U.S. Climate Change Technology Program

# STRATEGIC PLAN

September 2006

# To the Reader:

We are pleased to be able to present this *Strategic Plan* for the Climate Change Technology Program (CCTP). The technology strategy detailed in this *Plan* is an essential element of a comprehensive climate change strategy that includes undertaking short-term actions to reduce greenhouse gas emissions intensity, advancing climate science, and promoting international cooperation.

CCTP was created by the President in 2002—and subsequently authorized in the Energy Policy Act of 2005—to coordinate and prioritize the Federal Government's portfolio of investments in climate-related technology research, development, demonstration, and deployment (RDD&D). The portfolio totaled about $3 billion in Fiscal Year 2006.

The *Plan* expands on the themes presented in CCTP's *Vision and Framework for Strategy and Planning*. It provides the underpinnings for a robust RDD&D effort that can make advanced technologies available sooner and at a lower cost. It takes a century-long look at the nature of the climate change challenge and the potential for technological solutions across a range of uncertainties. Most anthropogenic greenhouse gases emitted over the course of the 21st century will come from equipment and infrastructure not yet built, a circumstance that poses significant opportunities to reduce or eliminate these emissions. The technologies outlined in this *Plan*—hydrogen, biorefining, clean coal, carbon sequestration, nuclear fission and fusion, advanced concepts in buildings, industry, transportation and electric energy storage and distribution, and others—have the potential to transform our economy in fundamental ways that can address not just climate change, but energy security, air quality, and other pressing needs.

The *Plan* articulates a vision of the role for advanced technologies, defines a supporting mission for the CCTP, establishes guiding principles for Federal R&D agencies to use in formulating R&D portfolios, outlines approaches to attain CCTP's strategic goals, and identifies a series of next steps toward implementation. We believe this *Plan* will strengthen the U.S. research enterprise and stimulate U.S. innovation and advance technology development in myriad ways. It is our hope that this *Plan* will inspire similar initiatives in other nations and enhance international collaboration on development and deployment of these technologies.

This document is the outcome of a long process involving governmental working groups, expert review, and a public comment period that stimulated thoughtful and energetic dialogue. It is our hope that with publication of the *Plan*, this dialogue will continue to inform and improve the Program.

The United States is working to ensure a bright and secure energy and economic future for our Nation and a healthy planet for future generations. Through a combination of near-term actions, enhanced scientific understanding of climate change, advanced technology development, and international cooperation, this future can become a reality.

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Chair, Committee on
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# Foreword

In February 2002, President George W. Bush reorganized the overarching management structure that coordinates and directs U.S. climate change research and development activities. Under this new structure, climate change science and climate-related technology research programs are integrated to an extent not seen previously. The Climate Change Science Program (CCSP), led by the Department of Commerce, was established to reduce the uncertainties in climate science and develop science-based resources to support decision makers. The Climate Change Technology Program (CCTP), the counterpart organization to CCSP, led by the Department of Energy, was formed to coordinate the Federal Government's portfolio of climate-related technology research and development activities, including technology deployment and adoption activities, which were supported by nearly $3 billion in Fiscal Year 2006, and to focus efforts on the subset of priority activities that are part of the President's National Climate Change Technology Initiative.

The CCTP's *Research and Current Activities* and *Technology Options for the Near and Long Term* reports provided detailed looks at, and introduced the public to, an array of technologies with the potential to reduce greenhouse gas emissions. Our goal with this *Strategic Plan* is to provide a long-term planning context, taking into account the many uncertainties, in which the nature of both the challenges and the opportunities for advanced technologies are illuminated and balanced. Along with its short companion document, CCTP's *Vision and Framework for Strategy and Planning*, the *Plan* provides an inspiring vision of what may be possible and a basis for setting priorities for research through its technology strategies and investment criteria. It also highlights those opportunities that are ripe for advancement.

The *Plan* was guided by the leadership of the Cabinet-level Committee on Climate Change Science and Technology Integration and its Interagency Working Group of agency deputies. It was prepared by an interagency team of six working groups, under the direction of CCTP Deputy Director Dr. Robert C. Marlay. Experts from many different disciplines have made significant contributions to the *Plan*. Without their efforts, this document would not have been possible.

Further, the *Plan* has benefited greatly from hundreds of comments received during the public comment period following release of the draft *Plan* in September 2005. We have been gratified by the quantity and quality of the comments we received, which reflect the importance of the Program. We were able to accommodate most comments, but even those we did not accept challenged our thinking and made the *Plan* stronger. We thank all of those individuals and groups who took time to make comments. As the *Plan* is forward-looking, we expect that public input will be an aspect of future updates to the *Plan*.

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# Strategic Plan

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## ACRONYMS AND ABBREVIATIONS

**ABR** Advanced Burner Reactor
**AFCI** Advanced Fuel Cycle Initiative
**AFV** Alternative Fuel Vehicles
**AGAGE** Advanced Global Atmospheric Gases Experiment
**ANL** Argonne National Laboratory
**APS** Aerosol Polarimetery Sensor
**AUV** Autonomous Underwater Vehicles

**BC** Black Carbon
**BES** Office of Basic Energy Sciences, U.S. Department of Energy
**BESAC** Basic Energy Sciences Advisory Committee
**BP** British Petroleum
**Btu** British Thermal Unit

**CCCSTI** Committee on Climate Change Science and Technology Integration
**CCP** Carbon Capture Project
**CCS** Carbon Capture and Sequestration
**CCSP** U.S. Climate Change Science Program
**CCTP** U.S. Climate Change Technology Program
**CDIAC** Carbon Dioxide Information Analysis Centre
**CEM** Continuous Emissions Monitor
**CETC** Natural Resources Canada CANMET Energy Technology Center
**CEQ** Council on Environmental Quality
**CFC** Chlorofluorocarbon
**$CH_4$** Methane
**CHP** Combined Heat and Power (system)
**CMM** Coal Mine Methane

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|---|---|
| **CMOP** | Coalbed Methane Outreach Program |
| **$CO_2$** | Carbon Dioxide |
| **COL** | Construction and Operating License |
| **CSLF** | Carbon Sequestration Leadership Forum |
| **CSP** | Competitive Solicitation Program |
| **CSRP** | Carbon Sequestration Regional Partnerships |
| **CT** | Computed Tomography |
| **CVD** | Chemical Vapor Deposition |
| **DAI** | Dangerous Anthropogenic Interference |
| **DG** | Distributed Generation |
| **DOC** | U.S. Department of Commerce |
| **DoD** | U.S. Department of Defense |
| **DOE** | U.S. Department of Energy |
| **DOI** | U.S. Department of the Interior |
| **DOS** | U.S. Department of State |
| **DOT** | U.S. Department of Transportation |
| **DPC** | Domestic Policy Council |
| **ECBM** | Enhanced Coal-Bed Methane |
| **EIA** | Energy Information Administration |
| **EJ** | Exajoule ($10^{18}$ Joules) |
| **EMF** | Energy Modeling Forum, Stanford University |
| **EOR** | Enhanced Oil Recovery |
| **EPA** | U.S. Environmental Protection Agency |
| **ESP** | Early Site Permit |
| **Euratom** | European Atomic Energy Community |
| **EU** | European Union |
| **FACE** | Free-Air $CO_2$ Enrichment |
| **FACTS** | Flexible Automated Control Transmission Systems |
| **FC** | Fuel Cell |
| **FCT** | Fuel Cell Turbine |
| **FES** | Fusion Energy Sciences, U.S. Department of Energy, Office of Science |
| **FFRDC** | Federally Funded Research and Development Center |
| **FHA** | Federal Highway Administration |
| **FTC** | Federal Trade Commission |
| **FTIR** | Fourier Transform Infrared Spectroscopy |
| **FY** | Fiscal Year |
| **GDP** | Gross Domestic Product |
| **Gen IV** | Generation IV |
| **GEO** | Group on Earth Observations |
| **GEO-SEQ** | Geological Sequestration (project) |
| **GEOSS** | Global Earth Observation System of Systems |
| **GHG** | Greenhouse Gas |
| **GIF** | Generation IV International Forum (nuclear power) |
| **GOSAT** | Greenhouse Gas Observing SATellite |
| **Gt** | Gigatonnes ($10^9$ tonnes or metric tons) |
| **GtC** | Gigatonnes ($10^9$ tonnes or metric tons) of Carbon |
| **GtC-eq.** | Gigatonnes ($10^9$ tonnes or metric tons) of Carbon Equivalent (emissions) |
| **GWP** | Global Warming Potential |
| **$H_2$** | Molecular Hydrogen |
| **$H_2S$** | Hydrogen Sulfide |
| **HAP** | Hazardous Air Pollutants |
| **HCFC** | Hydroclorofluorocarbon (refrigerant) |
| **HFC** | Hydrofluorocarbon |
| **HHS** | U.S. Department of Health and Human Services |
| **HNLC** | High Nutrient, Low Chlorophyll |
| **HSHL** | High Spectral Resolution LIDAR |
| **HTS** | High-Temperature Superconductivity (e.g. wire) |
| **HVACR** | Heating, Ventilation, Air Conditioning, and Refrigeration |
| **HVDC** | High Voltage Direct Current |
| **IAEA** | International Atomic Energy Agency |
| **ICF** | Inertial Confinement Fusion |
| **IEA** | International Energy Agency |
| **IEOS** | Integrated Earth Observation System |
| **IFE** | Inertial Fusion Energy |
| **IGCC** | Integrated Gasification Combined Cycle |
| **IMSS** | Image Multi-Spectral Sensor |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IPHE** | International Partnership for the Hydrogen Economy |
| **ITER** | International Thermonuclear Experimental Reactor (Latin for "the way") |
| **ITS** | Intelligent Transportation Systems |
| **IWG** | Interagency Working Group |
| **kg** | Kilogram |
| **kW** | Kilowatt |
| **kWe** | Kilowatt (electric) |
| **kWh** | Kilowatt-hour |
| **LANL** | Los Alamos National Laboratory |
| **LCCP** | Life-Cycle Climate Performance |
| **LED** | Light-Emitting Diode |
| **LFG** | Landfill Gas |
| **$LH_2$** | Liquefied Hydrogen |
| **LIBS** | Laser Induced Breakdown Spectroscopy |
| **LIDAR** | Light Detection and Ranging |
| **LNLC** | Low Nutrient, Low Chlorophyll |
| **MEA** | Monoethanolamine |
| **MFE** | Magnetic Fusion Energy |
| **MiniCAM** | Mini Climate Assessment Model (Pacific Northwest National Laboratory) |
| **MM** | Measuring and Monitoring |
| **MOF** | Microporous Metal Organic Frameworks |
| **mpg** | miles per gallon |
| **mph** | miles per hour |

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|---|---|
| **MSPI** | Multi-angle SpectroPolarimetric Imager |
| **MtC** | Megatonnes Carbon |
| **MWe** | Megawatt electric |
| **$N_2O$** | Nitrous Oxide |
| **NACP** | North American Carbon Program |
| **NAE** | National Academy of Engineering |
| **NAS** | National Academy of Sciences |
| **NASA** | National Aeronautics and Space Administration |
| **NEC** | National Economic Council |
| **NEPO** | Nuclear Energy Plant Optimization (Program) |
| **NCCTI** | National Climate Change Technology Initiative |
| **NERAC** | Nuclear Energy Research Advisory Committee |
| **NETL** | National Energy Technology Laboratory |
| **$NH_3$** | Ammonia |
| **NIF** | National Ignition Facility |
| **NNSA** | National Nuclear Security Administration, U.S Department of Energy |
| **$NO_X$** | Nitrogen Oxides |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NRC** | National Research Council or Nuclear Regulatory Commission |
| **NRCan** | Natural Resources Canada |
| **NREL** | National Renewable Energy Laboratory |
| **NSC** | National Security Council |
| **NSCR** | Non-Selective Catalytic Reduction |
| **NSF** | National Science Foundation |
| **NSTX** | National Spherical Torus Experiment |
| **NVFEL** | National Vehicle and Fuels Emission Laboratory |
| **OC** | Organic Carbon |
| **OCO** | Orbiting Carbon Observatory |
| **ODS** | Ozone-Depleting Substance |
| **OMB** | Office of Management and Budget |
| **ONR** | Office of Naval Research |
| **ORNL** | Oak Ridge National Laboratory |
| **OSTP** | Office of Science and Technology Policy |
| **PEM** | Polymer Electrolyte Membrane |
| **PFC** | Perfluorocarbons |
| **PM** | Particulate Matter |
| **PNNL** | Pacific Northwest National Laboratory |
| **POU** | Point Of Use |
| **PPPL** | Princeton Plasma Physics Laboratory |
| **PV** | Present Value |
| **Quad** | Quadrillion Btus ($10^{15}$ Btus) |
| **R&D** | Research and Development. Also used generically to mean RD&D and RDD&D |
| **RD&D** | Research, Development, and Demonstration |
| **RDD&D** | Research, Development, Demonstration, & Deployment |
| **RFI** | Request for Information |
| **SCR** | Selective Catalytic Reduction |
| **$SF_6$** | Sulfur Hexafluoride |
| **SNAP** | Significant New Alternatives Program |
| **SOFeX** | Southern Ocean Iron Fertilization Experiment |
| **SOIREE** | Southern Ocean Iron Enrichment Experiment |
| **$SO_X$** | Sulfur Oxides |
| **SQUIDS** | Superconducting Quantum Interference Devices |
| **SRES** | Special Report on Emissions Scenarios (of the IPCC) |
| **T&D** | Transmission and Distribution |
| **TgC** | Teragrams of Carbon |
| **Tg $CO_2$** | Teragrams Carbon Dioxide |
| **Tg $CO_2$-eq.** | Teragrams Carbon Dioxide Equivalent (emissions) |
| **UN** | United Nations |
| **UNDP** | United Nations Development Program |
| **UNEP** | United Nations Environmental Program |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **USAID** | U.S. Agency for International Development |
| **USDA** | U.S. Department of Agriculture |
| **USGEO** | United States Group on Earth Observation |
| **VAM** | Ventilation Air Methane |
| **VOC** | Volatile Organic Compounds |
| **W/$m^2$** | Watts per Square Meter |
| **WCRP** | World Climate Research Program |
| **WG** | Working Group |
| **WMO** | World Meteorological Organization |
| **WOCE** | World Ocean Circulation Experiment |
| **WRE** | T. Wigley, R. Richels, and J. Edmonds |