GTSP II: What Have We Learned?

GTSP Steering Group Meeting
May 2005

Jae Edmonds
25 May 2005
Cosmos Club
Washington, DC
Purpose of the Annual Meetings

To review progress in the GTSP, and

To solicit advise in directions for the future.
Thanks to the Sponsors

- Battelle Memorial Institute
- California Energy Commission
- Electric Power Research Institute—Climate Programs
- Electric Power Research Institute—Nuclear Programs
- Gas Research Institute
- General Motors
- Kansai Electric Power
- National Institutes for Environmental Studies (Japan)
- Rio Tinto
- US Department of Energy—Office of Science
- US Department of Energy—Office of Fossil Energy
Yesterday’s Technical Sessions

- **9:00 a.m.**  Welcome and Introductions—Ron Sands, Gerry Stokes, Jae Edmonds
- **9:15 a.m.**  Scenarios Overview—Hugh Pitcher, JGCRI
- **9:45 a.m.**  Value of Technology—Leon Clarke, JGCRI
- **10:15 a.m.** Break
- **10:30 a.m.** Technology Choice in Industry—Matthias Ruth, University of Maryland
- **11:15 a.m.** Technology and Climate Change in China—Ron Sands for Jiang Kejun, ERI, Beijing
- **12:00 noon** Working Lunch
- **1:00 p.m.**  Technology and Climate Change in India—P.R. Shukla, IIM, Ahmedabad
- **2:00 p.m.**  Technology in Buildings—Jae Edmonds, JGCRI
- **2:40 p.m.**  Break
- **3:00 p.m.**  Nuclear Technologies—Sonny Kim, JGCRI
- **3:45 p.m.**  Energy Challenges in Northeast Asia—Tae-Yong Jung, IGES, Japan
Today’s Agenda

8:00 a.m.  Continental Breakfast
8:30 a.m.  Welcome and Introductions  Richard H. Rosenzweig
8:40 a.m.  Purpose of Meeting  Charlette A. Geffen
8:50 a.m.  What Have We Learned?  Jae Edmonds
10:00 a.m.  Break
10:15 a.m.  Global Dimensions of the Energy Technology Strategy  Gerald Stokes
11:00 a.m.  Biotechnology: Challenges and Opportunities  Ari Patrinos
12:00 noon  Lunch
1:00 p.m.  The Economics of Biotechnology  Steven Smith
2:00 p.m.  Break
2:15 p.m.  The Status of the Carbon Capture and Storage Deep Dive  Marshall Wise & James Dooley
3:15 p.m.  The Midwest Regional Carbon Sequestration Project: Laying the Groundwork for CCSP Deployment on the Ground  Dave Ball
4:00 p.m.  Summary of Proceedings and Next Steps
4:30 p.m.  Adjourn
The GTSP
Phase II

Objective

To articulate the cost and environmental performance targets for technologies and technology systems in a climate constrained world and the institutional means of implementation.
GTSP Phase II

Implementation & Institutions

Deep Dives:
- Carbon Capture and Disposal
- Biotechnology
- Hydrogen & Transportation
- Renewables
- Nuclear
- Energy Intensity

Cross Cuts:
- Modeling, Scenarios & Non-CO₂ Gases
- Energy Intensity
Lessons from GTSP Phase I
Achieving the Reference Case Will Not Necessarily Be Easy

**Assumed Advances In**
- Fossil Fuels
- Energy intensity
  - Nuclear
- Renewables

**Gap technologies**
- Carbon capture & disposal
  - Adv. fossil
- H2 and Adv. Transportation
- Biotechnologies
  - Soils, Bioenergy, adv. Biological energy

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**Carbon Emissions**

- IS92a (1990 technology)
- IS92a
- 550 ppmv constraint

**The “Gap”**
A Technology Strategy Supports A Broad and Competitively Balanced Portfolio (There’s No Silver Bullet.)

- **Energy Intensity Improvements**
  - Industry
  - Buildings
  - Transportation

- **Wind and Solar**

- **Biotechnology**
  - Soils
  - Biomass crops
  - Advanced biotechnology

- **Nuclear**
  - Fission
  - Fusion

- **Carbon Capture and Storage**

- **Advanced Transformation Systems**
  - Electricity
  - Hydrogen
  - Bio-derivative fuels
Adding to the Portfolio Will Be Essential

Filling The Technology Gap
Technology Contributions Change With Place and Time

 Technologies that Could Fill the Regional "Gaps"

Shown in Millions of Tonnes Carbon

- Conservation
- Natural Gas & Oil Substitution
- Soil Carbon Sequestration
- Syntfuel-Carbon Capture and Sequestration
- Carbon Capture and Sequestration from Hydrogen Production
- Central Power-Carbon Capture and Sequestration
- Solar and Hydro
- Nuclear
- Biomass
- 550 ppmv Emissions

China

India

USA

Japan

Western Europe
Technology Alone Won’t NECESSARILY Stabilize CO$_2$ Concentrations

- **Energy Related Carbon Emissions**

  A reference case with advanced technology development of carbon capture and H$_2$, but no climate policy.

  A reference case with continued technology development, and no climate policy.

  Emissions path that stabilizes CO$_2$ concentrations at 550 ppm.
Why control costs?
- Wasted resources mean other worthy products go un-produced.
- Or, we settle for lower environmental quality.

Carbon Tax
- Uniformly & Efficiently Applied Over Time and Space

Technology Helps Control Cost

A reference case with continued technology development, and a limit on CO₂ concentrations at 550 ppm.

A reference case with advanced technology development of carbon capture and H₂, and a limit on CO₂ concentrations at 550 ppm.
GTSP Phase 2

What have we learned?
CCS

The story is more nuanced than we (the research community) told previously

- Regionally distributed resource associated with a specific place.
- Participation in the IPCC special report on CCS.
- The presence of CCS as an option in the context of a value to carbon affects important electric utility decisions.
- Seemingly minor technological parameters can have a large impact on the global energy system, e.g. capture rate on CO2 from power plants.
Technology & Stabilization Regimes

Stabilization of climate change can lead to large-scale deployment of technologies that are presently only minor components of the global energy system.

- Carbon dioxide capture and storage,
- Hydrogen, and/or
- Biotechnology—commercial biomass, terrestrial sequestration and technologies flowing from the intersection of genomics and nanotechnologies.
How Big?

Annual Carbon Storage

Cumulative Carbon Storage

PNNL MiniCAM Output, EMF-19, B2 scenario with CCS and H2
Storage Estimates Compared to Carbon Dioxide Capture Estimates—Regionally Unconstrained Storage
Estimates of Global Capacity Imply That Large Scale CCS Deployment Implies Usage of Deep Saline Formations


Total = 2,867 PgC

Coal Basins: 48
Depleted Oil Plays: 31
Gas Basins: 190
Deep Saline Formation On-shore: 1,540
Deep Saline Formation Off-shore: 1,057
Global CO$_2$ Storage Capacity: Now
Composition of Power Generation in Japan, 2095

Regionally limited CCS Available, 550 ppm

Unlimited CCS Assumed Available, 550 ppm
Better Estimates of Storage Would Make a Big Difference in Key Regions

Ratio of Cumulative Emissions 1990 to 2095 to Maximum Potential Geologic Storage Capacity by Region

- Latin America
- Africa
- Middle East
- Southeast Asia
- India
- China
- Korea
- Japan
- Australia_NZ
- Former Soviet Union
- Eastern Europe
- Western Europe
- Canada
- USA

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
The overriding conclusion from our work on CCS is that this technology is potentially an important component of a technology strategy to address climate change.
Biotechnology

- A portfolio unto itself
- Soil carbon
- Interface with agriculture & agricultural productivity.
- Potential of modern biological science to create revolutionary breakthroughs.
- Combining biotechnology with CCS.
Biomass and Land-Use Change Emission

- **Energy**
  - Biomass in B2 Reference and B2 Reference Stabilization Cases
  - Land-use Emissions

- **Land-use Emissions**
  - Land-Use Change Carbon Emissions

- **B2 Reference**
  - B2 Reference with Stabilization

- **B2 Reference with Climate Stabilization**

- **B2 Modern**
  - B2 Stable Waste & Trad
  - B2 Waste & Trad

- **Energy Land-use Emissions**
  - EJ/year

- **Pacific Northwest National Laboratory**
  - Operated by Battelle for the U.S. Department of Energy
H2 and Biotech
B2 AT with Stabilization

What if agricultural and biomass crop productivities could be maintained and a biological source of H2 that is cost-competitive with CH4?
Combining Biotechnology with CCS

We have begun to explore the implication of combining commercial biomass production with CCS in electricity production.

Preliminary work

The principal conclusion is that this combination of technologies could be an important component in a world that is limiting net CO$_2$ emissions to the atmosphere.

- Implications for land-use
- Implications for CCS deployment—complementary technologies.
- Last year the new transport sector was implemented for the USA only. This year the model is global.
- Energy demands in the new global transportation services are derived from the demand for transportation services
- \( \text{CO}_2 \) and non-\( \text{CO}_2 \) GHG’s are now part of the story.
- Distinction between passenger and freight.
- Distinction between modes and modal technology options.
• Top-down models generally have not considered nuclear technology explicitly.
• The fuel cycle is addressed explicitly
• Technological change is modeled explicitly:
  • Gen II
  • Gen III, and
  • Gen IV reactors.
• Fuels are tracked
Market penetration for Gen III and IV reactors is potentially thousands of reactors by the end of the century.

In the presence of a limit on CO₂ concentrations, nuclear energy deployment expands dramatically relative to the reference case.

The better the technology, and in particular, the lowering capital cost of advanced nuclear technologies, the greater their deployment and the larger their contribution to emissions reductions.

The extent of nuclear deployment depends importantly on the cost and performance of competing technologies. The cost and availability of CCS is of particular interest.
Potentially large component of both the reference case and response to climate change.

In most top-down models energy intensity is controlled by one parameter, AEEI.

AEEI provides significant emissions reductions in the reference case, but does not distinguish contributions by technology source.

Since the last Steering Group Meeting significant progress has been made in building the capacity to consider end-use energy technology explicitly in a top-down model.

This work was made possible by support from a GTSP related program sponsored by the US DOE Office of Energy Efficiency and Renewable Energy as well as GTSP sponsors.
Two buildings sectors: Residential and Commercial

Five residential service demands
- Heating
- Cooling
- Lighting
- Appliances & Other*
- Hot Water

Six commercial service demands
- Heating
- Lighting
- Office Equip*
- Other*
- Non-Comm Other*

* Several services suffer from substantial data limitations.

Illustrative Results of Scenario of Commercial Lighting Sector Development

Commercial Sector Lighting Shares

<table>
<thead>
<tr>
<th>Year</th>
<th>1990</th>
<th>2005</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
<th>2065</th>
<th>2080</th>
<th>2095</th>
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<tr>
<td>Technology Share</td>
<td>0%</td>
<td>10%</td>
<td>30%</td>
<td>50%</td>
<td>70%</td>
<td>90%</td>
<td>100%</td>
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Benefits Accruing from Advanced Technology

Research and Development

- Fluorescent
- Incandescent
- Solid state

A single U.S. region.

U.S. Region

Deep dives

Cross cuts

Implementation & Institutions

Modeling, scenarios & non-CO2 gases

Carbon capture and disposal

Biotechnology

Hydrogen & transportation

Renewables

Nuclear

Energy intensity

GTSP Phase II: New Developments

GTSP Phase II: New

Two buildings sectors: Residential and Commercial

Commercial Buildings

Residential Buildings

Heating

Lighting*

Appliances & Other*

Hot Water

Appliances & Other*
GTSP Phase II: New

modeling, scenarios & non-CO₂ gases

implementation & institutions

energy intensity

nuclear

renewables

gas & transportation

biotechnology

carbon capture and disposal

deep dives

cross cuts

GTSP
Global Energy Technology Strategy Program
Scenarios

- Developing new scenarios from the ground up for the CCSP process.
- Developing new GDPs cognizant of PPP versus MER issues.
- New energy technology assumptions.

Global Population

Regional Components of the Global Population
BAU Matters in Non-CO₂ GHGs

Global Methane Forcing

- B2-No CH4 Reductions
- B2
- Stab CO2 Only
- Stab Multigas

Year: 1990, 2010, 2030, 2050, 2070, 2090

Forcing (W/m²): 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8
Limiting GMST to 2°C

CO₂ Emissions

Fossil Fuel Carbon Emissions

- 2020, 7.6 PgC/y
- B2 Ref Stabilization

1990 2005 2020 2035 2050 2065 2080 2095
Uncertainty in Climate Sensitivity
GMST Change Stabilization at $\Delta T<2^\circ C$
For Climate Sensitivities of 1.5, 2.5, and 3.5$^\circ C$
Whither GTSP?

GTSP Phase 2 is in its 3rd year.

We are beginning the process of documenting the lessons learned.

- Carbon dioxide capture and storage
- Biotechnology
- Hydrogen and advanced transportation systems
- Nuclear power
- Energy efficiency
- Other renewables
- Cross-cutting themes
GTSP Phase III

We are also beginning to think about the shape of future research and the frame for a potential GTSP Phase III.

- Technology development and deployment will be time and place dependent.
- The muddle in the middle
  - Regional
  - Temporal
  - Technology specific

Your comments are welcome.