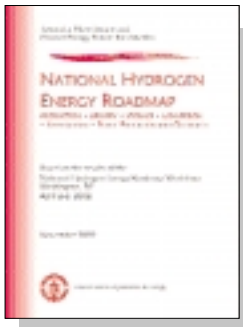
The CCTP and its participating Federal R&D agencies are working to meet the climate change challenge through focused research aligned with one or more of the following goals:

- reducing emissions from energy end-use and infrastructure;
- reducing emissions from energy supply;
- capturing and sequestering carbon dioxide (CO_2);
- reducing emissions of other GHGs; and
- enhancing capabilities to measure and monitor GHG emissions.

The work of the CCTP will help identify a number of the most promising technologies that may achieve these goals and will ultimately be included in the President's NCCTI. While the current level of investment is robust, it must be continually focused and targeted to meeting our goals.

For example, President Bush and DOE Secretary Spencer Abraham have already announced the following major technology initiatives in 2003 alone:

Hydrogen Fuel Initiative: President Bush launched the Nation's first comprehensive hydrogen initiative during his State of the Union Address on January 28, 2003, and committed $1.2 billion over five years for the Initiative. Together with the FreedomCAR Initiative, a partnership of major U.S. automakers, the Hydrogen Fuel Initiative will facilitate commercialization of hydrogen-powered fuel cell vehicles and hydrogen infrastructure technologies by 2015. The *National Hydrogen Energy Roadmap*, announced by Secretary Abraham in November 2002, outlines specific research objectives for this Initiative.



The National Hydrogen Energy Roadmap is the foundation for the country's first comprehensive hydrogen initiative.

(http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/national_h2_roadmap.pdf)

International Partnership for the Hydrogen Economy (IPHE): Secretary Abraham announced the International Partnership for the Hydrogen Economy on April 28, 2003, at the International Energy Agency Ministerial Meeting in Paris. The IPHE will coordinate international efforts to develop a hydrogen economy by facilitating collaborative R&D and common codes and standards for hydrogen fuel.

Carbon Sequestration Leadership Forum (CSLF): Secretary Abraham and Under Secretary of State for Global Affairs, Paula Dobriansky rolled out the first ministerial-level international organization for addressing carbon sequestration technologies and policy issues on February 27, 2003. CSLF is coordinating carbon capture and storage R&D with international partners and private industry.

FutureGen: Concurrent with the CSLF, the Bush Administration unveiled FutureGen, a $1 billion, 10-year public-private demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant.

Targeted Incentives for Carbon Sequestration: On June 6, 2003, Agriculture Secretary Ann Veneman announced for the first time consideration will be given to management practices that store carbon and reduce GHG emissions in setting priorities and implementing USDA's forest and agriculture conservation programs, such as the Environmental Quality Incentives Program and Conservation Reserve Program. USDA will provide financial incentives, technical assistance, demonstrations, pilot programs, education, and capacity building, along with measurements to assess the success of these efforts.

International Thermonuclear Experimental Reactor (ITER): ITER will help answer tough questions about fusion power and advance both the science and technology of fusion by opening the way to a vast array of critical experiments. This experiment is a crucial element in the path forward to satisfying global energy demand and dramatically improving America's energy security while significantly reducing greenhouse gas emissions.

Working With Other Nations

In pursuing these approaches to climate change, the U.S. is committed to working with other countries, especially developing countries, to build future prosperity along a cleaner and better path. The President's strategy promotes cooperative relationships so that international activities to address climate change are complementary. Many of our major technology initiatives are undertaken in partnerships with other countries. Since June 2001, the U.S. has engaged in bilateral partnerships with Australia, Canada, China, seven Central American countries (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama), the European Union, India, Italy, Japan, New Zealand, Republic of Korea, and the Russian Federation on issues ranging from climate change science to the Administration's technology initiatives to policy approaches.

Role for Technology and Innovation

"Our approach must be consistent with the long-term goal of stabilizing greenhouse gas concentrations in the atmosphere. Our actions should be measured as we learn from science and build on it. Our approach must be flexible to adjust to new information and take advantage of technology."

President George W. Bush
June 11, 2001

While significant uncertainties remain with respect to our scientific understanding of the Earth's climate, we can act now to address the factors that may contribute to potential climate change. In the near-term, in order to enable continued economic growth and reduced emissions, the U.S. is vigorously pursuing a wide array of technology deployment, voluntary and outreach programs, tax incentives to encourage new technology adoption, and financial and technical assistance programs to promote energy efficiency. (http://www.whitehouse.gov/news/releases/2003/09/20030930-4.html)

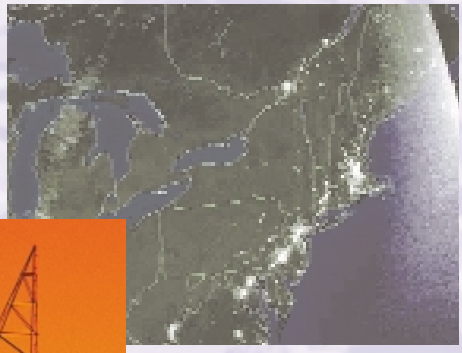
For the longer-term, the U.S. is investing in a diverse portfolio of energy technologies with the potential to yield substantial reductions in emissions of GHGs. Given the considerable lead times for energy technology development, deployment and commercialization, investment in a diverse portfolio of technologies must be made today. The U.S. continues to be a leader in these investments. Indeed, some of the technologies highlighted in this report may bring about the type of energy revolution that can dramatically improve our global 21st century energy system, with significantly reduced GHG emissions as a result.

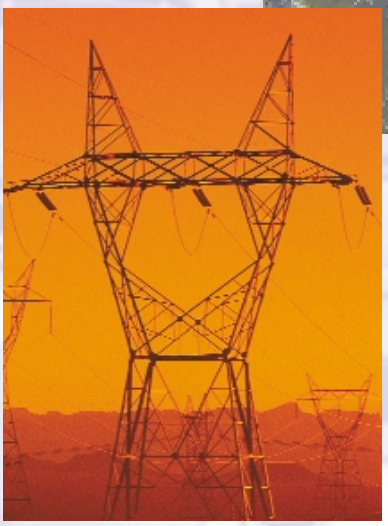
Reducing Emissions from Energy End-Use and Infrastructure

The Chesapeake Bay Foundation's Philip Merrill Environmental Center demonstrates energy-efficient design. The Center uses two-thirds less energy than a typical office building. One-third of the building's energy is derived from renewable sources.

One of the major opportunities to reduce emissions from energy end-use and reverse America's growing dependence on foreign oil is to transform our Nation's fossil fuel dependent economy to a clean hydrogen economy. In a significant step toward this goal, President Bush established the FreedomCAR partnership with major U.S. automakers and the Hydrogen Fuel Initiative to help facilitate the commercialization of hydrogen-powered fuel cell vehicles by 2015.

Other opportunities to reduce emissions exist in almost every segment of the economy where there are vast technical possibilities to improve energy end-use efficiency. For example, "superconducting" materials can almost eliminate the loss of electricity flowing through typical transmission lines. Also, energy storage technologies such as batteries, flywheel storage, superconducting magnetic storage, supercapacitors, and others, can improve the efficiency and reliability of the electric utility system by reducing the requirements for spinning reserves to meet peak power demand. Therefore, we achieve better use of baseload generation and enable greater use of intermittent renewable energy technologies.





The August 2003 blackout (satellite photo) in parts of Northeastern U.S. underscored the importance of the National Energy Policy's recommendations to modernize the national electric grid. A modernized grid would improve reliability and facilitate the adoption of advanced technologies that improve efficiency and provide power from distributed sources.

With an expanding global economy, accompanied by advancing technology, the next couple of decades will likely see significant efficiency gains in most industrialized countries and potentially greater improvements in transition economies. Improving energy end-use will reduce energy consumption and associated emissions and reduce vulnerability to supply disruptions, price spikes and threats to electricity infrastructure. Technology innovation in transmission and distribution, including such areas as high-temperature superconductivity, has the potential to help alleviate these problems. It can create a more reliable, robust electric grid with greater efficiency, relibility and security.

FreedomCAR

"FreedomCAR isn't an automobile, it's a new approach to powering the cars of the future... The gas-guzzler will be a thing of the past."

Energy Secretary Spencer Abraham
January 9, 2002

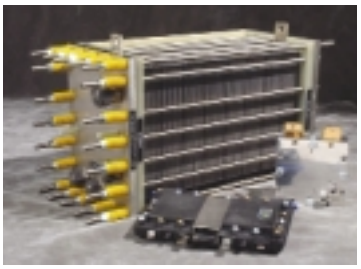
The C-A-R in FreedomCAR stands for Cooperative Automotive Research. DOE is leading this ambitious, cost-shared, government-industry R&D partnership with the U.S. Council of Automotive Research, a cooperative research organization formed by Ford Motor Company, General Motors Corporation, and the DaimlerChrysler Corporation. FreedomCAR's goal is the development of cars and trucks that are:

- cheaper to operate;
- pollution-free;
- competitively priced; and
- free from oil

General Motors recently introduced its new HyWire fuel cell vehicle, the first drive-by-wire fuel cell vehicle prototype. In the HyWire, the driver operates the vehicle via an electronic control unit rather than a steering wheel and pedals.

Emissions from transportation will decline significantly as such cars and trucks replace those in today's fleet. DOE and its partners are pursuing R&D in fuel cells, hydrogen production and storage, and safety.

Fuel cell vehicles represent a radical departure from vehicles with conventional internal combustion engines. Automobiles powered by pure hydrogen fuel cells emit no pollution and no CO_2. The only exhaust is pure water. Fuel cell vehicles can be fueled with pure hydrogen gas stored onboard in high-pressure tanks or other storage systems. They also can be fueled with hydrogen-rich fuels—such as methanol, natural gas, or even gasoline—



A fuel cell works like a battery but does not require recharging. Instead, it uses hydrogen or hydrogen-rich fuels to produce electricity.

that are converted into hydrogen gas by an onboard device called a "reformer." Before fuel cell vehicles make it to local auto dealerships, significant R&D is required to reduce cost and improve performance. Furthermore, effective ways must be found to produce and store hydrogen and other fuels.

In addition to the President's FreedomCAR Initiative, a number of other promising climate change technologies are being pursued, including advanced heavy-duty vehicle technologies, zero energy homes and commercial buildings, solid-state lighting, and superconductivity.

Advanced Heavy-Duty Vehicle Technologies

The Department of Transportation (DOT) supports heavy-duty vehicle technology R&D ranging from locomotives to large trucks to inter-city buses. Some of the most exciting work involves fuel cell transit buses, which run on set routes, refuel at a limited number of locations, and are maintained by expert technicians, making them ideal for testing new technology.

A recent DOT and DOE collaboration proved the concept of a viable fuel cell bus. DOT has extended its efforts and plans to have 13 buses in demonstration projects nationwide by the end of 2004. These efforts are helping to lay the foundation for the commercial viability of heavy-duty vehicle fuel cells and their supporting infrastructure.

With support from DOE and DOT's Federal Transit Administration (FTA), a 30-foot fuel cell hybrid bus combining several cutting-edge technologies was developed. The bus is currently in revenue service operation.

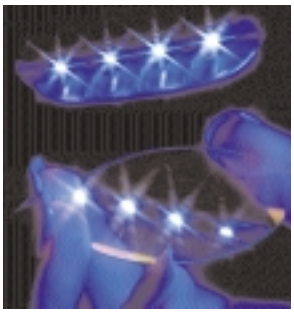
Zero Energy Homes & Commercial Buildings

DOE's Zero Energy Homes (ZEH) concept is bringing a new approach to U.S. homebuilders. ZEH combines revolutionary, energy-efficient construction techniques and appliances with commercially available renewable energy technologies such as solar-water heating and solar electricity. The current goal is to enable new homes to perform at least 50 percent more efficiently than homes built to current minimum efficiency standards, but the longer-term goal is to construct net "zero-energy" building systems.

The 820-acre Civano neighborhood near Tucson, Arizona was designed to promote economic growth and ecological harmony. Civano is minimizing the use of natural resources, in part by using renewable energy and creating building designs that are energy efficient. All the homes in the community use less than 50 percent of the energy of a conventionally built home.

Solid-State Lighting

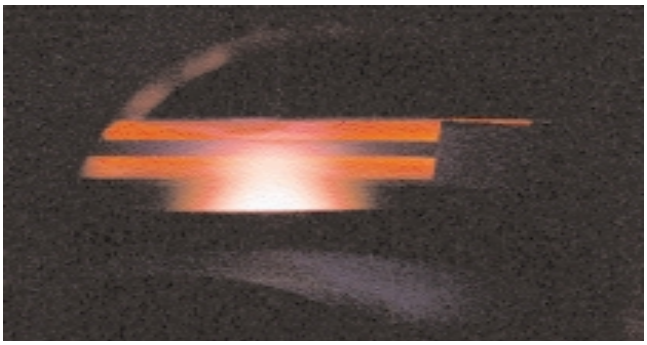
DOE's solid state lighting research may produce dramatic changes in lighting technology that will fundamentally alter the way we view artificial light. Lighting currently accounts for about 20 percent of U.S. electricity consumption. The most widely used sources of artificial light are incandescent and fluorescent lamps. Solid-state lighting is a new technology that has the potential to be 10 times more energy efficient than incandescent lighting. Accordingly, this technology could revolutionize the illumination of homes, offices, and public spaces.



Unlike conventional lighting, solid-state lighting creates light without producing heat. A semi-conducting material such as a light-emitting diode (LEDs) converts electricity directly into light and is extremely energy efficient. DOE's Sandia National Laboratory, a leader in solid-state lighting, hosts a web site with comprehensive information on LEDs. (http://lighting.sandia.gov)

Superconductivity

Superconductivity has the potential to revolutionize our electric transmission systems in the same way fiber optics revolutionized the communications industry. Unlike conventional wires made of materials such as copper, superconducting wires made of advanced materials have the ability to carry large electrical current without resistance losses. High Temperature Superconductors (HTS) conduct electricity with extremely high efficiency. When an electrical conductor is cooled sufficiently, electrical resistance disappears, which allows a very large electrical current to flow through it.



DOE is at the forefront of worldwide efforts to develop new processes for manufacturing high quality, high temperature superconducting materials. Researchers at Los Alamos National Laboratory have developed superconducting tape shown above that carries high electrical currents that are 200 times greater than copper wire.

Reducing Emissions from Energy Supply

Current global energy supplies are dominated by fossil fuels, namely, coal, oil and natural gas. Transition to a low carbon future will require the pursuit of multiple technology options. Further improvements in efficiency of energy supply technologies, deployment of renewable technologies, a shift from high carbon to low carbon fuel (e.g. natural gas, synthesis gas, methanol and hydrogen), and increased use of nuclear energy can play important roles. Moreover, developments in advanced coal-based power generation that enable the production of both electricity and large quantities of hydrogen while capturing and sequestering carbon dioxide ($CO_{2)}$ would allow continued use of this plentiful domestic fuel.

Nuclear, solar, geothermal and wind energies emit few, if any, GHGs.

The Washbash River Coal Gasification Repowering Project, an Integrated Gasification Combined Cycle (IGCC) facility, is considered one of the cleanest coal-based power generation facilities in the world. It is owned by General Energy and Cinergy.

FutureGen

"Today I am pleased to announce that the United States will sponsor a $ 1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant..."

President George W. Bush
February 27, 2003

FutureGen is a public-private initiative to build the world's first integrated sequestration and hydrogen production power plant. When operational, the prototype will be the cleanest fossil fuel fired power plant in the world. The plant will be a "living prototype" with future technology innovations incorporated into the design as needed. An industrial consortium representing the U.S. coal and power industries will lead the project and other countries will be invited to participate through the Carbon Sequestration Leadership Forum.

FutureGen, when operational, will be the world's first zero emission fossil fuel power plant. The coal-based Integrated Gasification Combined Cycle (IGCC) plant will produce electricity and hydrogen and be configured to capture its CO_2 emissions.

Hydrogen Fuel Initiative

The Hydrogen Fuel Initiative complements the FreedomCAR Initiative by focusing primarily on research to produce, store, and deliver hydrogen. Although hydrogen is the most abundant natural element, it must be produced or reformed from the fuels or materials with which it is bonded. Steam reforming of natural gas is currently the most widely used and economical hydrogen production method. Hydrogen can also be produced from diverse sources, including coal, oil and gas, or nuclear and renewable energy. The Initiative is exploring all of these options with the goal of producing hydrogen with zero emissions and ensuring that the required infrastructure technologies to deliver hydrogen safely are developed.

Hydrogen Production from Fossil Fuels

DOE is investigating promising new technologies to produce large quantities of moderate-cost hydrogen from natural gas and coal while capturing and sequestering CO_2 in the process. One exciting technology for hydrogen production from natural gas is the advanced Ion Transport Membrane (ITM), which produces and uses oxygen in a single step to generate synthesis gas. DOE is also advancing technologies that can utilize coal, one of America's most abundant natural resources, for large-scale production of hydrogen.

The world's first hydrogen energy station featuring the co-production of hydrogen fuel and electric power will serve as a commercial demonstration of hydrogen as a safe and clean energy alternative. The project is a public-private partnership between DOE, the City of Las Vegas, Air Products and Chemicals, Inc., and Plug Power.

Nuclear Hydrogen Initiative

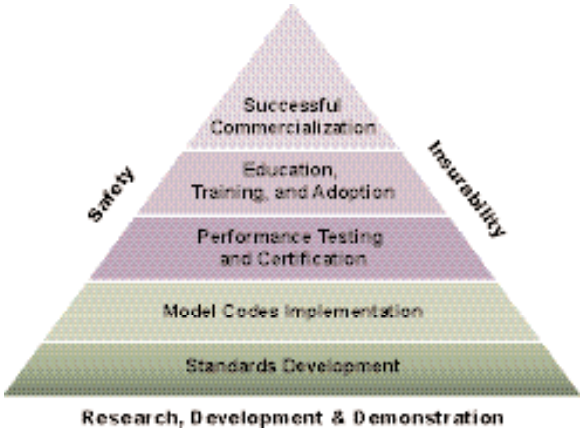
Under the Nuclear Hydrogen Initiative, R&D will be conducted on enabling technologies to demonstrate nuclear-based hydrogen producing technologies and to develop deployment alternatives to meet future needs for increased hydrogen consumption. By 2016, the Initiative intends to demonstrate economic, commercial-scale hydrogen production using an advanced high temperature reactor system design capable of generating both electrical power and very high temperature heat, which is required to snap the chemical bonds holding the hydrogen in chemical compounds. An advanced high-temperature reactor will provide heat to an adjacent hydrogen plant where one of two chemical processes will produce 10 tons of hydrogen an hour for commercial sale, and turn turbines to make electricity, all without emitting any GHGs.

Hydrogen From Renewable Energy

For the past few years, DOE has significantly expanded its work on hydrogen production from renewable sources. This work includes direct production of hydrogen using sunlight or biomass, as well as indirect production of hydrogen using electrolysis, with power supplied from biomass, wind, solar energy, geothermal energy, and hydropower sources.

Hydrogen Infrastructure

Widespread commercialization of hydrogen fuel cell vehicles will require development of an accompanying hydrogen infrastructure. Currently, hydrogen delivery systems exist only for the merchant hydrogen market in the chemical and refining industries. In the transformation to a hydrogen economy, this system will be insufficient for expected hydrogen fuel needs of the future. This infrastructure will require changes that address all transport and safety concerns.



Several steps, ranging from R&D through creating design and performance standards, are necessary to achieve insurable commercial systems. R&D is the most important element of the safety pyramid because it provides the critical data needed to create performance standards.

Hydrogen Safety

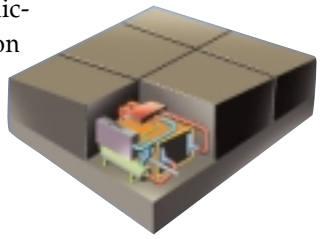
For decades, industry has demonstrated that hydrogen can be used safely in a wide variety of applications and conditions. However, handling hydrogen will be new to most consumers. In order to instill a robust safety culture to support a national hydrogen infrastructure, developers must optimize new fuel storage and delivery systems for safe everyday use, and consumers must become familiar with hydrogen's properties and risks. DOE and DOT are working together to assemble technology partnerships with industry to collaborate on codes and standards required for safe and effective hydrogen delivery and utilization.

Hydrogen Storage & Delivery

Hydrogen storage poses unique technical challenges. On-board storage of hydrogen currently requires large and heavy storage tanks due to the low energy density of the hydrogen fuel (i.e., a large volume of fuel is required for a reasonable vehicle driving range). Low-cost, efficient hydrogen storage will also be required to support the development of hydrogen refueling infrastructure.

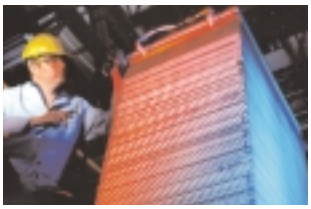
Fuel Cell Systems

In addition to fuel cell work for vehicles undertaken by the FreedomCAR Initiative, other fuel cell research on power and utility systems is on-going under DOE's Fuel Cells Systems Program including the public-private Solid State Energy Conversion Alliance (SECA). Headed by DOE's National Energy Technology Laboratory (NETL) and the Pacific Northwest National Laboratory, SECA is working to develop and demonstrate solid oxide fuel cell (SOFC) power systems that could be configured for a broad array of applications with minimal differences in core module components. Through the use of this mass customization technique, DOE and its partners hope to help bring about dramatic cost reductions required for fuel cells to be more competitive with traditional power sources.



Key to SECA's ambitious fuel cell cost reduction goal is the development of a compact, lightweight, 3-10 kilowatt "building block" module that can be mass produced.

The Department of Defense (DOD) also has a strong commitment to developing fuel cells. One of DOD's key R&D efforts is the development of a logistics fuel reformer/processor for mobile electric power (MEP) fuel cells. The logistics fuel reformer/processor could provide the ability to reform fuels to hydrogen in place of conventional generators. This would result in power generation systems that would not only increase troop mobility but also lower noise levels, increase efficiency and lower emissions.



Fuel cell systems could provide a revolutionary new option for generating electricity with efficiencies, reliability and environmental performance unmatched by conventional electricity generating approaches.

International Partnership for the Hydrogen Economy

"...working together with international partners, we can leverage scarce resources and advance the schedule for research, development, and deployment of hydrogen production, storage, transport, and end-use technologies."

Energy Secretary Spencer Abraham
June 16, 2003

Under DOE leadership, the International Partnership for the Hydrogen Economy (IPHE) now involves more than a dozen countries. IPHE is helping to make the hydrogen economy a reality by organizing and implementing focused research internationally. By leveraging resources and collecting the world's best minds, IPHE will advance cooperative R&D and commercial uses of hydrogen production, storage, transport and distribution. IPHE will also facilitate the establishment of common codes and standards and undertake activities to promote hydrogen and fuel cell programs.

Nuclear Power Generation IV

On July 23, 2001, Secretary of Energy Spencer Abraham announced the signing of a formal charter by the U.S. and governments of leading nuclear nations, including Argentina, Brazil, Canada, France, Japan, Republic of Korea, and the United Kingdom, which established the Generation IV International Forum. The Forum is dedicated to the development of the next generation of safe, economic, emission-free and proliferation resistant nuclear reactor and fuel cycle technologies by 2030. While today there are about 440 nuclear power plants operating worldwide, further advances in technology will broaden opportunities for expanded nuclear energy use in the future

"GEN IV" refers to the next generation of safe nuclear power plants that are being developed to produce low-cost electricity and hydrogen without any GHG emissions.

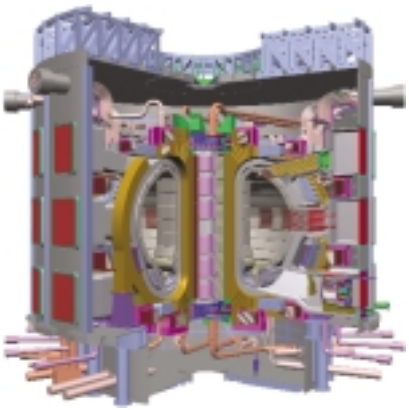
Generation IV systems represent a new generation of nuclear energy and fuel cycle technologies that can be made available in the 2015-2030 timeframe, and offer significant advances in the areas of sustainability, proliferation resistance and physical protection, safety, and economics. High operating temperatures and improved efficiencies make some Generation IV systems ideal for providing clean burning hydrogen needed to power fuel cell driven vehicles in the future, as well as providing hot water for nearby communities or energy to effect seawater desalinization.

International Thermonuclear Experimental Reactor (ITER)

"I am pleased to announce that the United States will join ITER, an ambitious international research project to harness the promise of fusion energy. The results of ITER will advance the effort to produce clean, safe, renewable, and commercially-available fusion energy by the middle of this century."

President George W. Bush
January 30, 2003

The ITER Project is a unique international collaboration intended to develop fusion as a practical source of energy to meet the world's growing demand for power. Fusion energy is the same energy that powers the sun. On Earth fusion energy can be fueled, in part, by a heavy isotope of hydrogen, which can be extracted from sea water. ITER follows decades of research and development by more than 30 countries worldwide. Participating countries in ITER including the U.S., are committed to begin construction on an international fusion R&D facility by the end of 2004.



The machines to be built by ITER aim to improve a number of aspects of the fusion process. Fusion is the nuclear process by which two hydrogen nuclei unite, usually under conditions of extreme heat and pressure, to create a single helium nucleus, releasing enormous amounts of energy.

In addition to these initiatives, other promising technologies are being pursued in the areas of renewable energy, advanced biotechnology, and nuclear energy.

Renewable Energy

Renewable energy encompasses a range of different technologies that can play important roles in reducing GHG emissions. DOE currently makes significant renewable energy investments in wind, solar, geothermal, and biomass.

Wind

Wind energy is the Nation's fastest growing renewable energy resource. Over the last two decades, wind power has made great leaps in technology and price competitiveness, but there is room for more technology improvements. One challenge for wind power is to develop cost-effective wind turbines that can generate electricity in low-wind areas. DOE's R&D investments in this area can help open a vast wind resource for the Nation.

A wind turbine's drive-train components -- generators, gearboxes, shafts and bearings -- convert the slow-rotating mechanical energy from the rotor to electrical energy. DOE and its industry partners are studying these components to make them more effective and less expensive to manufacture, operate and maintain.

Solar Photovoltaics (PV)

DOE is investing a significant share of its renewable energy R&D in solar photovoltaics (PV). The two primary types of PV technologies available commercially today are crystalline silicon and thin films. Thin-film PV technologies are being developed as a means of substantially reducing the cost of PV systems and much progress has been made. With further progress, thin films could result in truly low-cost PV electricity that can become competitive in energy markets.

Thin film PV is one component of DOE's renewable energy R&D portfolio. Researchers at the National Renewable Energy Laboratory are networking to reduce the cost of this technology, making for a wide range of new products.

Agricultural Programs For Biomass and Other Renewable Energy Systems

"The conversion of biomass into biobased products, fuels and energy offers significant benefits to the nation through healthier rural economies, improved environmental quality and improved energy independence."

Agriculture Secretary Ann Veneman
September 5, 2003

"This Administration is committed to the development of a next-generation of biorefineries that serve the nation by producing cost-competitive biobased industrial products and transportation fuels such as ethanol and biodiesel."

Energy Secretary Spencer Abraham
September 5, 2003

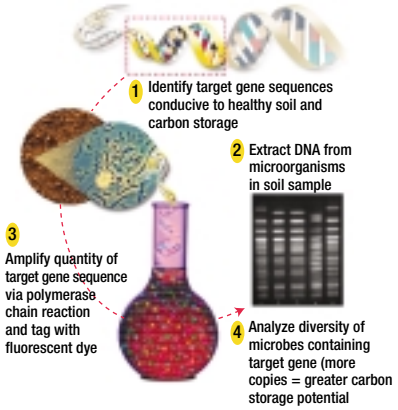
The U.S. Department of Agriculture (USDA) and DOE are currently funding research, development and demonstration projects under the Biomass Research and Development Act of 2000. There are a number of projects focusing on technologies to generate energy from animal waste, convert biomass to hydrogen, and develop innovative biorefinery processes. At Dartmouth University, for example, work is underway to integrate leading biomass pretreatment technologies with enzymatic digestion and hydrolyzate fermentation. In another example, Cargill Incorporated is working on platform chemicals from an oilseed refinery.

USDA is assisting farmers, ranchers, and rural small businesses develop renewable energy systems and make energy efficiency improvements to their operations. Eligible projects include those that derive energy or hydrogen from wind, solar, biomass, or geothermal sources.

USDA geneticists are breeding switchgrass to improve its biomass yield and its ability to recycle carbon as a renewable energy crop.

Advanced Biotechnology

Genetic science is progressing at a breathtaking pace, yet much remains to be discovered. Work at DOE that could be called "Advanced Biotechnology" seeks to revolutionize the applications of biotechnology to produce new fuels and reduce GHG emissions.



By testing, analyzing and mapping microbial DNA, researchers at IBEA, Oak Ridge National Laboratory and Los Alamos National Laboratory are advancing biotechnology to store carbon and produce hydrogen.

One of DOE's advanced biotechnology partnerships is with the Institute for Biological Energy Alternatives (IBEA). IBEA is applying the same strategy applied to the Human Genome Project by genetically mapping an entire ecosystem. A key area of IBEA's work is dissecting the genetic code of microorganisms that consume CO_2 and release hydrogen. By studying the genetic instructions of the microorganisms, IBEA hopes to create similiar, more efficient, man-made organisms. This advancement would allow scientists to use micro-organisms to generate hydrogen, for example, or to break down CO_2 from power-plant emissions. Another exciting Advanced Biotechnology project involves genetically modifying a plant's metabolism to take up more CO_2 and thus sequester additional carbon in soils.

Scientists supported by DOE at the National Laboratories and universities are using genomic information being collected from different plant species to design plants capable of sequestering atmospheric CO_2 in plant tissues and soil organic matter. Strategies being developed are to increase CO_2 uptake (photosynthesis) from the atmosphere and to enhance the partitioning of carbon assimilated in photosynthesis to long-lived biochemicals that will remain in plants and soils for extended periods.

Nuclear Energy

Nuclear technology options in the U.S. climate change technology portfolio are important because nuclear energy offers the possibility of producing substantial amounts of reliable, affordable electricity without GHG emissions. It can also be harnessed to produce vast quantities of hydrogen to help fuel a new, pollution-free economy. The expanded use of nuclear energy must also satisfactorily address a number of other unique and important issues, such as nuclear waste management. These issues are being addressed through DOE's advanced nuclear energy technology programs.

The energy generated by one pound of nuclear fuel can provide the hydrogen equivalent of 250,000 gallons of gasoline without any GHG emissions.

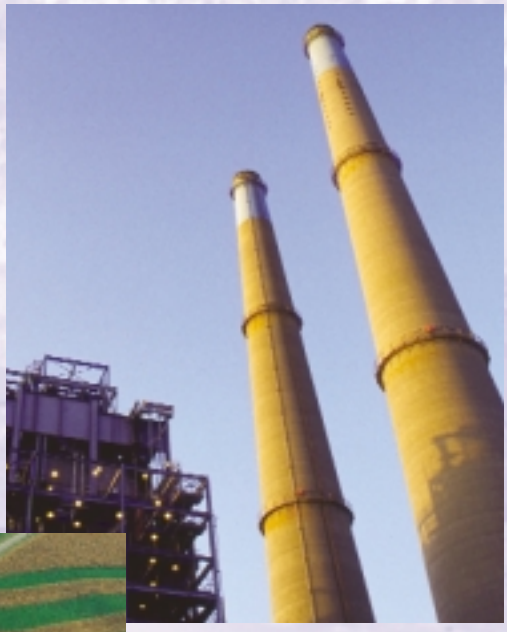
Nuclear Power 2010

The Nuclear Power 2010 Program, unveiled by DOE Secretary Abraham in February 2002, is a joint government-industry cost-shared effort aimed at identifying new sites for nuclear power plants, developing advanced plant technologies, and demonstrating new regulatory processes. Under the Early Site Permit (ESP) program, each of three power generation companies will develop, submit and seek Nuclear Regulatory Commission approval of an ESP application at one of their existing commercial nuclear power plant sites. Another key goal of Nuclear Power 2010 through which DOE is also providing limited—but critical—support to private companies, is to test a one-step licensing procedure for nuclear reactors, the combined Construction and Operating License (COL) process. This procedure offers resolution of all public health and safety issues associated with construction and operation of a new nuclear power plant before a power generation company begins incurring substantial construction costs. Successful demonstration of the COL process will enable the private sector to decide, as early as 2005, to order new nuclear power plants for deployment in the U.S. in the next decade.

Advanced Fuel Cycle Initiative

Of the challenges that must be addressed to enable a future expansion in the use of nuclear energy in the United States and worldwide, none is more important or more difficult than dealing effectively with spent nuclear fuel. DOE's Advanced Fuel Cycle Initiative (AFCI) is developing advanced fuel cycle technologies, which include spent fuel treatment, advanced fuels, and transmutation technologies, for application to current operating commercial reactors and next-generation reactors. Transmutation technologies can transform long-lived radioactive materials in spent fuel into short-lived or non-radioactive materials and significantly reduce the absolute volume of high-level nuclear waste requiring geologic disposal, lowering the cost of its disposal. Through these technologies, there is the potential to extract energy from nuclear waste and make it available to the national power grid, a potentially huge source of energy.

Capturing and Sequestering Carbon Dioxide



Fossil fuels will likely remain the mainstay of global energy production well into the 21st century. "Carbon sequestration" is the term given to a suite of technologies that can remove CO_2 from large point sources, such as power plants, oil refineries and industrial processes, or from the air itself. The CO_2 can then be stored in geologic formations such as depleted oil and gas reservoirs, deep coal seams or saline reservoirs. It can also be stored in plants, trees and soils by increasing their natural CO_2 uptake.

CO_2 uptake can be increased in natural ecosystems. USDA estimates that an additional 12 million tons of carbon equivalent emissions can be reduced by 2012 by targeting GHG emissions reductions and carbon sequestration under its conservation program. CO_2 emissions can also be captured from fossil fuel power plants and transported for storage in geologic formations such as saline reservoirs or abandoned oil reservoirs.

Because carbon sequestration holds the potential both to reduce emissions of CO_2 from point sources and to remove CO_2 from the air, sequestration research has grown over the last five years from small-scale, largely conceptual studies, to one of the highest single technology priorities. Federal agencies are exploring innovative or breakthrough concepts on carbon capture and various modes of sequestration, including terrestrial, geologic, and oceanic. Additionally, through the Carbon Sequestration Leadership Forum, the United States is collaborating with more than a dozen other countries on carbon capture and storage technologies.

The Carbon Sequestration Leadership Forum

"The Carbon Sequestration Leadership Forum will help unite interested governments and focus attention on the development of carbon sequestration technologies."

Energy Secretary Spencer Abraham
February 27, 2003

Established by the U.S. State Department and DOE in February 2003, the Carbon Sequestration Leadership Forum (CSLF) coodinates data gathering, R&D and joint projects to advance the development and deployment of carbon sequestration technologies worldwide. CSLF held its first ministerial-level meeting on carbon sequestration in June 2003. High-level representatives from 14 countries, the European Commission, and over 400 members of the international energy, business and government communities participated and signed CSLF charter.

CARBON SEQUESTRATION LEADERSHIP FORUM PARTNERS
Australia
Brazil
Canada
China
Colombia
European Commission
India
Italy
Japan
Mexico
Norway
Russian Federation
South Africa
United Kingdom
United States

Multi-Agency Carbon Sequestration Research

DOE carbon sequestration research activities encompass all aspects of carbon sequestration and is composed of three elements: a core R&D program, FutureGen, and the Regional Carbon Sequestration Partnerships. Core R&D efforts are aimed at developing a portfolio of technologies to cost-efficiently capture and permanently store CO_2. These technologies will provide the technical base for the program's two initiatives.

Core R&D emphasizes technologies that directly capture CO_2 from large point sources and store the emissions in geologic formations. Reducing net CO_2 emissions from these facilities with CO_2 capture technology represents an opportunity to achieve substantial emissions reductions. Storing CO_2 in geologic formations is considered an attractive option for a number of reasons. In the case of depleted oil reservoirs or deep coal seams, CO_2 can be

Carbon capture technologies are being developed under DOE's Carbon Sequestration Program to capture CO_2 emissions from large point sources such as the oil refinery pictured above.

used to enhance oil recovery or produce methane thus providing economic incentive to store carbon. Furthermore, saline reservoirs are geographically located througout the world and have the capacity to store vast amounts of CO_2.

Both the ocean and many terrestrial ecosystems are sinks of atmospheric CO_2 that could potentially be enhanced. The DOE R&D program on carbon sequestration includes research to provide a scientific underpinning needed to develop and understand the potential effectiveness of strategies for enhancing carbon sequestration in terrestrial ecosystems and the ocean, including study of possible unintended consequences of that sequestration.

DOE also supports a multi-laboratory consortium for Carbon Sequestration in Terrestrial Ecosystems (CSiTE) to perform fundamental research on mechanisms that can enhance terrestrial carbon sequestration as one component of a more comprehensive carbon management strategy. CSiTE is investigating mechanisms and critical pathways for creating larger and longer-lasting terrestrial carbon pools and seeking to understand, quantify, and enhance natural mechanisms where substantial amounts of carbon are assimilated and sequestered by terrestrial ecosystems.

CSiTE's fundamental and basic research focuses on (i) developing scientific understanding of carbon capture and sequestration mechanisms across multiple scales from the molecular to the landscape; (ii) developing conceptual and simulation models for extrapolation of sequestration information across scales of time and space; and (iii) estimating a National carbon sequestration potential that includes analysis of the potential environmental consequences and economic implications. The CSiTE

consortium maintains cooperative research agreements with other Federal agencies, universities and with environmental institutions.

DOE also supports research on two potential methods of enhancing ocean sequestration. One is direct injection of a relatively pure CO_2 stream that has been generated at a power plant or industrial source, and the other enhances net oceanic uptake from the atmosphere through iron or other types of nutrient fertilization. DOE's R&D focuses on the long-term effectiveness and potential environmental consequences of this carbon sequestration strategy.

The core DOE Carbon Sequestration Program also includes research to accelerate understanding of the functional genomics of plant species (e.g., poplar trees) that might be used to modify plant genetics and/or management of plants and ecosystems to both take up more CO_2 from the atmosphere and to store it in long-lived pools such as recalcitrant soil organic matter. This work is carried out at the National Laboratories, universities, and private research organizations.

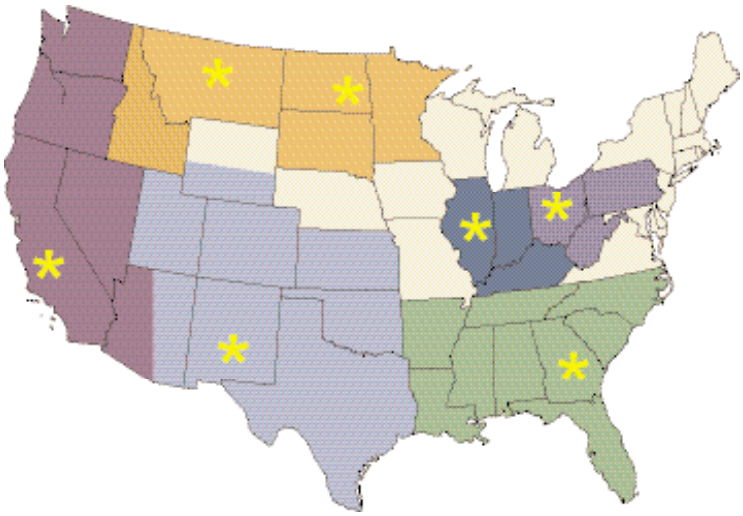
USDA's global change research program, conducted under the CCSP, is strengthening efforts to determine the significance of terrestrial systems in the global carbon cycle and to identify agricultural and forestry activities that can contribute to GHG reductions in the atmosphere. USDA research agencies are supporting the President's directive to develop accounting rules and guidelines for carbon sequestration projects. Contributions include the development of improved emission and sequestration coefficients, new tools for accurately measuring carbon and other greenhouse gases, and the development of improved methodologies.

Regional Carbon Sequestration Partnerships

"These partnerships...will become the centerpiece of our sequestration program."

Energy Secretary Spencer Abraham
November 21, 2002

On August 16, 2003, DOE named seven regional partnerships of state agencies, universities, and private companies to form the core of a nationwide network designed to determine the best approaches for capturing and permanently storing GHGs. Collectively, the partnerships include more than 140 organizations spanning 33 states, three Indian nations, and two Canadian provinces.



DOE's seven regional carbon sequestration partnerships, announced in August 2003, will investigate the potential for carbon sequestration in their region. They will also identify any infrastructure, safety and envionmental issues that must be addressed in order to ensure that CO_2 can be safely and permanently stored.

The Partnerships will develop a framework to validate and potentially deploy carbon sequestration technologies with a focus on determining which sequestration approaches are best suited for each geographic region. They will also study regional regulations, safety and environmental concerns, and the infrastructure that would be required if sequestration technologies were to be deployed. At the end of the first, two-year phase, the partnerships will recommend technologies for small-scale validation testing in a Phase II competition expected to begin in 2005.

Reducing Emissions of Other Greenhouse Gases

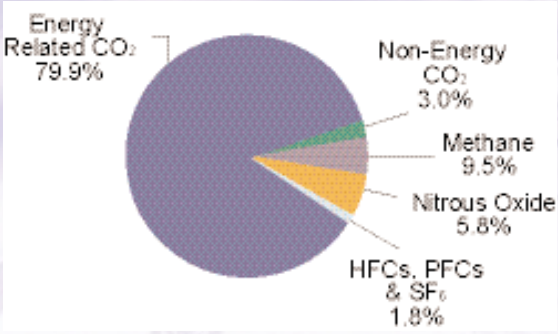
Global Warning Potentials (100 Year Time Horizon)

GAS	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	23
Nitrous oxide (N_2O)	296
HYDROFLUORCARBONS	
HFC-23	12000
HFC-125	3400
HFC-134a	1300
HFC-143a	4300
HFC-152a	120
HFC-227ea	3500
HFC-43-10mee	1500
FULLY FLUORINATED SPECIES	
SF_6	22200
CF_4	5700
C_2F_6	11900
C_4F_{10}	8600
C_6F_{14}	9000

The concept of global warming potential (GWP) was developed to compare the ability of each GHG to trap heat in the atmosphere relative to another gas. In this case, CO_2 is the reference case. Methane, for example, has a GWP of 23 over a 100-year period. This means that on a kilogram for kilogram basis, methane is 23 times more potent than CO_2 over a 100-year period. (IPCC Third Assessment Report)

Other greenhouse gases cover a broad array of gases other than CO_2, principally methane (CH_4), nitrous oxide (N_2O), sulfur hexaflouride (SF_6), and other chemicals that are effective global warmers. These other GHGs are more potent as energy absorbers than CO_2 (per unit weight) and have cumulatively contributed between one-fifth and one-third of the total estimated global warming potential since pre-industrial times. Therefore, reducing non-CO_2 GHG emissions is an important component of any GHG mitigation strategy.

The U.S. is a world leader in reducing emissions of non-CO_2 GHGs. These emissions come from many sources and sectors, including energy production (coal mining and oil and gas systems), agriculture, transportation, waste disposal, heating and cooling applications, aluminum and magnesium production, semiconductor manufacturing, and electricity transmission. By working closely with specific emitting sources, voluntary programs have demonstrated the value of technology in reducing non-CO_2 GHG emissions and have identified emerging technologies with the promise of larger future emission reductions. Two areas demonstrate these types of activities and progress: methane recovery from coal mines and SF_6 substitution in magnesium production.



CO_2 from burning fossil fuels is the dominant GHG source category in the U.S., typically comprising close to 80 percent of all GHG emissions. However, other GHGs must not be overlooked. DOE, EPA, and USDA are working closely with industry and agriculture to achieve voluntary reductions through new management practices and technology.

Methane Recovery from Coal Mines

Methane is liberated during underground and surface coal mining as part of normal mining operations. Most emissions result from natural degasification or ventilation systems employed at underground mines to ensure that methane levels remain within safe concentrations. EPA and DOE are working with the coal industry through the President's Climate VISION Initiative to reduce emissions by recovering methane gas liberated during mining. Innovative technologies are being developed to capture and produce coalbed methane (CBM) and coal mine methane (CMM). In particular, technologies to oxidize the low-concentration methane contained in mine ventilation air have the potential to substantially reduce emissions. Furthermore, the development of advanced drilling technologies such as in-mine and surface directional drilling systems may enable fewer wells to produce more gas, thus increasing efficiency and reducing emissions.

EPA and DOE are working cooperatively with CONSOL Energy to demonstrate thermal oxidation of ventilation air methane using Megtec's Flow Reversal Reactor. Ventilation air methane equipment, such as the Megtec Vocsidizer, uses up to 100 percent of the methane released from a mine ventilation shaft. It generates heat that can be used for power production.

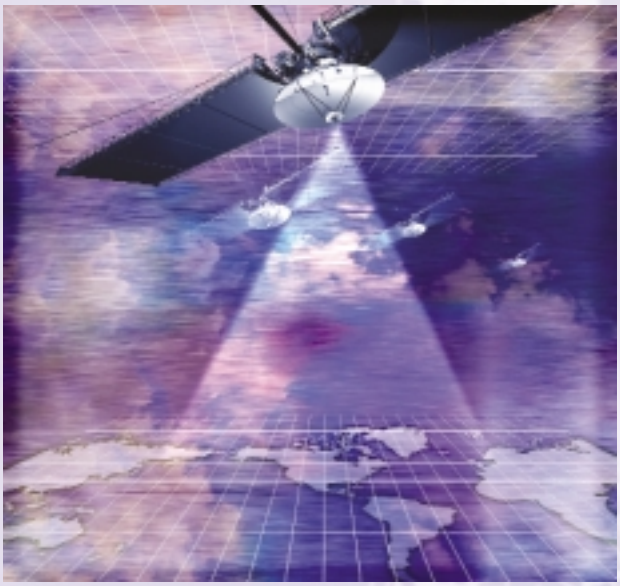
SF_6 from Magnesium Production

For more than 25 years, magnesium metal producers and casting companies have used SF_6 mixed with dry air and/or CO_2 as a protective cover gas to prevent the oxidation and burning of molten metal. EPA and the U.S. magnesium industry, with the support of the International Magnesium Association (IMA), are working in a voluntary partnership to eliminate SF_6 emissions. Promising new cover gas alternatives are now commercially available and are undergoing further evaluation in production-scale trials. The partnership's early success has led to growing industry optimism that it can eliminate all SF_6 emissions by 2010, as part of the President's Climate VISION Initiative.

SF_6, a potent GHG, is used as a cover gas in the magnesium industry to prevent the burning of molten metal. Alternative cover gas technologies are now being developed that meet or exceed current performance requirements and offer significant environmental benefits. The top photograph uses a cover gas while the second photo is without a cover gas.

Enhancing Capabilities to Measure and Monitor GHG Emissions

A wide array of GHG sensors, measurement platforms, monitoring and inventorying systems, and inference methods will likely be needed to meet basic GHG emissions measurement requirements of the future. Measurement systems must be developed that can establish baselines and measure carbon storage and GHG fluxes on various scales, from individual projects to large geographic areas. Improved measurement and monitoring technologies and capabilities can also inform the state of climate science and help to identify and guide future opportunities for technology development.



NASA satellites with new and improved sensors will be mounted in Earth observing satellites to provide valuable data on GHGs that can improve understanding of their impacts on climate change.

Measuring and monitoring of GHG emissions is an example of the Climate Change Science Program (CCSP) and the Climate Change Technology Program (CCTP) working together. Many of the baseline measurements, observations and sensing systems used to advance our understanding of climate change science are being developed as part of the CCSP. The CCTP efforts are focused primarily on measuring and monitoring the applications and performance of various climate change technologies, such as in terrestrial (soils and agriculture) and geologic sequestration. The coupling of both Programs presents new opportunities to measure and monitor GHG emissions and to better understand the roles of various technologies in affecting GHG inventories and flows.

Laser Induced Breakdown Spectroscopy (LIBS)

With support from NASA, USDA and DOE, LIBS is one of the longer-running success stories of Federally funded R&D. In July 2003, researchers from Los Alamos National Laboratory received an unprecedented 4th R&D 100 Award for a novel LIBS application called CARISS (Compositional Analysis by Raman-Integrated Spark Spectroscopy). This application is the only field-deployable instrument that can fit into a briefcase and provide a complete chemical analysis of a material, including soil carbon, at various depths. With this breakthrough, the time and cost of soil carbon measurements has been reduced by at least a factor of 100. Kansas State University will soon lead the testing protocol validation of LIBS for soil carbon measurement, which will be instrumental in facilitating its rapid commercialization.

Under the Applied Terrestrial Sequestration Partnership, USDA, DOE and NETL are working to improve measuring and monitoring of GHG emissions and changes in soil carbon. Supported by all three agencies and NASA, LIBS is a breakthrough carbon measurement technology. Its ability to quickly and cost effectively measure carbon in soils will be key to the monitoring of terrestrial sequestration projects.

Agriflux

USDA is developing a new network of 30 sites for measuring the effects of environmental conditions and agricultural management decisions on carbon exchange between the land and the atmosphere. Studies will identify crop management practices to optimize crop yield, crop quality, and carbon sequestration and carbon dioxide concentrations and other environmental conditions expected in the 21st century. Research will lead to new ways for prediction and early detection of drought in agricultural systems based on weekly and monthly climate forecasts.

Ameriflux

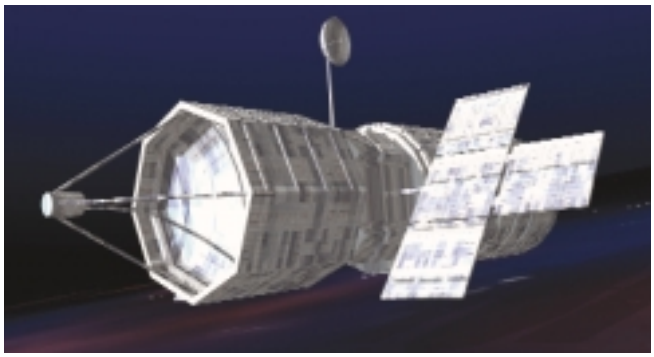
AmeriFlux is a research network used in collecting, synthesizing, and disseminating long-term measurements of CO_2, water, and energy exchange for a variety of terrestrial landscapes across the United States. There are about 75 AmeriFlux sites, and roughly half of them have been operational 5 years or longer; a few sites have data records of 10 years or longer. The AmeriFlux network is lead by DOE with joint support from other agencies (NASA, NOAA, USDA, NSF, USGS). The network produces two important greenhouse gas data products: (i) spatial and time-series information on atmospheric concentration of CO_2 and water vapor (key greenhouse gases), and (ii) the net exchange of CO_2 between the atmosphere and biosphere, which is important for estimating terrestrial carbon sequestration. AmeriFlux data products are important for constraining models that simulate quantitatively the exchange of CO_2 between the atmosphere and terrestrial biosphere.

The AmeriFlux network is part of an international scientific program of flux measurement networks (e.g., AmeriFlux, FLUXNET-Canada, CarboEurope, AsiaFlux) that seeks to better understand the terrestrial carbon cycle. The overall network (i.e., FLUXNET) provides unique and coordinated data for understanding the role of the terrestrial biosphere as a source or sink of CO_2 in the atmosphere, and for estimating worldwide potentials of terrestrial carbon sequestration.

Ameriflux towers such as the one pictured above are taking long-term measurements of CO_2 and water vapor fluxes in 15 sites throughout the world, including the U.S. Data gathered from these measurement sites are important to understand interactions between the atmospheric and terrestrial systems.

Remote Sensing

Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. Remote sensing provides data critical to weather prediction, agricultural forecasting, resource exploration, and environmental monitoring. Under development at NASA, new and improved sensors will be mounted in Earth observing satellites. This new family of sensing technologies includes infrared, optical and infrared spectrometry, laser, light detection and ranging, and radar. Additionally, computing power capable of handling large amounts of technology is being applied to meet the challenges of data analysis and intrepretation. NASA has 18 current satellites carrying over 80 sensors on-orbit, with detailed plans for deploying scores of additional sensors on 12 satellites over the next 10+ years.



Satellites provide valuable data on CO_2, aerosols, water clouds, and methane.

NOAA is undertaking monitoring program improvements, including a regional/continental scale pilot program using aircraft and an onboard sampling system. The initiative focuses on improving carbon dioxide monitoring over continents, which requires vertical profile measurements to obtain data representative of regional scale (e.g., 1000 km). The pilot program will cover North America in the first few years, expanding to a full global operational capability over several years. The near-term elements of the initiative are completion of a network of 36 atmospheric vertical profiling stations utilizing aircraft and tall towers in North America; extension of the global network capability (at a sparser sampling distribution); sustaining current CO_2 flux towers in representative U.S. ecosystems; conducting research and development to operationalize satellite retrievals of carbon dioxide from existing satellite data streams; and developing operational capability to assimilate carbon data into numerical weather models.

Integrated Earth Observations

U.S. Federal agencies observe the Earth across a hierarchy of spatial scales on their own as well as in partnership with other agencies, commercial endeavors, and international entities.

In conjunction with the Climate Change Science Program, the CCTP will enable a hierarchical system of measuring and monitoring tools, including sensors deployed on satellites and aircraft, observations from ground networks, point-source sensors, and in situ stations.

Earth observation technologies enable measuring and monitoring systems that observe and account for the quantities and fluxes of greenhouse gases in the Earth's atmosphere, including CO_2, CH_4, NO_2, HFCs, PFCs, SF_6, O_3, ozone precursors, and aerosols and black carbon. Of equal importance, these technologies enable systems that observe and account for the sequestration of CO_2, including approaches for long-term holding atmospheric carbon in the oceans, on the land and underground. The global and long-term nature of the challenge requires observations across spatial scales from local to global, and across temporal scales from instantaneous monitoring of point sources and sinks to decadal monitoring of atmospheric composition and carbon sequestration.

Inventories of Specific Source Categories

The Environmental Protection Agency (EPA) has just completed a round of intensive inventory improvements for specific source categories, particularly for industrial and agricultural sources with high-global-warming-potential. Previous efforts have addressed tailpipe testing for NO_2 from mobile sources and collection of more detailed data for landfill and wastewater emissions. Currently, the EPA is improving greenhouse gas inventories and emissions estimation methods for all source categories. The EPA is addressing methodological and data needs for methane from livestock and manure, methane from iron and steel industries, and carbon dioxide from cement, lime, and gypsum production. The EPA is also paying particular attention to improving methods dealing with manure application and nitrogen content for soil carbon, emissions data for rice, landfill models, and sludge for agricultural soils. The EPA is developing complex emission models by enhancing the DayCent and Century models for estimating NO_2 and CO_2 from agricultural soils.

Conclusion

Under President Bush's leadership, the U.S. is now embarked on a long-term challenge, guided and paced by science, to explore and develop innovative and advanced climate change technologies. These technologies are expected to make a significant contribution to meeting the President's climate change goals, near- and long-term. President Bush made a commitment to pursue a sensible, science-based approach to climate change and build on America's capacity to innovate and develop technology. The President directed Federal agencies to apply their R&D resources to both the science and the technology. He established a new Cabinet-level management structure to guide and oversee this multi-agency effort. He directed his Cabinet Secretaries to enhance international collaboration, which has resulted in several bold new initiatives.

These actions, illuminated further by the projects highlighted in this report, signal a serious, long-term commitment to move forward in addressing climate change. They evidence strong Federal leadership in engaging America's research enterprise to spur innovation. Focused Federal investments can help bring about revolutionary technologies that will lead to dramatically reduced GHG emissions.

The Climate Change Technology Program continues to coordinate R&D efforts among all the participating Federal agencies and to help identify priority areas. As reflected in this report, there are a number of promising, cutting-edge technologies already well underway in today's U.S. climate change technology portfolio. From these R&D investments, undertaken in partnership with others, opportunities will arise to fundamentally transform and dramatically improve our 21st century energy system, with significantly reduced greenhouse gas emissions as the result.

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Page 6: HyWire, GM Fuel Cell Car, General Motors Corporation; 5kW Fuel Cell Manufactured by PlugPower (large cell), 25 watt Fuel Cell (three cell stack) Manufactured by H2Economy (smaller silver cell), 30 watt Cell Manufactured by Avista Labs, NREL, Stiveson, Matt; A Prototype Hydrogen Fuel Cell Bus (by ISE Research, Thor Industries and UTC Fuel Cells) at SunLine Transit Agency, NREL, SunLine Transit Agency

Page 7: Energy Efficient Housing at the Civano Development in Tucson, Arizona, NREL, James, George; closeup view of a LEDS substrate, Sandia National Laboratories, Randy Montoya; High Temperature Superconductor YBCO TAPE, Los Alamos National Laboratory

Page 9: Sacramento Municipal Utility District's (SMUD) Photovoltaic Array with Nuclear Cooling Towers in the Background, NREL, Gretz, Warren; Turbine Installation at the Nine Canyon Wind Project; Largest Wind Farm to be Built in Washington State, NREL, Energy Northwest; The Wabash River Coal Gasification Repowering Project, General Energy and Cinergy

Page 10: FutureGen Power Plant, U.S. Department of Energy; Hydrogen Fueling Dispenser at the Las Vegas Energy Station, Air Products and Chemicals, Inc.

Page 11: The SECA 3-10 Kilowatt Building Block, Pacific Northwest National Laboratory; Fuel Cell Stack, U.S. Department of Energy

Page 12: U.S. Energy Secretary Spencer Abraham, U.S. Department of Energy; GEN IV Nuclear Reactor Design, U.S. Department of Energy

Page 13: ITER – Fusion Process Machines, ITER/Princeton; Wyoming Wind Farm, Road, NREL, Eugene Water and Electric Board; PV Integrated into a Solar Awning over a Back Porch in California, NREL, AstroPower

Page 14: Switchgrass Crop, Agricultural Research Service, U.S. Department of Agriculture, Hampton, Brett; DNA Analysis of Soil Microbes, Los Alamos National Laboratory; Advanced Plant Growth, Los Alamos National Laboratory

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