U.S. Climate Change Technology Program

CCTP Strategic Plan
Public Review Draft

Overview Presentation
for
Senate Energy and Natural Resources Committee Staff

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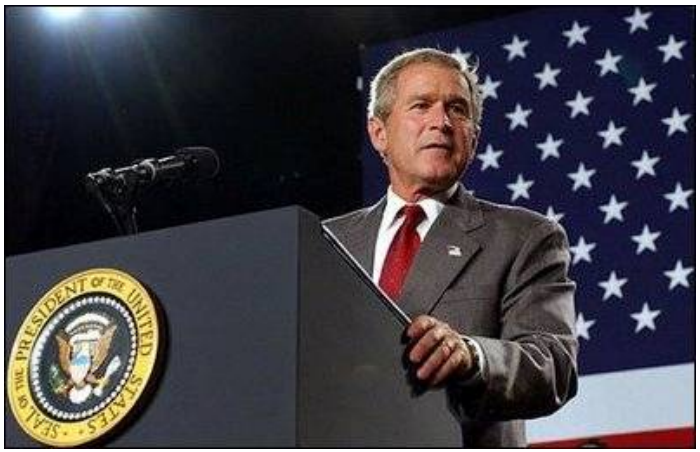
U.S. Department of Energy
January 24, 2006

Presidential Leadership . . .



"I reaffirm America's commitment to the United Nations Framework Convention and its central goal, to stabilize atmospheric greenhouse gas concentrations at a level that will prevent dangerous human interference with the climate."

"(We will) set America on a path to slow the growth of our greenhouse gas emissions and, as science justifies, to stop and then reverse the growth of emissions."

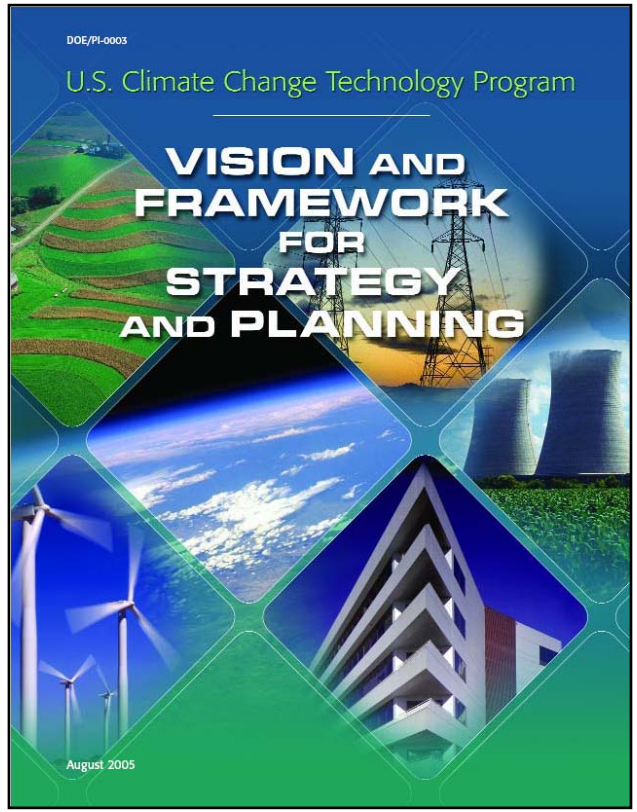
- President George W. Bush
February 14, 2002

Overview

- Policy & Planning Context
- Strategic Goals to Achieve President's Vision
- Planning & Analysis Under Conditions of Uncertainty
- Technology Strategies for Each Goal's Attainment
- Portfolio Principles and Criteria for Investment
- Key Initiatives & Core Elements of the R&D Portfolio
- International Collaborations
- Roadmap to Goals Attainment and Expected Benefits
- Summary of Public Comments
- A Path Forward -- Conclusions and Next Steps

Policy and Planning Context

- **Presidential Leadership**
- **Cabinet-Level Engagement**
- **Near-Term Actions**
- **Financial Incentives for Investments**
- **$5 Billion / Year In Federal S&T**
  - **Science to Inform Policy**
  - **Technology to Facilitate Action**
- **U.S. Climate Change Technology Program Now Authorized by Energy Policy Act of 2005**



www.climatetechnology.gov

CCTP Vision and Mission

- CCTP Vision

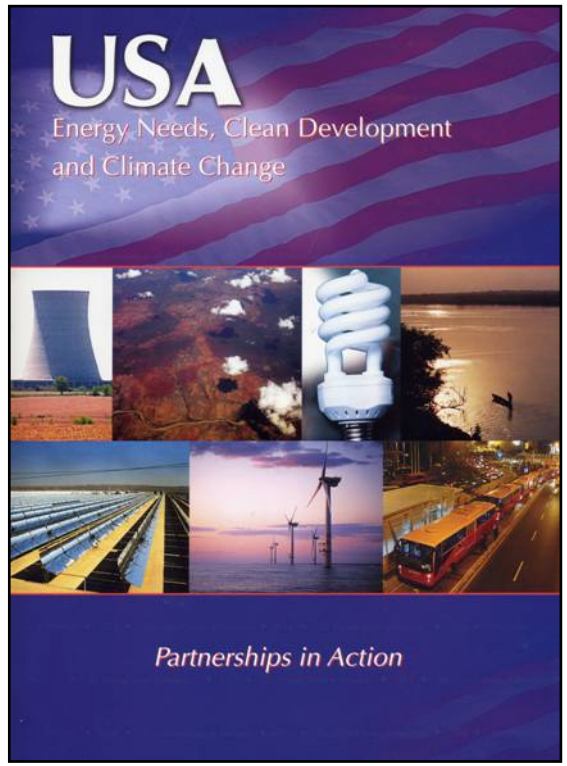
The CCTP vision is to attain on a global scale, in partnership with others, a technological capability that can provide abundant, clean, secure, and affordable energy and related services needed to encourage and sustain economic growth, while simultaneously achieving substantial reductions in emissions of greenhouse gases and mitigating the risks of potential climate change.

- CCTP Mission

The CCTP mission is to stimulate and strengthen the scientific and technological enterprise of the United States, through improved coordination and prioritization of multi-agency Federal climate change technology R&D programs and investments, and to provide global leadership, in partnership with others, aimed at accelerating development of new and advanced technologies that can attain the CCTP vision.

Near-Term Actions . . .

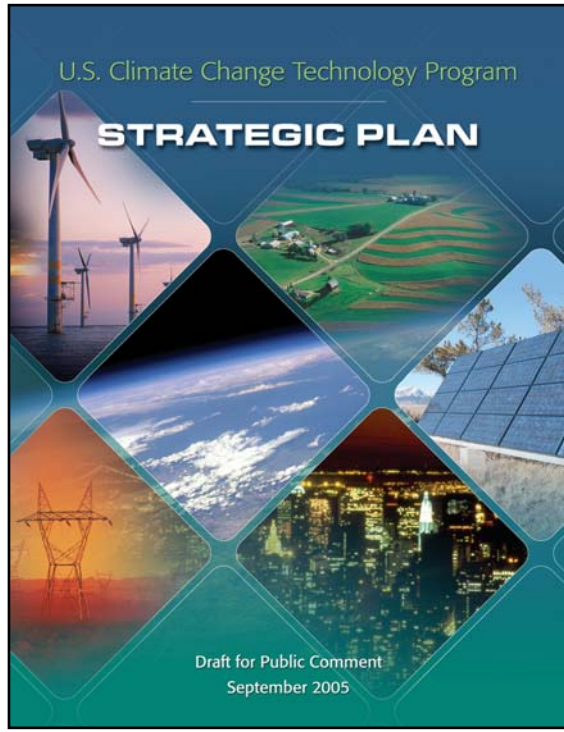
- **Voluntary Programs**
  - Climate VISION
  - Climate Leaders
  - SmartWay Transport Partnership
  - Voluntary Reporting of Emissions Reductions, EPACT 1605(b)
- **Incentives for Investment**
  - Tax incentives for Renewable Energy, Hybrids, Deployment Partnerships
  - USDA Incentives for Sequestration
  - USAID and Global Environmental Fund
  - Tropical Forest Conservation



http://www.state.gov/g/oes/

Strategic Plan

- **Purposes:**
  - **Provide Federal Leadership**
  - **Articulate a Vision for Progress**
  - **Strengthen U.S. Research Enterprise**
  - **Accelerate Adv. Technology Develop**
  - **Guide Formulation of R&D Portfolio**
  - **Provide Framework for Priority-Setting**
  - **Enhance Opportunities for Partnering**
- **Public Comments Invited Sept. 22**
- **Final Plan in 2006**



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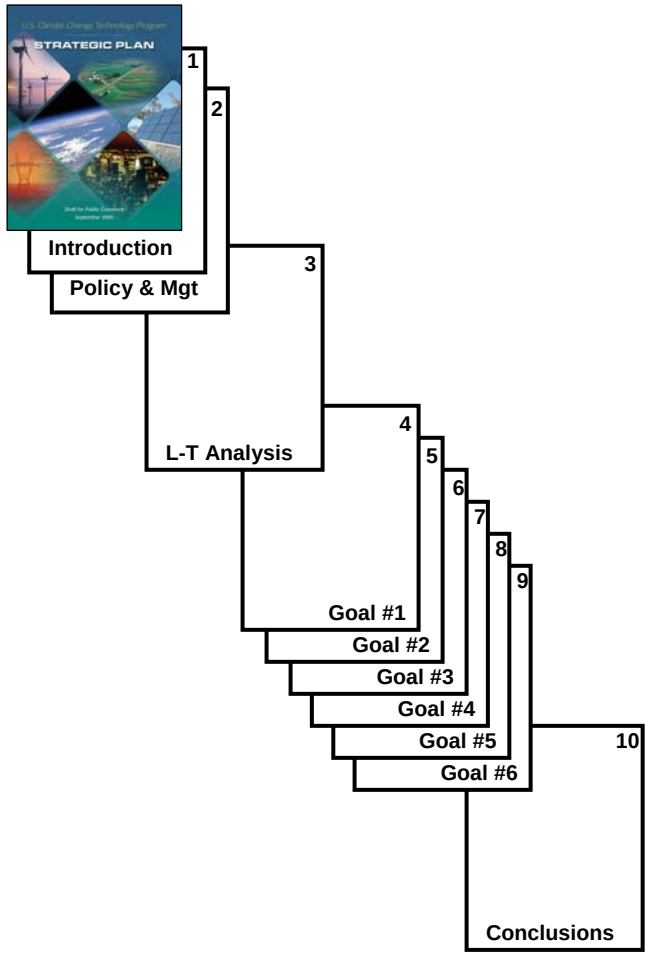
Organization of the Strategic Plan

- **Front Materials**
  - **Introduction**
  - **Policy & Management**
  - **Prioritization Process**
- **Analysis and Options**
- **Strategic Goals (x6)**
  - **Role of Technology**
  - **Technology Strategy**
  - **Current Portfolio**
  - **Future Research Directions**
- **Conclusions & Next Steps**

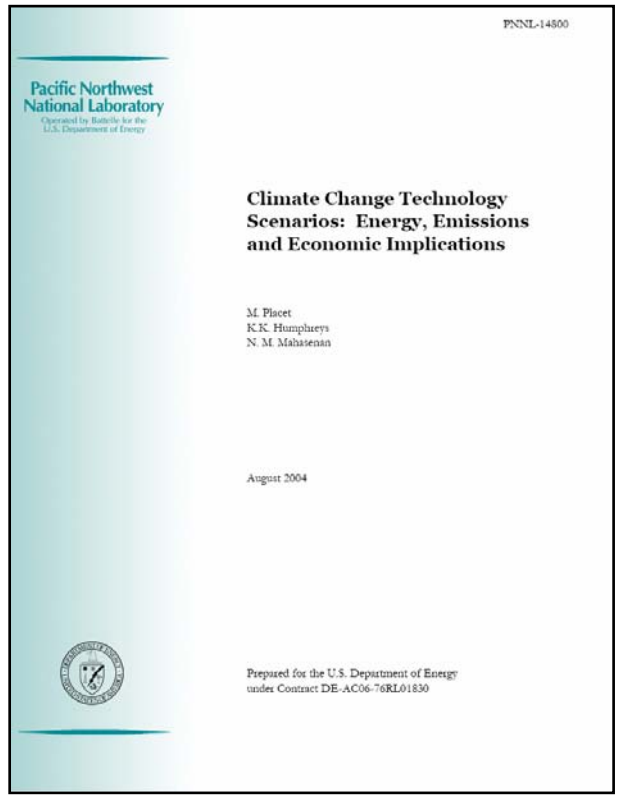


Strategic Goals to Achieve President's Vision

	100-Year Challenge Up To: (GTC – Giga-Tonnes Carbon Eq.)
• Emissions-Related Goals	
1. Reduce GHG Emissions From Energy End Use & Infrastructure	– 360
2. Reduce Emissions From Energy Supply	– 340
3. Capture & Sequester CO_2	– 330
4. Reduce Emissions of Non-CO_2 Gases	– 160
• Crosscutting Goals	
5. Improve Capabilities for Measuring & Monitoring GHGs	– –
6. Bolster Supporting Basic Science	– –

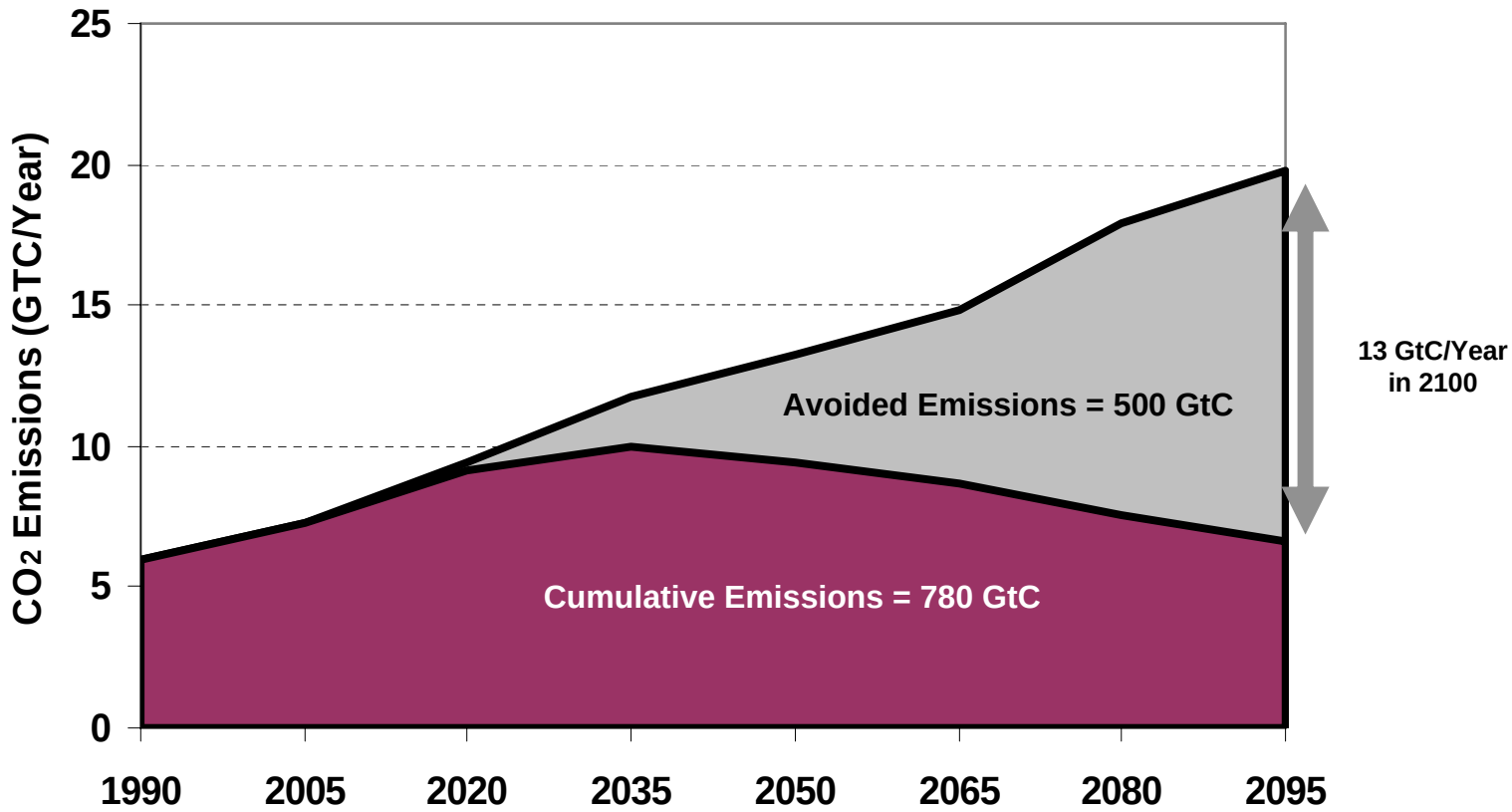
Planning & Analysis Under Conditions of Uncertainty

- Global Perspective
- 100-Year Planning Horizon
- Uncertainty Across GHG Stabilization Goals
- Technology Scenarios
- Technology Competitions
- Economic Benefits



http://www.pnl.gov/energy/climate/climate_change-technology_scenarios.pdf

One Example of Constrained Emissions



GTC = Giga-Tonnes Carbon

How Big is a Gigaton? Using Today's Technology, These Actions Can Cut Emissions by 1 GtC/Year

Today's Technology	Actions that Provide 1 Gigaton / Year of Mitigation
Coal-Fired Power Plants	Build 1,000 "zero-emission" 500-MW coal-fired power plants (in lieu of coal-fired plants without CO_2 capture and storage)
Geologic Sequestration	Install 3,700 sequestration sites like Norway's Sliepner project (0.27 MtC/year)
Nuclear	Build 500 new nuclear power plants, each 1 GW in size (in lieu of new coal-fired power plants without CO_2 capture and storage)
Efficiency	Deploy 1 billion new cars at 40 miles per gallon (mpg) instead of 20 mpg
Wind Energy	Install capacity to produce 50 times the current global wind generation (in lieu of coal-fired power plants without CO_2 capture and storage)
Solar Photovoltaics	Install capacity to produce 1,000 times the current global solar PV generation (in lieu of coal-fired power plants without CO_2 capture and storage)
Biomass fuels from plantations	Convert a barren area about 15 times the size of Iowa's farmland (about 30 million acres) to biomass crop production
CO_2 Storage in New Forest.	Convert a barren area about 30 times the size of Iowa's farmland to new forest

Giga-Tonnes = 10^9 Metric-Tonnes (1000 Kilograms)

Technology Scenarios Explore the Future

Technology Scenario #1: "Closing the Loop on Carbon"

Advanced Coal, Gasification, Carbon Capture, Sequestration, and Hydrogen Technologies Augment the Standard Suite of Technologies

Technology Scenario #2: "A New Energy Backbone"

Technological Advances in Renewable Energy and Nuclear Power Give Rise New Competitive Realities, Reducing Dominant Role of Fossil Fuels

Technology Scenario #3: "Beyond the Standard Suite"

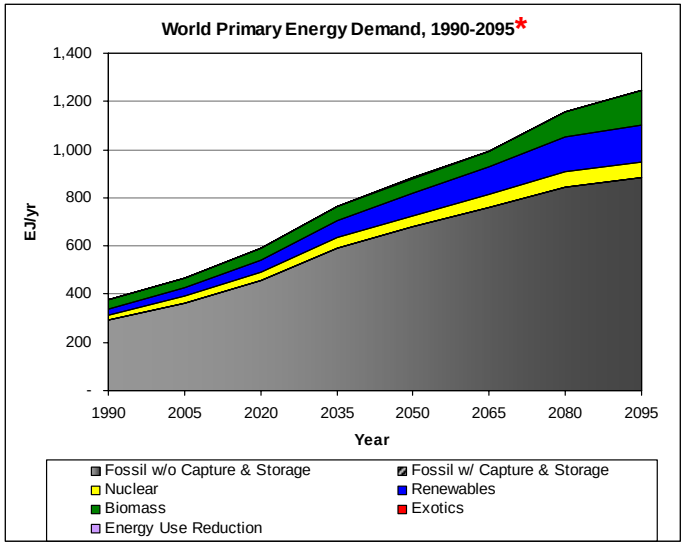
Novel and Advanced Technologies (e.g., Fusion, Large Scale Solar, and Bio-X) Emerge to Play Major Roles, Complementing the Standard Suite.

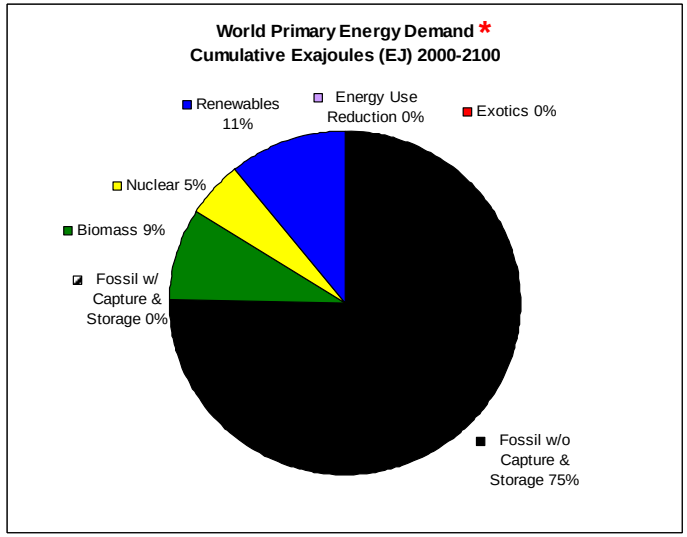
Common Characteristics Across Scenarios:

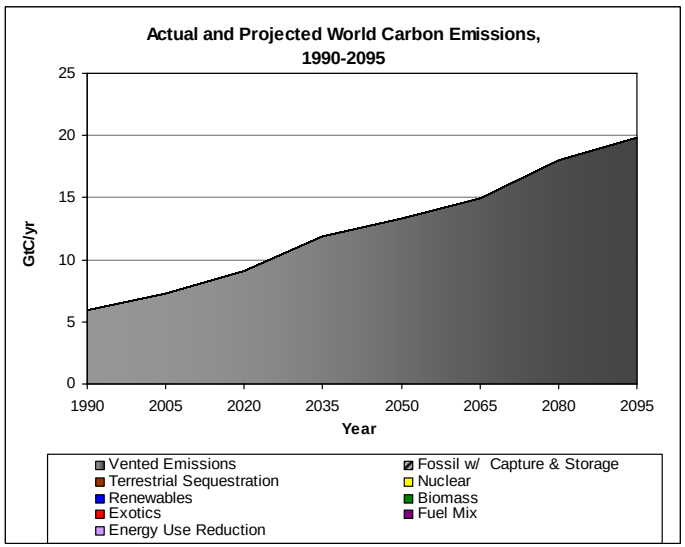
- ✓ *Hydrogen and Liquid Biofuels Become Significant Energy Carriers*
- ✓ *The Full Potential of Conventional Oil & Gas is Realized*
- ✓ *Dramatic Gains in Energy Efficiency Occur*
- ✓ *Successful Management of other GHGs*
- ✓ *Early Market Penetration of Low-Cost Terrestrial Sequestration*

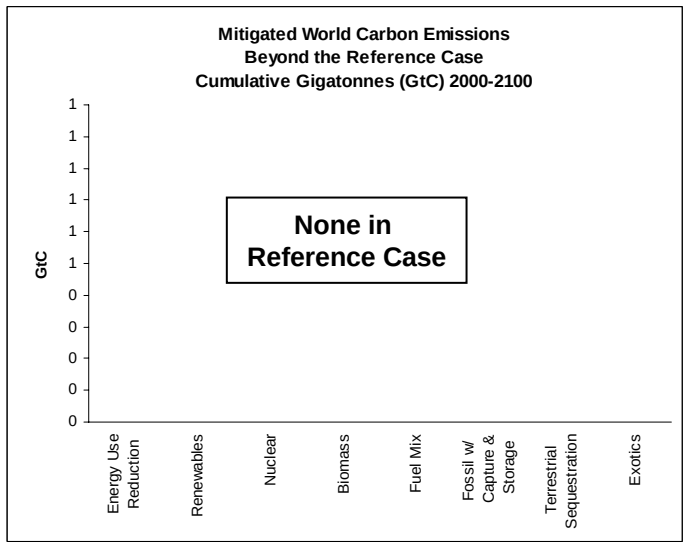
Reference Case

(Including "Reference Case" Assumptions About Advancing Technology)





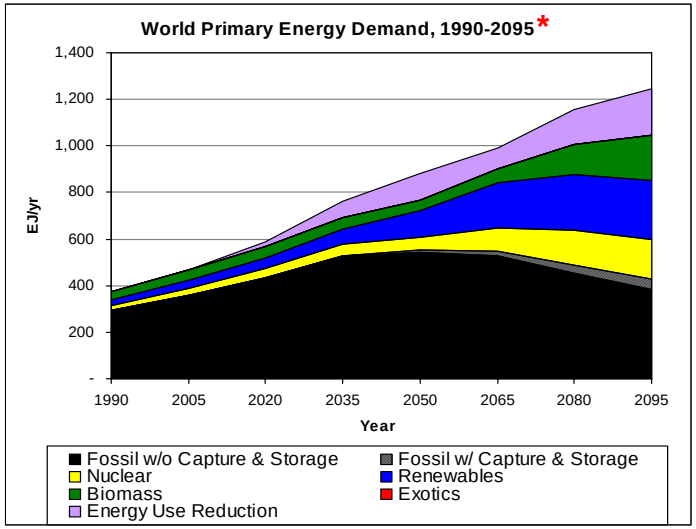


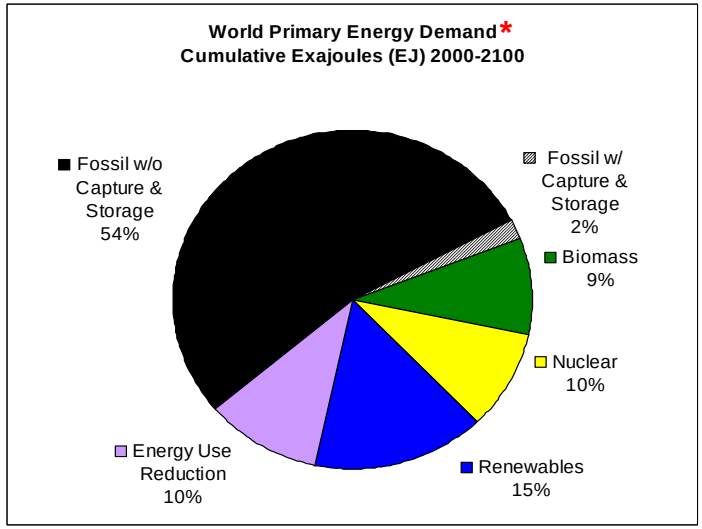


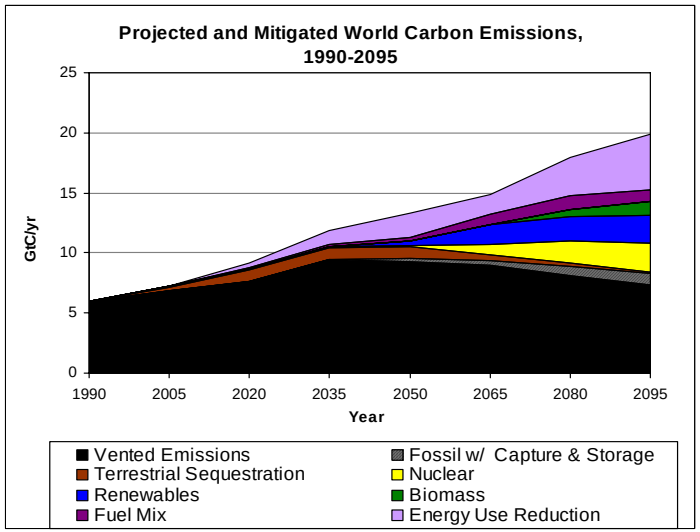
*** Reference Case includes energy efficiency improvements (i.e., improvements in energy use per unit of economic output) at a an rate of change that is consistent with long-term historical rates.**

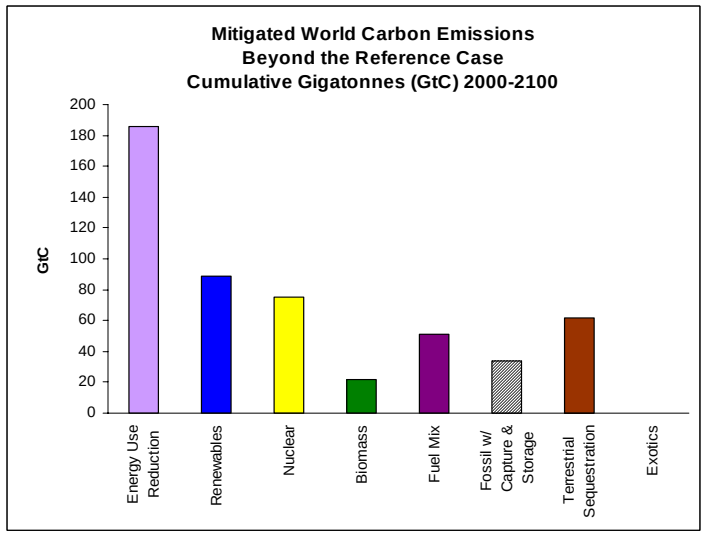
New Energy Backbone -- Highly Constrained Emissions Case

(At approximately the 550 ppm level of stabilized concentrations)



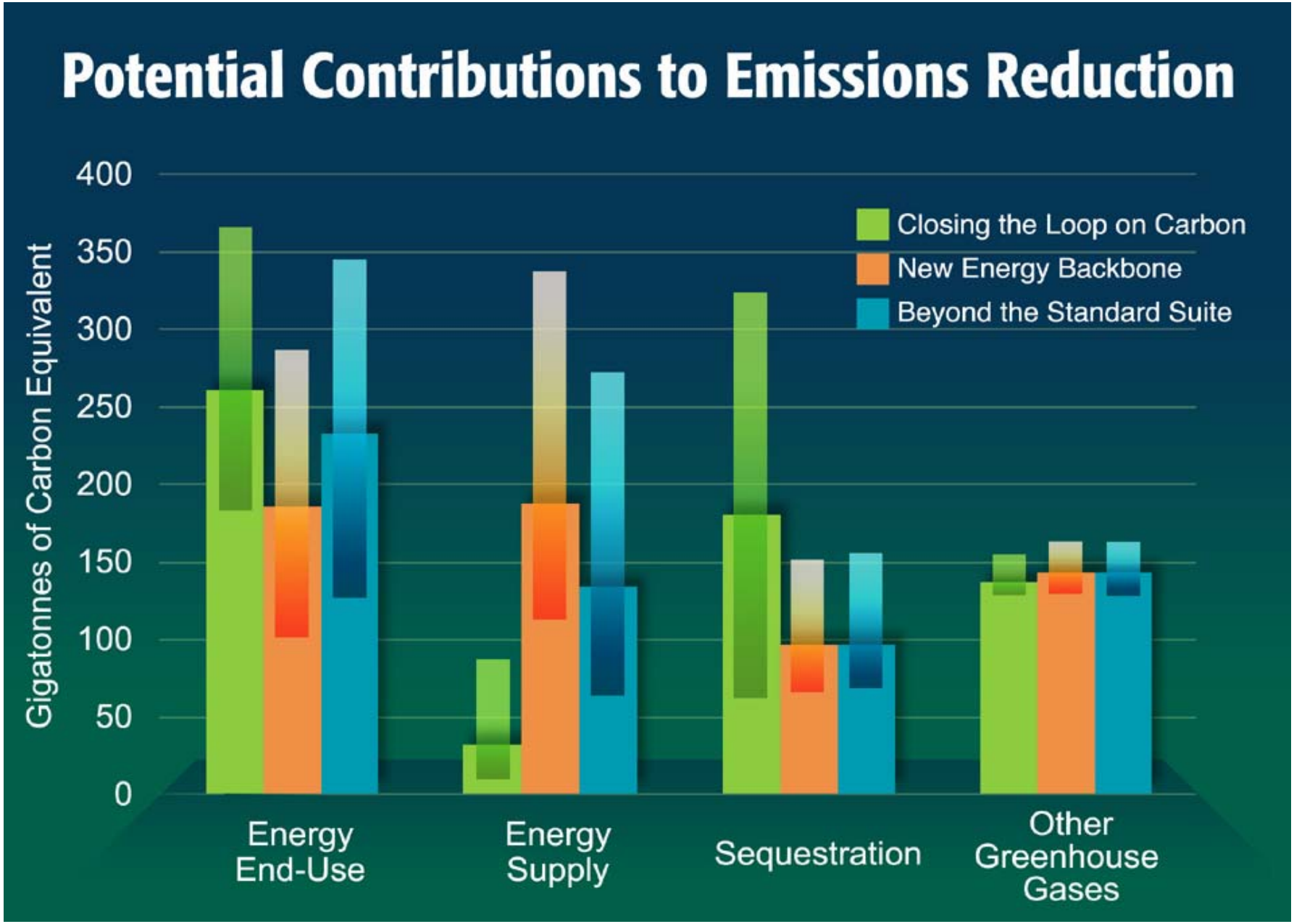






*** Reference Case includes efficiency improvements (i.e., improvements in energy use per unit of economic output) at an annual rate of change that is consistent with long-term historical rates. Shaded areas for "Energy Use Reduction" indicate accelerated improvements, demand reductions, and other economic substitutions.**

Potential Contributions to Emissions Reduction



Source: Placet M; Humphreys, KK; Mahasenan, NM. *Climate Change Technology Scenarios: Energy, Emissions and Economic Implications*. Pacific Northwest Nation Laboratory, PNL-14800, August 2004. Available at: http://www.pnl.gov/energy/climatetechnology.stm

CCTP Goal #1: Reduce Emissions from Energy End-Use and Infrastructure

100-Year Challenge
Up to 360 GTCE

- **Transportation**
  - **Light Vehicles & Heavy Vehicles, Buses**
  - **Intelligent Systems, Aviation, Fuels**
- **Buildings**
  - **Envelope, Equipment,**
  - **Whole Building Integration**
- **Industry**
  - **Energy Conversion & Use, Processes,**
  - **Enabling Technologies, Resource Recovery**
- **Electric Grid and Infrastructure**
  - **Superconductivity, T&D, Storage,**
  - **Sensors & Controls, Power Electronics**

Example of "GPRA" Goals for Each CCTP Strategic Area

- **Light Vehicles**
  - **Electric Propulsion Systems**
    - » **15-year life capable of delivering at least 55 kW for 18 seconds and 20 kW continuous at a system cost of $12/kW peak**
  - **Oil-Based Internal Combustion Engine Powertrain Systems**
    - » **Costing $35/kW, having peak brake engine efficiency of 45 percent, and that meet or exceed emissions standards**
  - **Electric Drivetrain Energy Storage**
    - » **15-year life at 200 Wh with discharge power of 25kW for 18 seconds and $20/kW**
  - **Material and Manufacturing Technologies for High Volume Production Vehicles**
    - » **50 percent reduction in the weight of vehicle structure and subsystems, affordability, and increased used of recyclable/renewable materials;**
  - **H_2-Based Internal Combustion Engine Powertrain Systems**
    - » **Operating on hydrogen with a cost target of $45/kW by 2010 and $30/kW in 2015**
    - » **Peak brake engine efficiency of 45 percent, and that meet or exceed emissions standards**

CCTP Goal #2: Reduce Emissions from Energy Supply

- Low-Emission Fossil-Based Fuels & Power
- Hydrogen, Bio-Based, and Low Carbon Fuels
  - Production, Storage, Use
  - Infrastructure, Safety
- Renewable Energy
  - Wind
  - Solar Photo-Voltaics Power, Solar Thermal, Biomass
  - Hydro, Geothermal
- Nuclear Fission
  - Near-Term Deployment
  - Next Generation Fission
  - Advanced Fuel Cycles
- Fusion or Other Novel Sources
  - ITER, Bio-X

100-Year Challenge
Up to 340 GTCE

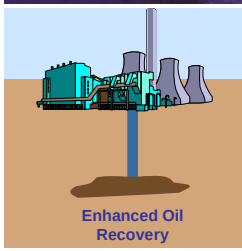
Example of "GPRA" Goals for CCTP Strategic Area for Goal #2

- **Solar Photovoltaic Power**
  - **Research program goals focus on:**
    - » Scaling up laboratory-sized PV cells to much larger sizes suitable for product markets
    - » Validation of new module technologies for outdoors use to achieve 30-year outdoor warrantable lifetimes
    - » Addressing of substantial technical issues associated with high-yield, first-time, and large-scale (greater than 100 MW/yr**) manufacturing for advanced technologies.**
  - **Long-term cost goal for electricity from PV cells for residential PV applications**
    - » $0.06/kWh, compared to costs ranging from $0.18 to $0.23/kWh in 2004.
  - **Interim cost goal:**
    - » To reduce the 30-year user cost for PV electric energy to a range of $0.14 to $0.19/kWh by 2010

CCTP Goal #3: Capture and Sequester Carbon Dioxide

- CO_2 Capture
  - Capture of CO_2 From Large Point Sources
- Geologic Storage
  - Permanent Storage in Geologic Formations
- Terrestrial Sequestration
  - Land-Based, Biological Sequestration (Trees, Soils, or Other Organic Materials)
- Ocean Sequestration
  - Ocean Sequestration May Play a Role as Science Advances and Potential Effects Understood

100-Year Challenge
Up to 330 GTCE



Example of "GPRA" Goals for CCTP Strategic Area for Goal #3

- **Geologic Storage**
  - **The goal of geologic storage R&D portfolio is to:**
    - » Develop domestic CO_2 underground storage repositories capable of accepting around a billion tons of CO_2 per year.
  - **Toward this goal, there is a need to:**
    - » demonstrate that CO_2 storage underground is safe, environmentally acceptable, and an acceptable GHG mitigation approach.
  - **Another need is to demonstrate an effective business model for CO_2 enhanced oil recovery and enhanced coalbed methane, where significantly more CO_2 is stored for the long term than under current practices.**

CCTP Goal #4: Reduce Emission of Non-CO_2 Greenhouse Gases

100-Year Challenge
Up to 160 GTCE

- Methane Collection and Use
- Reducing N_2O and Methane Emissions from Agriculture
- Reducing Use of High Global Warming Potential (High GWP) Gases
  - Hydrofluorocarbons, perfluorocarbons
- Black Carbon Aerosols

Example of "GPRA" Goals for CCTP Strategic Area for Goal #4

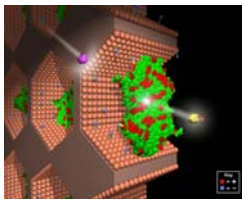
- **High-GWP Gases in Semi-Conductor Processing**
  - **Abatement May Be Achieved by Two Mechanisms:**
  - **Lowering Emissions from Waste Streams, via Thermal Destruction**
    - » Reduces Emission by more than 99%, while minimizing:
    - » NOx emissions to levels at or below emissions standards
    - » Water use and burdens on industrial wastewater-treatment systems
    - » Fabrication floor space, Unscheduled outages, Maintenance costs.
  - **Lowering Emissions by Plasma Destruction**
    - » Lowers exhaust stream concentrations of high GWP gases by two to three orders of magnitude from etchers and plasma-enhanced chemical vapor deposition chambers
    - » Transforms those gases into molecules that can be readily removed from air emissions using known scrubbing technologies

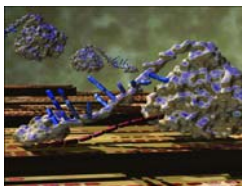
CCTP Goal #5: Improve Capabilities to Measure and Monitor GHG Emissions

- **Energy Production and Efficiency Measurement**
  - **Direct and Indirect Measurements From Point and Mobile Sources**
- **Carbon Capture, Storage & Sequestration**
- **Assess Integrity of Subsurface Reservoirs**
- **Measurement of Non-CO_2 Gases**
- **Integrated Measuring & Monitoring System Architecture**
  - **Collect, Analyze and Integrate Data**

CCTP Goal #6: Bolster Basic Science Contributions to Technology Development

- **Strategic Research**
  - **Needed to Support a Broad Range of Applied Technology R&D**
- **Exploratory Research**
  - **Basic Exploratory Research of Innovative or Novel Concepts to Produce "Breakthrough Technologies"**
- **Fundamental Research**
  - **Provides Underlying Foundation of Scientific Knowledge**





Portfolio Principles and Investment Criteria

Portfolio Principles

- Balanced and Diversified Portfolio
  - No Silver Bullet
  - R&D Investment Involves Risk
  - Diverse Technology Options can Hedge Against Risk
- Ensure Factors Affecting Market Acceptance are Addressed
- Timing of Commercial Readiness is an Important Consideration

Criteria for Investment

- Maximize Expected Return on Investment
- Acknowledge the Proper and Distinct Roles for the Public and Private Sectors
- Focus on Technology with Large-Scale Potential
- Sequence R&D Investments in a Logical, Developmental Order

Key Initiatives & Core Elements of the R&D Portfolio

Significant Elements of the Core Portfolio

- Energy Efficiency and Renewable Energy
- FreedomCAR and Fuel Partnership
- 21st Century Truck Partnership
- Clean Coal and Other Power Systems
- Nuclear Power 2010

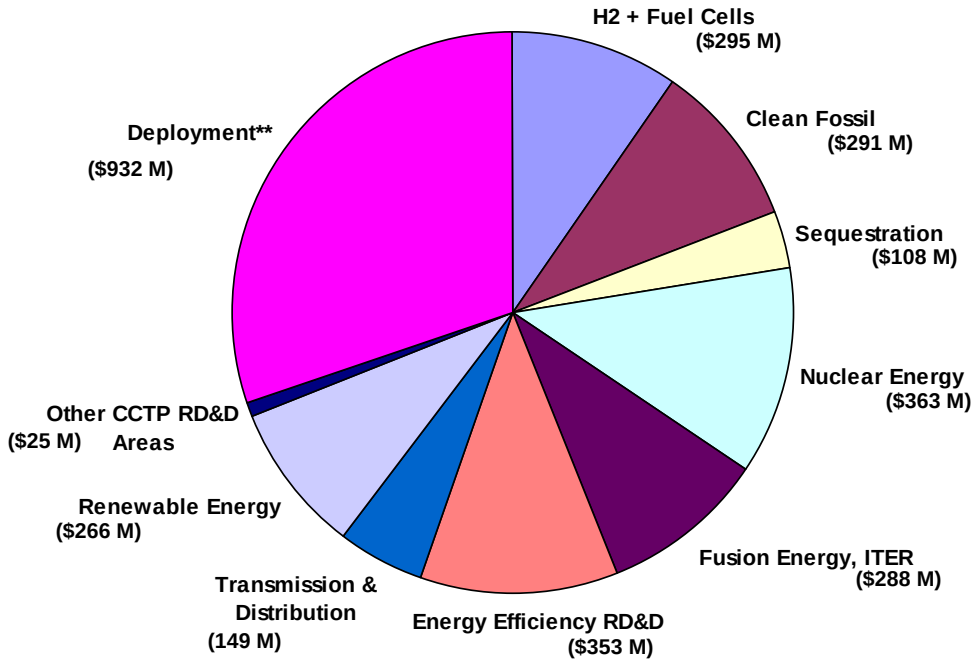
Key Technology Initiatives

- Hydrogen Fuel Initiative
- Carbon Sequestration
- FutureGEN
- Generation IV Nuclear Energy Initiative
- ITER

CCTP Portfolio- FY-2006 R&D Investments*

Percent of CCTP FY06 Budget*

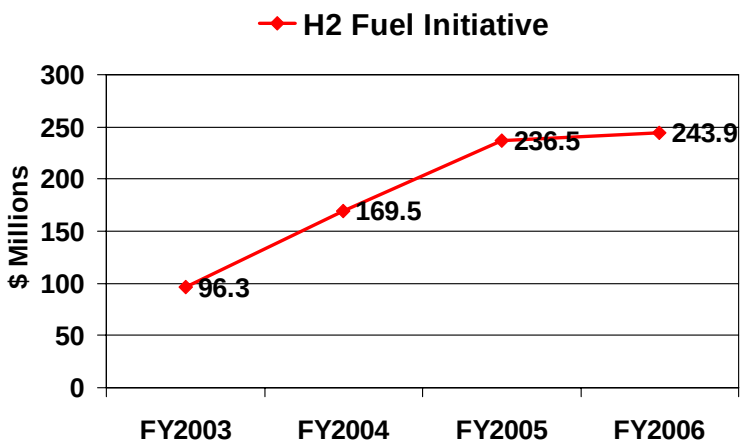
Total Multi-Agency FY06 Budget: $ 3,069 Million

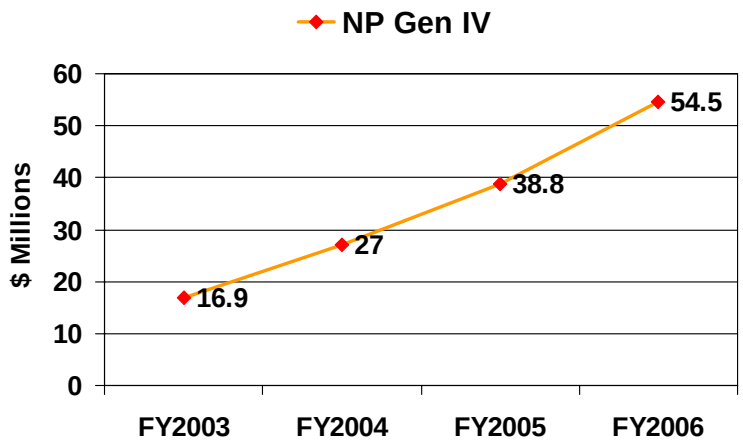


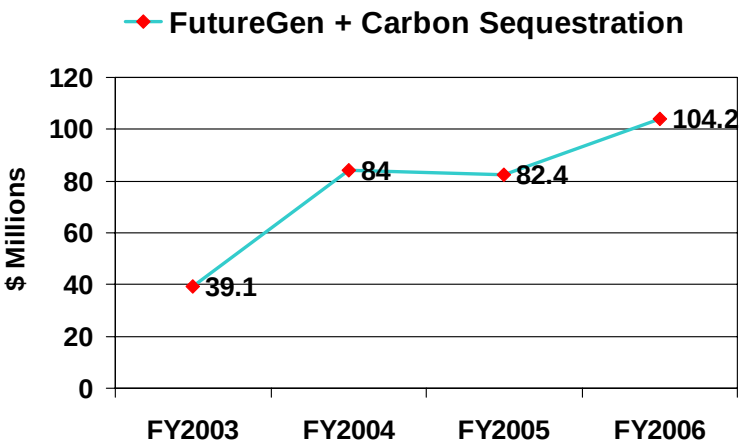
* DOE estimate from CCTP FY06 Budget Authority as Enacted
All Other CCTP Federal Agencies estimated from FY06 Budget Request

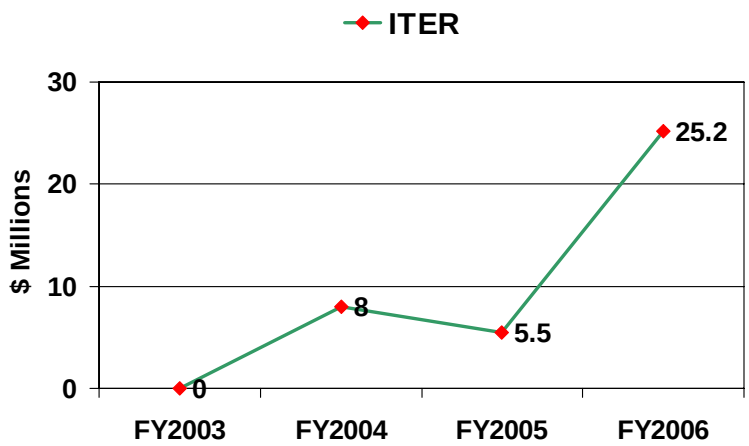
** Deployment is 86% Energy Efficiency

FY 2006 Budget Results* – Key Initiatives









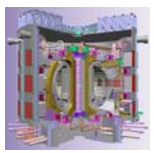
* Budget Authority as Enacted

Complemented by Multi-Lateral Partnerships for S&T Cooperation

- **Carbon Sequestration Leadership Forum:** 19 Members; Focused on CO_2 Capture & Storage Technologies.

- **International Partnership for the Hydrogen Economy:** 17 Members; Organizes, Coordinates, and Leverages Hydrogen RD&D Programs.

- **Generation IV International Forum:** 11 Members; Devoted to R&D of Next Generation of Nuclear Systems.



- **ITER:** 6 Members; Project to Develop Fusion as a Commercial Energy Source.

- **Methane to Markets:** 16 Members; Recovery and use of Methane from Landfills, Mines, and Oil & Gas Systems.

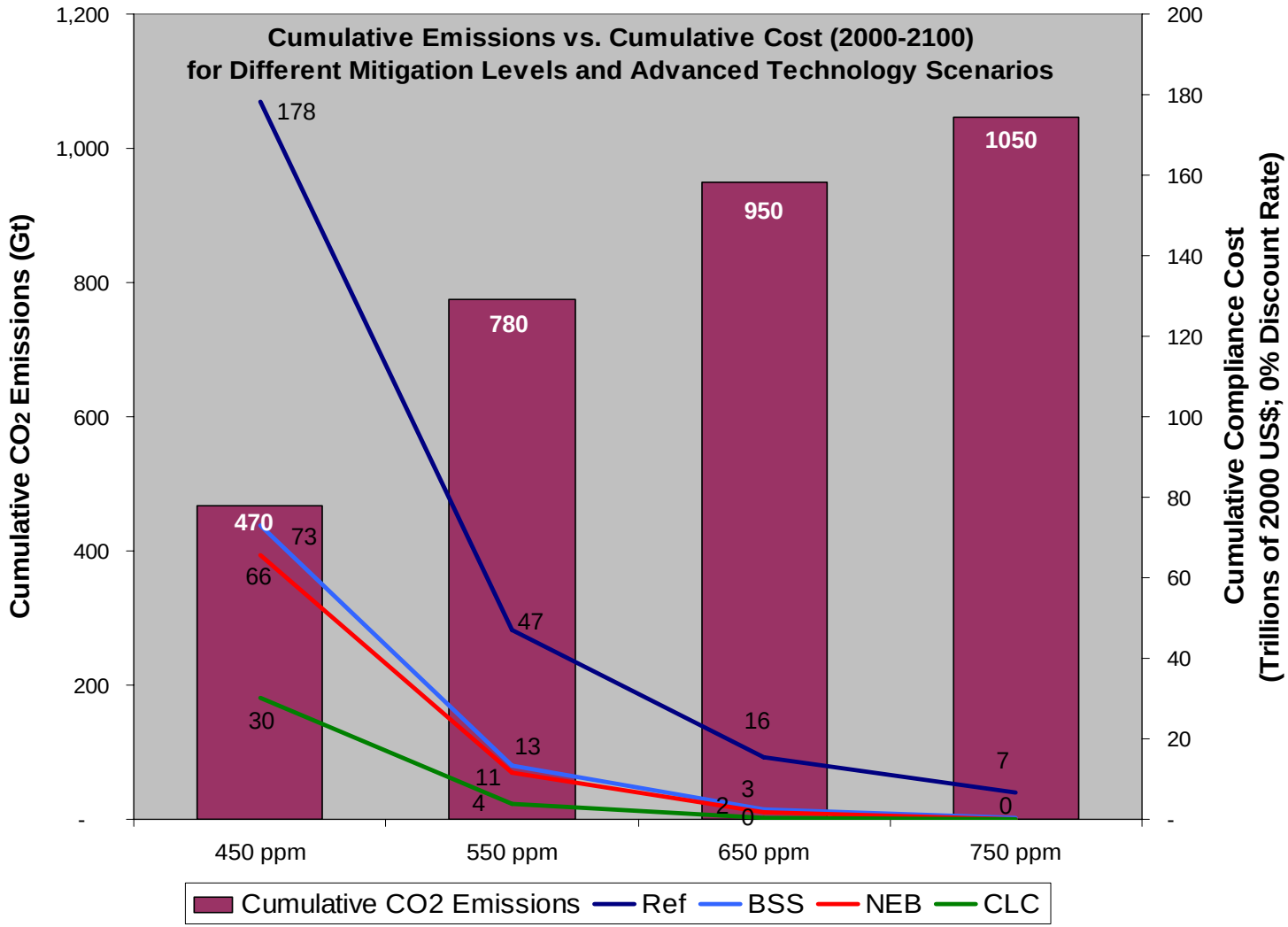
Other International Partnerships are Continuing to Evolve

- Asia-Pacific Partnership
- International Partnership on BioEnergy
- G8 Gleneagles Plan of Action
- International Renewable Energy and Energy Efficiency Partnership
- 20 Bi-Lateral Agreements
- Global Earth Observation System of Systems

CCTP Roadmap to Goal Attainment

CCTP Goals	Near-Term	Mid-Term	Long-Term
Goal #1 Energy End-Use & Infrastructure	• Plug-In Hybrid Electric Vehicles • Engineered Urban Designs • High-Efficiency Appliances • Net-Zero Energy Homes • High-Efficiency Industrial Processes & Boilers • High-Temperature Superconductivity Demos	• H_2 Fuel Cell Vehicles • Low-Emission Aircraft • Net-Zero Buildings • Solid-State Lighting & HVACR • Transformational Technologies for Energy-Intensive Industries • Advanced Energy Storage	• Large-Scale Use of Eng. Urban Designs • Net-Zero Communities • Integration of Industrial Power, Tools, Process, and Techniques • Superconducting Trans-mission and Equipment
Goal #2 Energy Supply	• IGCC Coal Plants • Stationary H_2 Fuel Cells • Wind, Hydro, Solar & Geothermal • Biomass, Biodiesel, Clean Fuels • Distributed Electric Generation • Enhanced Nuclear Power	• FutureGen Scale-Up • H2 Production from Nuclear & Renewables • Low-Speed Wind Power • Community-Scale Solar • Advanced Bio-Refining of Cellulose & Biomass • Gen IV Nuclear Plants	• Zero-Emission Fossil Energy • H_2 & Electric Economy • Large-Scale Renewable Energy • Bio-Inspired Energy & Fuels • Large-Scale Nuclear Energy • Fusion Power Demonstration
Goal #3 Capture, Storage & Sequestration	• CSLF & Regional Partnerships • Oxy-Fuel Combustion • Enhanced Oil Recovery • Soils Conservation • Dilution of Direct Injected CO_2	• CO_2 Transport Infrastructure • Geologic Storage Proven Safe • Soils Uptake & Land Use • Ocean CO_2 Biological Impacts Addressed	• Carbon & CO_2 Based Products & Materials • Track Record of Successful CO_2 Storage Experience • Large-Scale Sequestration • Safe Long-Term Ocean Storage
Goal #4 Other Gases	• Methane to Markets • Precision Agriculture • Alternatives to High GWP Refrigerants • PM Emission Standards	• Methane Emissions Reduction • Soil Microbial Processes • PFC Substitutes • Catalysts That Reduce N_2O to Elemental Nitrogen in Diesel Engines	• Sort, Tag, Process, and Recycle to Eliminate Landfill Waste • Zero-Emission Agriculture • Reduced High GWP Emissions from Waste Streams
Goal #5 Measure & Monitor	• Low-Cost Sensors and Communications	• Large Scale, Secure Data Storage System	• Fully Operational Integrated MM Systems Architecture

Expected Benefits of Advanced Technology Development



Public Comments on Draft Strategic Plan

- **Positives**
  - **Addresses Long-Term Challenge Broadly and Substantively**
  - **Ambitious Visioning of Roles for Technology**
  - **Breaks New Ground With a 100-Year Planning Horizon**
  - **Multi-Agency Approach to Federal Climate Change RDD&D**
- **Negatives**
  - **Plan Appears to Lack Sense of Urgency**
  - **Plan Lacks Supporting Policies or Forcing Functions**
  - **No Acknowledgement of EPAct 2005**
  - **Insufficient Attention to Short and Medium-Term Technologies**
  - **No Mention of Fuller Utilization of Existing Technologies**
  - **No Prioritization of Projects**
  - **No Emphasis on Technical Workforce of the Future**
  - **Does Not Address Geo-Engineering or Adaptation**
  - **Does not Address Ocean Acidification**

Conclusions and Next Steps

- Climate Change is a Long-Term Global Challenge
- Progress Requires Better Remedies
- CCTP Strategic Plan Outlines Ambitious Undertaking to Accelerate Technology Development
- U.S. Effort, Alone, Will Likely Be Insufficient and Must Be Complemented by International Cooperation
- Plan Strengthens U.S. Efforts and Provides Means for Engaging Others
- Deployment in U.S. Supported by $Billions in Incentives
- Plan Expected to be Published in 2006

Back-Up Slides

CCTP-Related Financial Incentives* in EPACT
2005-2015 ($ Millions)

	10-Years
• Renewable Energy	
– Extend Renewable Electricity Production Credit	2,747
– Renewable Energy Bonds	411
• Nuclear	
– Production Credit for Advanced Nuclear	278
• Fossil	
– Investment in Clean Coal Facilities, Including IGCC	1,612
• Energy Infrastructure (Transmission)	1,549
• Conservation and Energy Efficiency	1,284
• Alternative Motor Vehicles and Fuels	1,318
• Total CCTP Related Tax Incentives	9.2 B

* Title XVII also authorizes loan guarantees not scored here

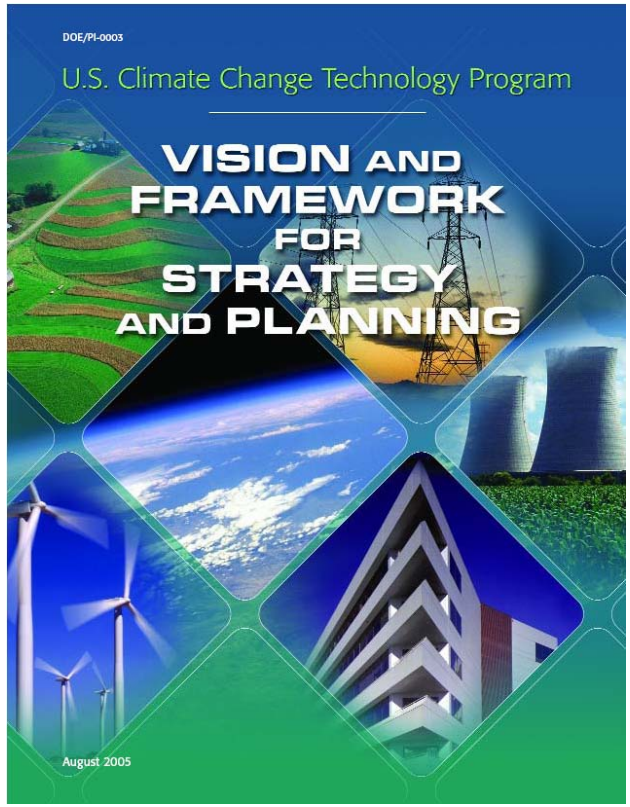
Financial Incentives for Investment . . .

Over $3 Billion/Year in Tax Incentives	$M / Year*
• Renewable Energy Production Credits	355
• Residential Solar Energy Systems (Tax Credit)	10
• Hybrid and Fuel Cell Vehicles (Tax Credit)	316
• Industry for Landfill Gas and Combined Heat and Power	133
• Biofuels, Coal Bed Methane (Production Credit)	1,000
• Biomass Ethanol (Exemption from Excise Taxes)	1,100
• Hydroelectric, Biomass Elec. (Excl. of Interest on Bonds)	100
• Clean Fuel Cars, Truck and Refueling Stations	50
• Investment Tax Credits for Solar, Geothermal Facilities	50
• Total	3,114

* Congressional Research Service Analysis of Tax Expenditures for 2003

The U.S. is Committed, With Climate Change Policy and Programs

- Presidential Leadership
- Cabinet-Level Engagement
- Near-Term Actions
- Financial Incentives for Investments
- $5 Billion / Year In Federal S&T
  - Science to Inform Policy
  - Technology to Facilitate Action
- International Initiatives
- Deliberate Approach to Long-Term Goal, Consistent with UNFCCC
- Climate Friendly Technologies
- A Collaborative Path Forward



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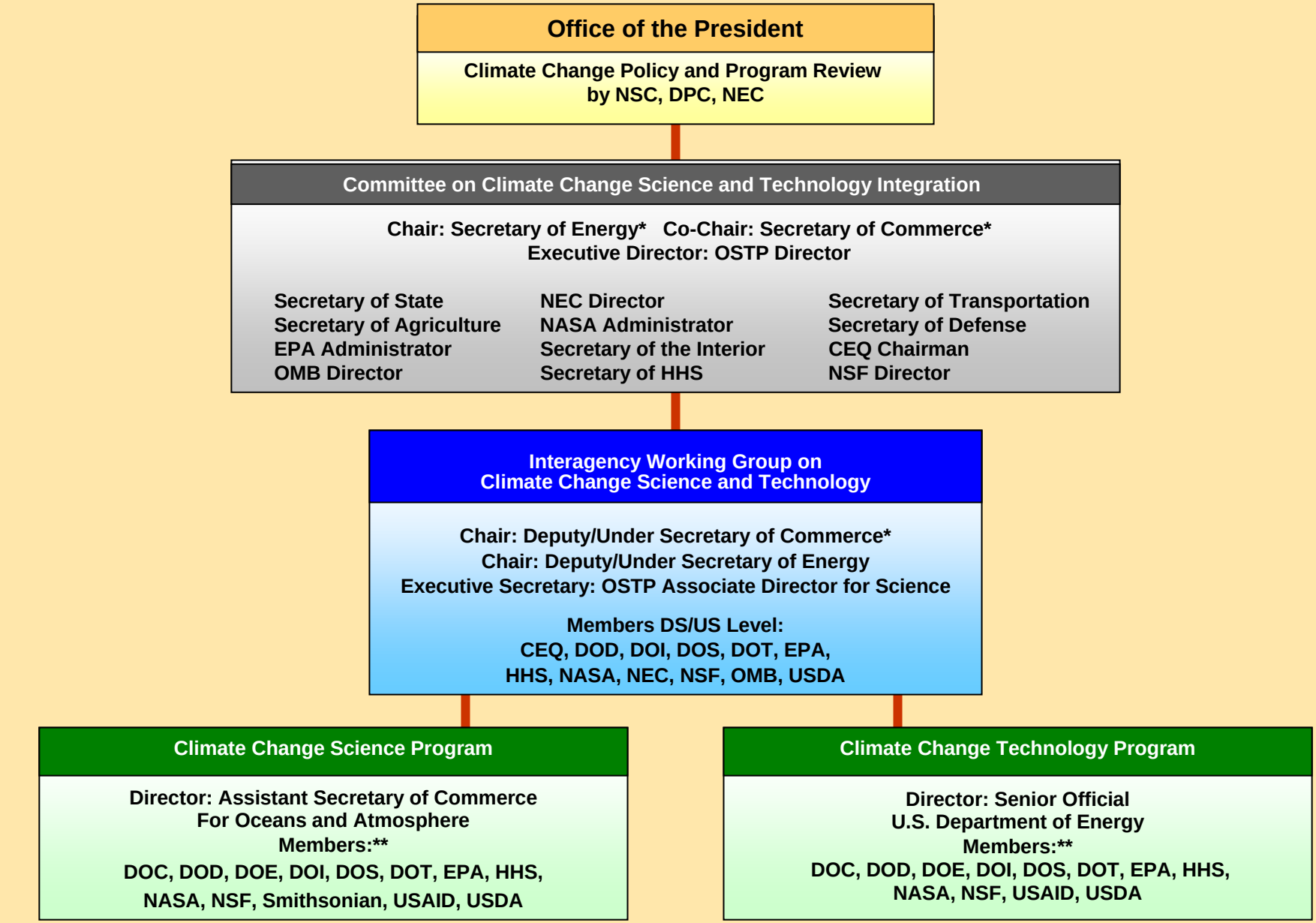
Cabinet-Level Engagement

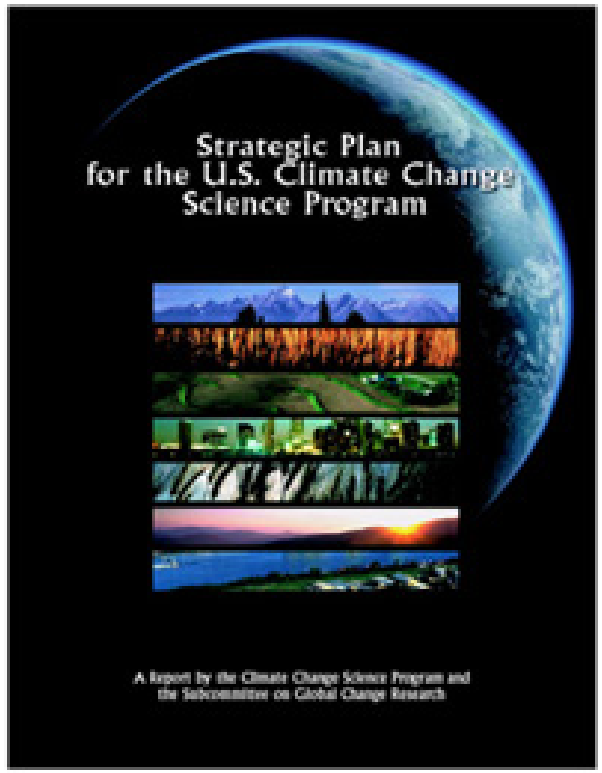


* Chair and Vice Chair of Committee and Working Group alternate annually.

** CEQ, OSTP, and OMB also Participate

Science -- Seeking Better Knowledge and Understanding – to Inform Policy

- **U.S. Climate Change Science Program**
  - **An Ambitious Program of Research**
  - **$2 Billion / Year**
- **Climate Science Goals**
  1. **Improve Knowledge of Climate and Environment**
  2. **Improve Quantification of Forces Driving Changes to Climate**
  3. **Reduce Uncertainty in Projections of Future Climate Changes**
  4. **Understand Sensitivity and Adaptability of Natural and Manmade Ecosystems**
  5. **Explore Uses and Limits of Managing Risks and Opportunities**



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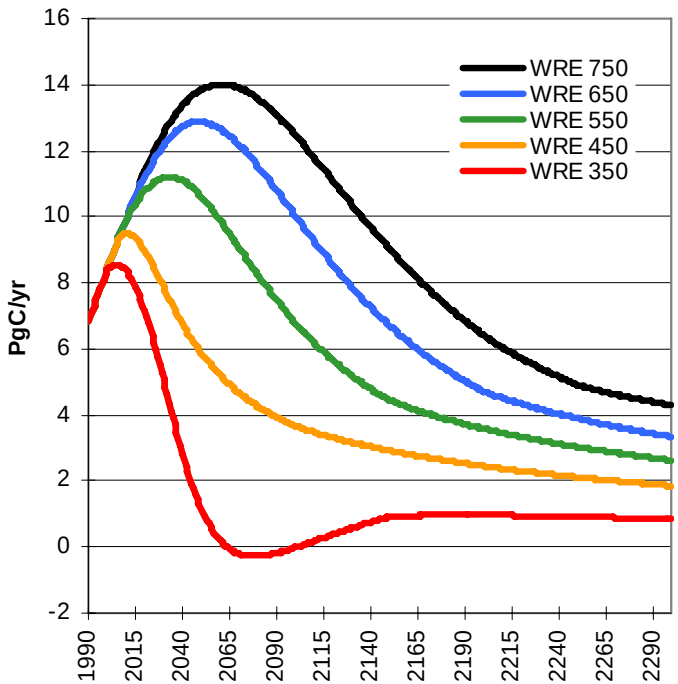
CCTP Core Approaches (Next Steps)

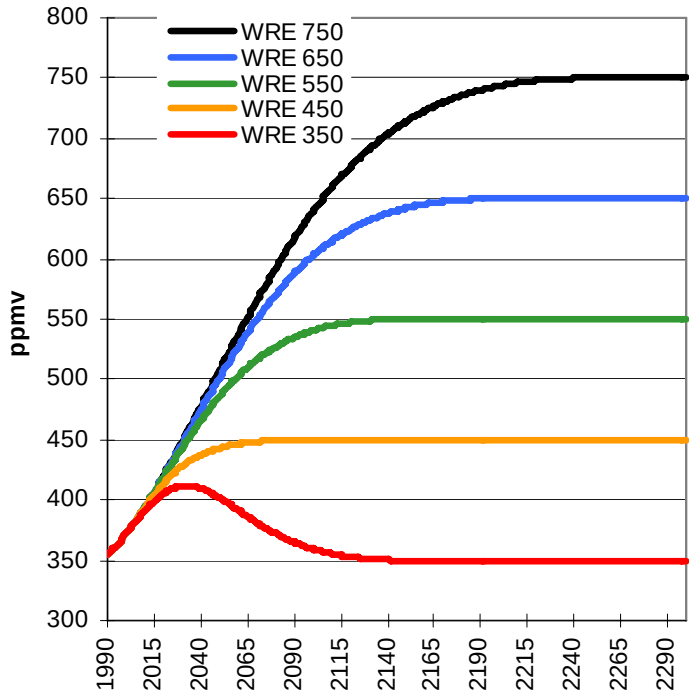
- **The CCTP Employs 7 Core Approaches to Stimulate Participation by Others and Ensure Progress Toward Strategic Goals:**
  - **Strengthen Climate Change Technology R&D**
  - **Strengthen Basic Research Contributions**
  - **Enhance Opportunities for Partnerships**
  - **Increase International Cooperation**
  - **Support Cutting-edge Demonstrations**
  - **Ensure a Viable Technology Workforce of the Future**
  - **Provide Supporting Technology Policy**

Planning Under Uncertainty – Alt. Paths to the President's Goal …

Emission Trajectories



Concentration Trajectories



T.M.L. Wigley, R. Richels, & J.A. Edmonds (WRE), Nature, January 18, 1996, "Economic and Environmental Stabilization of Atmospheric Concentrations"