The Global Energy Technology Strategy Program

Selected Key Findings from the First Decade of Research—Phases 1&2

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Global Energy Technology Strategy Program

GTSP is a major enterprise
- An international,  
- Public-private research enterprise,  
- 9 years of research

Goal: *To undertake research to articulate the role of energy technologies and technology systems and their complex interplay in a climate-constrained world in the near-, mid- and long-term.*

- Explored 6 technology “deep dives”—CO$_2$ capture and storage, biotechnology, hydrogen systems, nuclear energy, wind and solar, end-use energy in buildings, industry, and transport in an strategic integrated analysis.
Acknowledgements

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A Note on Units
CO$_2$ Versus C

1 ton C = 44/12 tons of CO$_2$
     = 3$^2$/3 tons of CO$_2$
     = ~4 tons of CO$_2$

$1$/ton CO$_2$ = $3^2$/3 tons of C
     = ~$4$ tons of C

Both appear in the literature.
This presentation used tons of carbon.
Key Findings of the GTSP

- Climate is a long-term problem, with implications for actions today.
- Stabilizing the concentration of CO$_2$ means fundamental change to the global energy system.
- Technology will play a central role in addressing a growing mitigation challenge in the near-, mid- and long-term.
- Six technology systems could play dramatically greater roles in a climate constrained world.
  - CO$_2$ capture and storage, Biotechnology, Hydrogen systems, Nuclear energy, Wind and solar, and End-use energy technologies, though none is a “silver bullet.”
- A strategy to develop and deploy technology should be part of a larger program—including scientific research, emissions limitation, and adaptation to climate change.
Climate change is a long-term strategic problem with implications for today.

- Stabilization of greenhouse gas concentrations is the goal of the Framework Convention on Climate Change.
- Stabilizing CO₂ concentrations at any level means that global, CO₂ emissions must peak and then decline forever.
A global commitment to stabilizing CO₂ concentrations requires a carbon price that escalates over time.

- Price of carbon should start low and rise steadily to minimize society’s costs.
- Eventually all nations and economic sectors need to be covered as the atmosphere is indifferent as to the source of CO₂ emissions.
- The response to this escalating price of carbon will vary across economic sectors and regions.

Global Value of Carbon

- 450 ppm stabilization
- 550 ppm stabilization
- 650 ppm stabilization
- 750 ppm stabilization

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The role of technology
Future projections of energy use and CO₂ emissions assume significant technological progress in their no-climate-policy, business-as-usual cases.
Stabilizing CO₂ concentrations means fundamental change to the global energy system.

**History and Reference Case**
- Preindustrial CO₂ Concentration: ~280 ppm
- Present CO₂ Concentration: ~380 ppm
- 2100 CO₂ Concentration: ~740 ppm

**Stabilization of CO₂ at 550 ppm**
- 2100 CO₂ Concentration: ~550 ppm

The graphs illustrate the energy consumption (EJ/year) from 1850 to 2100, categorized by energy sources:
- Oil
- Natural Gas
- Coal
- Biomass Energy
- Non-Biomass Renewable Energy
- Oil + CCS
- Natural Gas + CCS
- Coal + CCS
- Nuclear Energy
- End-use Energy
The response to this escalating price of carbon will vary across economic sectors and regions.

Stabilization changes the sources of fossil CO₂ emissions. Utility emissions drop to virtually zero. Transportation emissions dominate.
CO₂ Capture and Storage
For stabilization scenarios from 450-750ppmv, most integrated assessment models show a demand for no more than 600 GtC (2,220 GtCO₂) storage over the course of this century.

Published estimates of potential storage capacity place the potential global geologic CO₂ storage capacity at approximately 3,000 GtC (11,000 GtCO₂).
Potential geologic storage reservoirs are distributed heterogeneously.

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% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Even if potential storage is limited, there is substantial economic value in deploying CCS.
The challenge of scale
The Challenge of Scale—near term

CO₂ Storage—550 ppm Stabilization Case

Monitored CO₂ Storage Today

2020 (550 ppm)

Millions of Tons of Carbon per Year

0 10 20 30 40 50 60 70 80

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JGCRI
Joint Global Change Research Institute

University of Maryland

Pacific Northwest National Laboratory
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In the mid- and long-term the challenge grows

**CO₂ Storage Rate Level 2 (~550 ppm)**

- Monitored CO₂ Storage Today
- 2020 (550 ppm)
- 2050 (550 ppm)
- 2095 (550 ppm)

**Millions of Tons of Carbon per Year**

- 2020 (550 ppm): 0
- 2050 (550 ppm): 1,000
- 2095 (550 ppm): 2,000

**In the mid- and long-term the challenge grows.**
CO₂ emissions mitigation during 2005 to 2050 is just the start

- The time scale of emissions mitigation is a century or more.
- Energy technology will be needed to help control emissions in the NEAR-, MID-, and Long-term to address climate change.
- Investments in basic scientific research in the first half of the 21st century can be transformed into energy technologies that can become a major part of the global energy system in the second half of the century.
Nuclear energy
Climate policy accelerates the expansion of the market for nuclear power...

Regardless of whether there is a global climate policy that seeks to stabilize atmospheric concentrations of greenhouse gases, nuclear energy is already an important energy supplier and is expected to continue to expand throughout this century.

The market for nuclear power to generate hydrogen for the transportation sector is a small portion of the market for electricity.
Issues that, while difficult to quantitatively model, might impact the projected growth of nuclear power in the 21st century.

- Public policies designed to address proliferation concerns
- Nuclear waste

**Nuclear Power Production by Technology 550 ppm Stabilization Scenario**

Fourth generation reactors could have an important role in addressing waste, and proliferation issues.
Bioenergy and Land use
The successful deployment of bioenergy in a climate-constrained world depends as much on the continued productivity advances for non-energy crops as for the energy crops—no one is making more land.

**Technology Interplay—Bioenergy with Agricultural Productivity**
Oil Supply—Global

Stabilization extends the life of conventional oil, reduces shale oil production, eliminates coal liquefaction and promotes bioenergy.

Reference

550 ppm CO₂
To the atmosphere all carbon counts the same. Carbon cycle implications of valuing terrestrial carbon emissions.
Bioenergy with CO\textsubscript{2} Capture and Storage

- Technologies can work in combinations.
- Combining bioenergy with CO\textsubscript{2} capture and storage could provide a way to produce energy and produce NEGATIVE emissions of CO\textsubscript{2}.
End use energy efficiency and fuel choice
Electrification

- The world is electrifying.
- Emissions mitigation increases the relative role of electricity.
- Electricity prices fall relative to fossil fuel prices.
End-use Energy Technologies

Three sectors
- Buildings
- Industry
- Transportation

Emissions reductions come from two sources
- Energy efficiency improvements
- Fuel substitution

Buildings 550 ppm

Transportation 550 ppm
Stabilization of CO$_2$ concentrations means fundamental change to the global energy system

... but the character of the global energy system will depend on technology developments:

- CO$_2$ capture and storage (CCS) plays a potentially large role assuming that the institutions make adequate provision for its use.
- Biotechnology has dramatic potential, but important land-use implications.
- Hydrogen could be a major new energy carrier, but requires important technology advances in fuel cells and storage.
- Nuclear energy could deploy extensively throughout the world but public acceptance, institutional constraints, waste, safety and proliferation issues remain.

- Wind & solar could accelerate their expansion particularly if energy storage improves.
- End-use energy technologies that improve efficiency and/or use energy carriers with low emissions, e.g. electricity deploy more extensively.
The GTSP Report

Copies of the Report are Available here

And on the Web

http://www.pnl.gov/gtsp

or

http://gtsp.battelle.org
END