Modeling Long-term Technology Strategy for Climate Change

Workshop on
Economic and Environmental Modeling

Jae Edmonds

19-20 January 2004

New Delhi, India

GTSP Global Energy Technology Strategy Program

Battelle | Office of Science U.S. Department of Energy | JGCRI Joint Global Change Research Institute | University of Maryland

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The Global Energy TECHNOLOGY STRATEGY (GTSP)

Addressing Climate Change

A international, public/private collaboration to assess the role that technology can play in addressing the long-term issue of climate change

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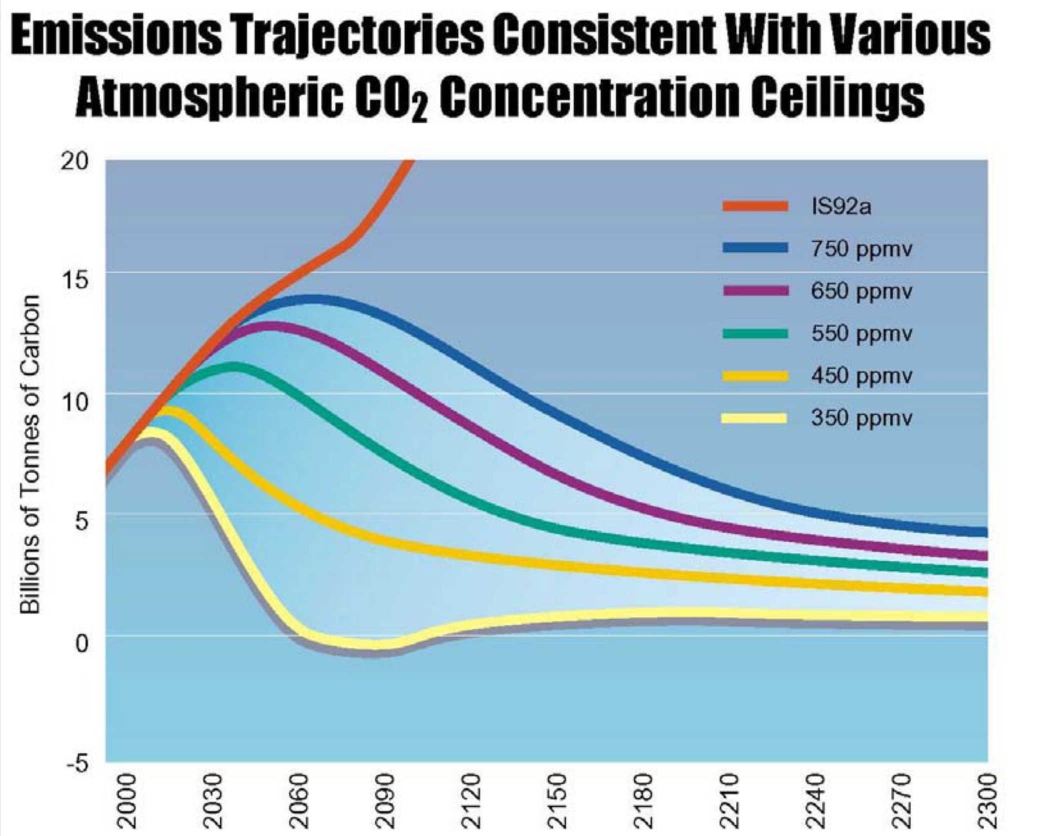
AGENDA

- Boundary conditions.
- Technology in context.
- Futures with and without credible commitments to limit cumulative carbon emissions.
- Technology and some technology modeling insights.

Stabilizing CO_2 Concentrations

- Stabilization of greenhouse gas **concentrations** is the goal of the Framework Convention on Climate Change



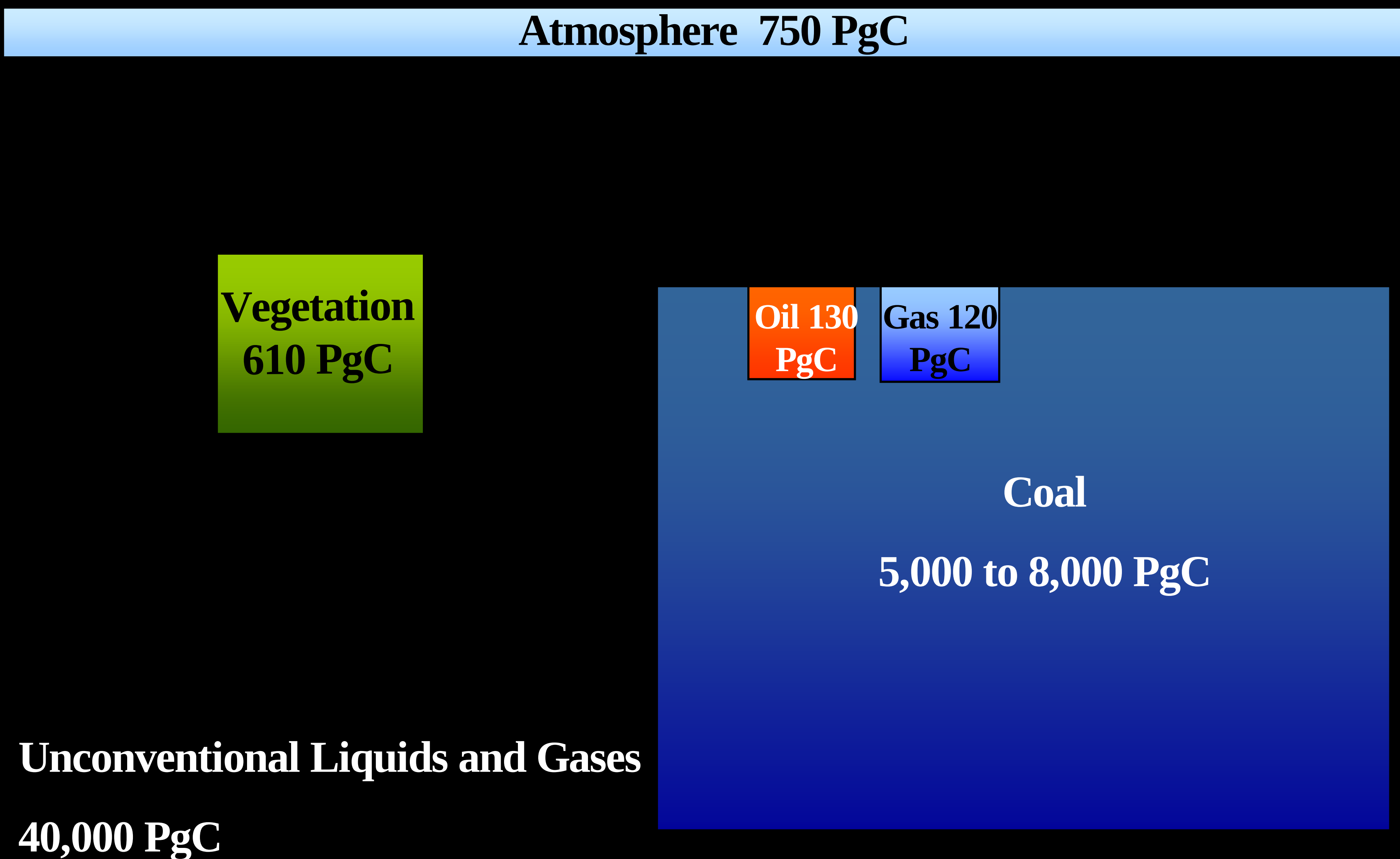
- Stabilizing the concentration of CO_2 is a very long term problem

- Stabilization means that GLOBAL emissions must peak in the decades ahead and then decline indefinitely thereafter.

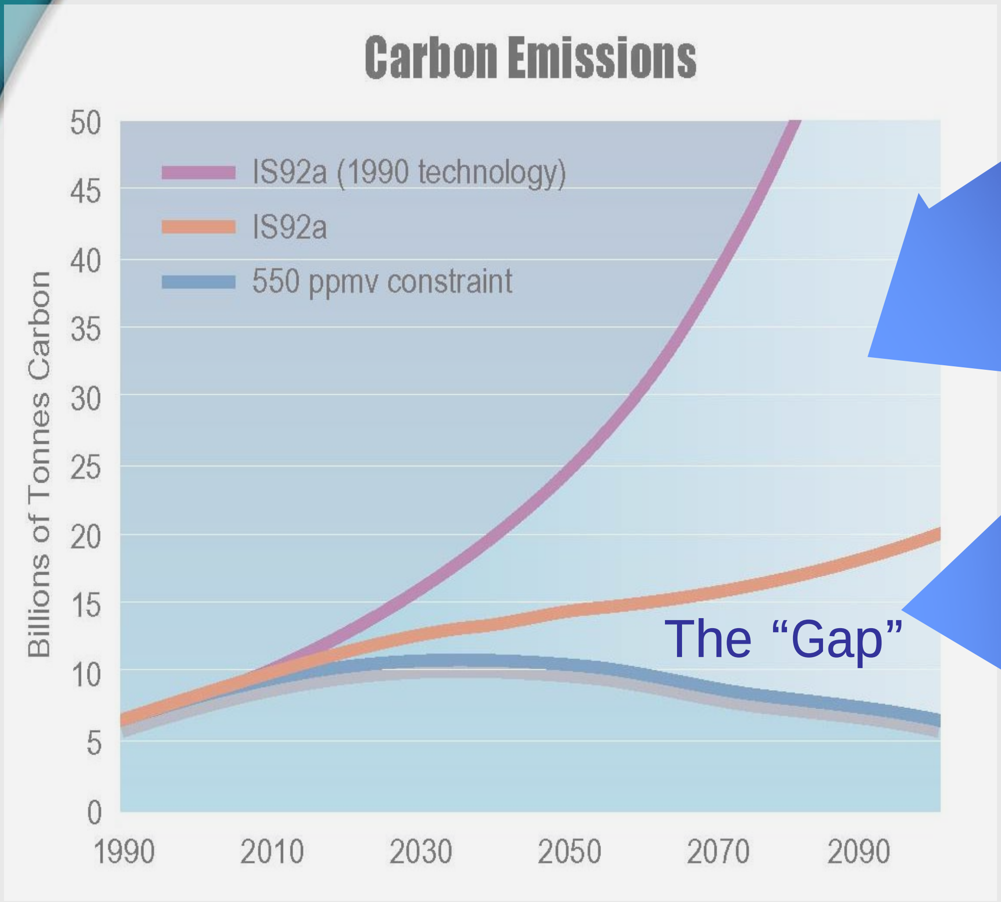
Will the Problem Go Away on Its Own?

Won't the limited conventional oil and gas resource force a transition in the near term to a world based on energy efficiency and renewable and nuclear energy forms?

FOSSIL FUEL RESOURCES



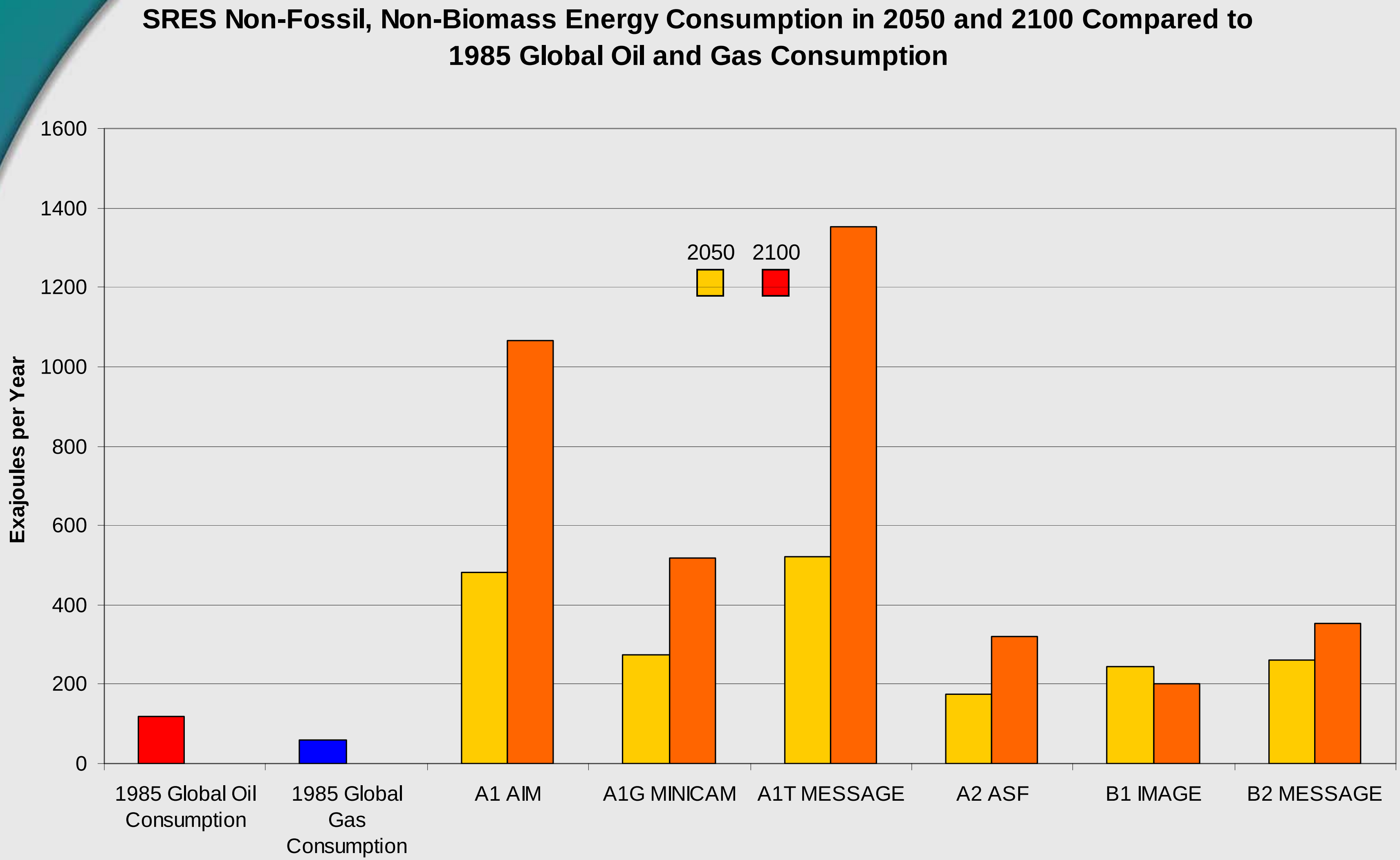
Stabilizing CO_2
Base Case and "Gap" Technologies



<u>Assumed</u> 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

Technology Assumptions in SRES Marker Scenarios



SRES Scenario and Modelling Team

TECHNOLOGY IS PART OF A POLICY RESPONSE PORTFOLIO

- Improved scientific understanding;
- Adaptation to climate change;
- Emissions mitigation;
- Technology development.

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Technology Availability & Stabilizing Greenhouse Gas Concentrations

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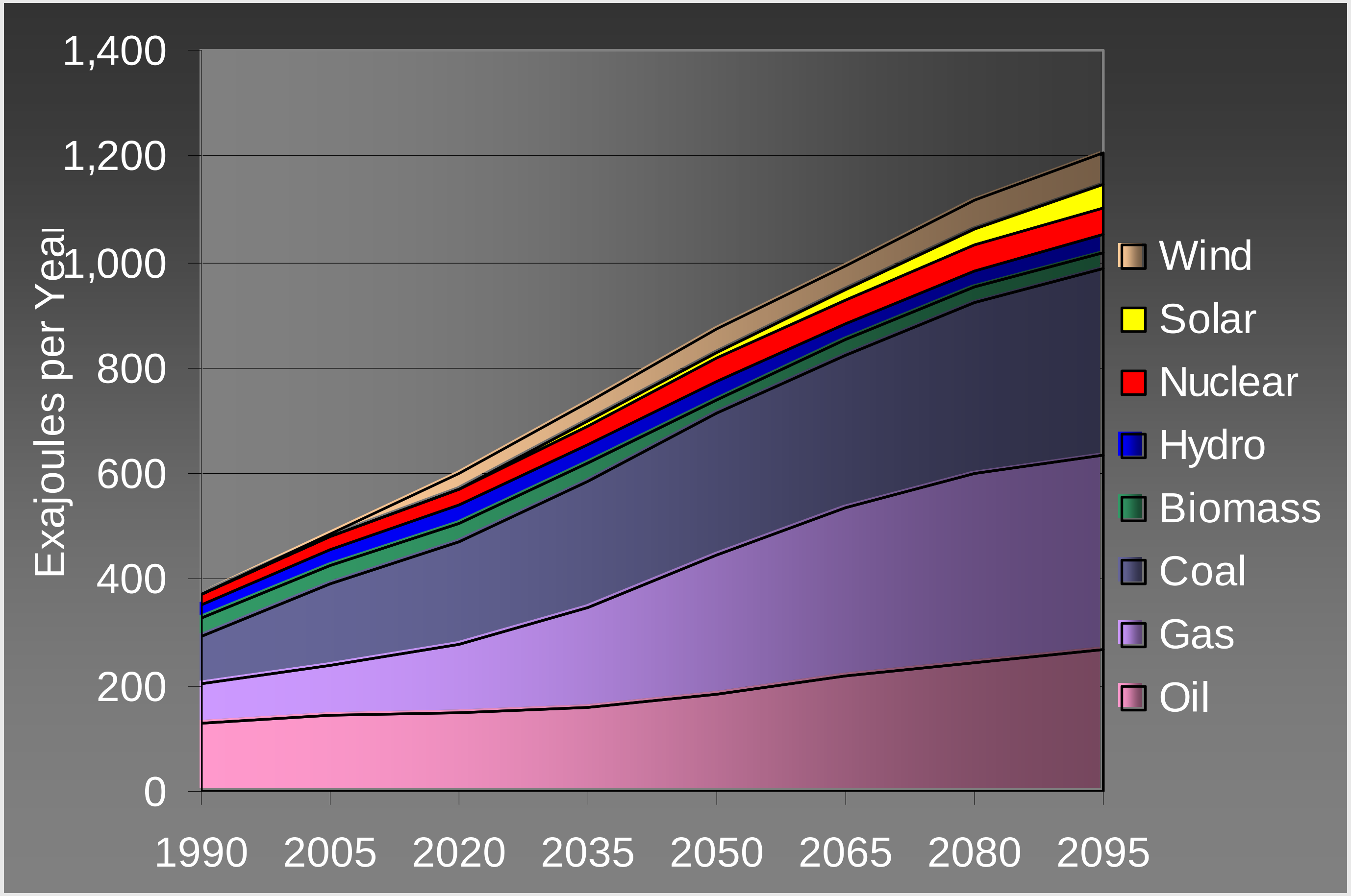
The Reference Primary Energy System
SRES MiniCAM B-2



Four Cases

MiniCAM B2

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

MiniCAM B2 550

the reference case with continued technology development, and 550 ppmv CO_2 stabilization.

MiniCAM B2 AT

the reference case with advanced technology development of carbon capture and h2, but no climate policy.

MiniCAM B2 AT550

the reference case with advanced technology development of carbon capture and h2, and 550 ppmv CO_2 stabilization.

WARNING!!!

The Advanced Technology Case Is Just One of Many Possible Outcomes for Investments in a Diversified Portfolio of Energy Technology R&D

Includes information from three “deep dives” undertaken under the GTSP

- **Carbon Capture and Storage**
- **Bio-technology**
- **Hydrogen and Advanced Transportation Systems**

GTSP "Deep Dives"

- Carbon Capture and Storage
- Bio-technology
- Hydrogen and Advanced Transportation Systems
- **Nuclear (fission/fusion)**
- **Wind, Solar and Other Renewables (including SSP)**
- **Energy Intensity**

Cross-Cutting Themes

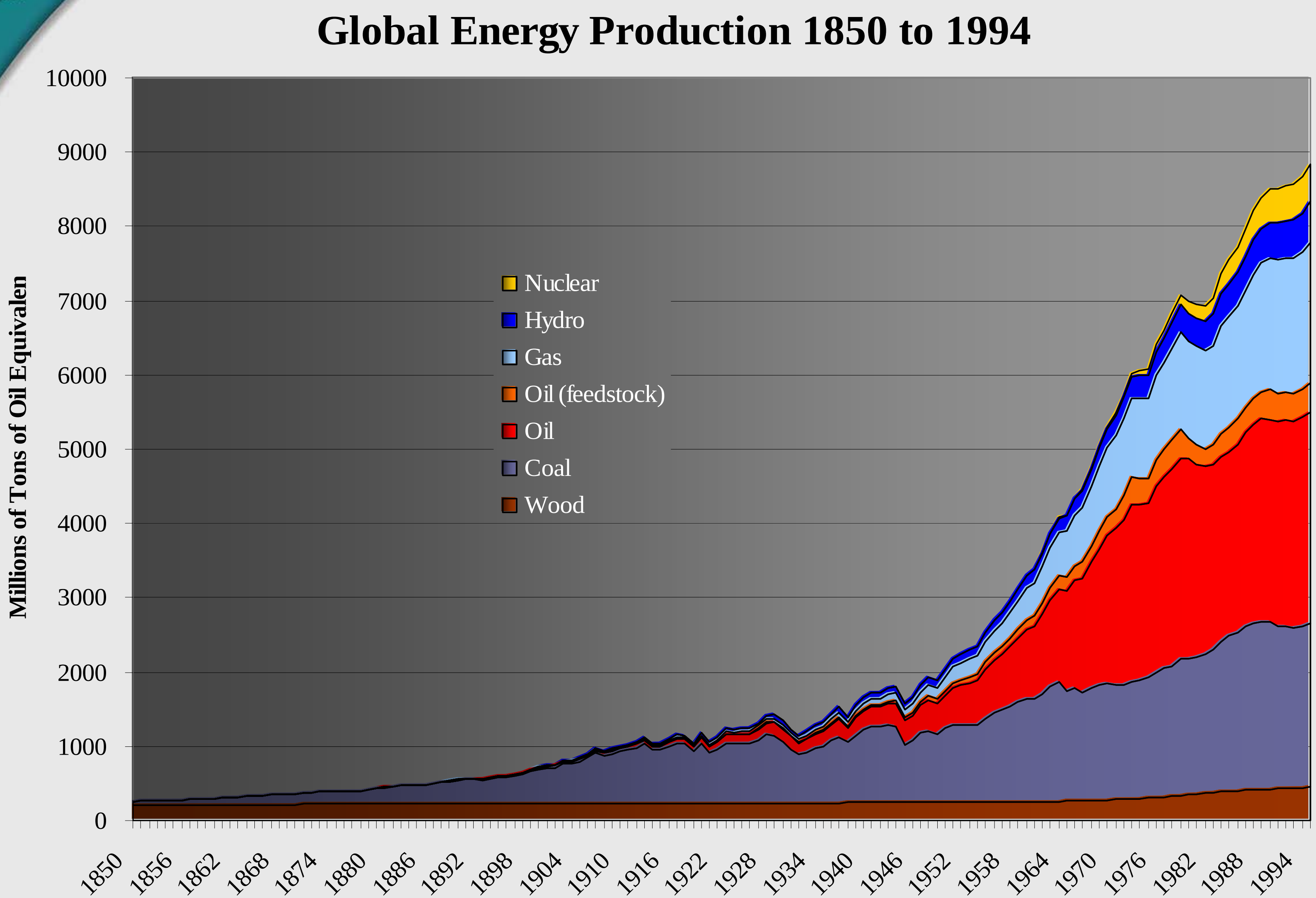
- **Modeling**
- **Non-CO_2 Greenhouse Gases**
- **Scenarios**
- **Institutions and Implementation**

It is presently impossible to predict which technology R&D investments will be successful and when.

A diversified portfolio provides a hedge against:

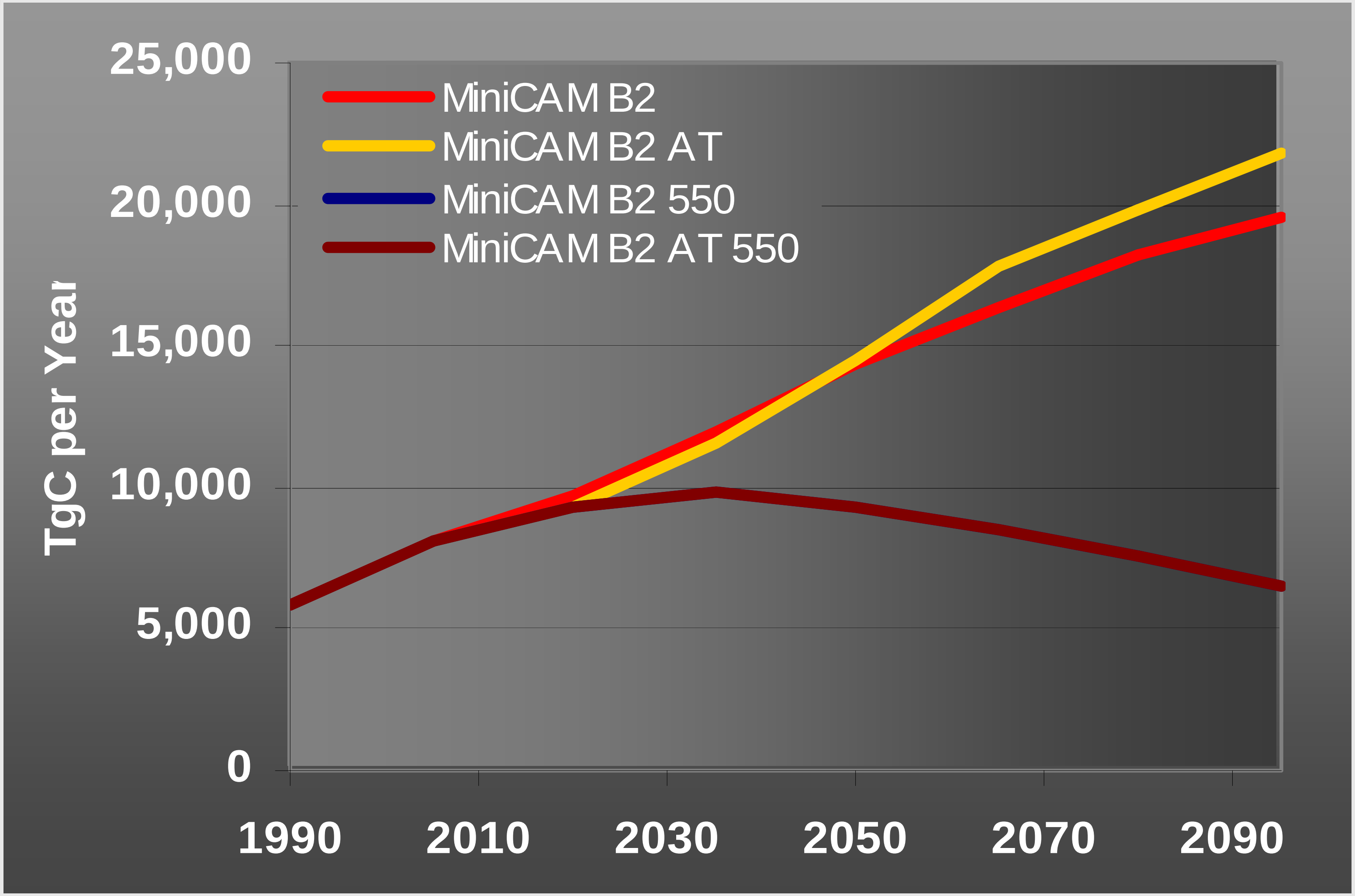
- Uncertainty in timing and degree of success for individual technologies.
- Changing patterns of technology needs over time.
- Variety of regional technology needs—one size will not fit all.

The World Has Exhibited Increasing Diversification in Energy Sources



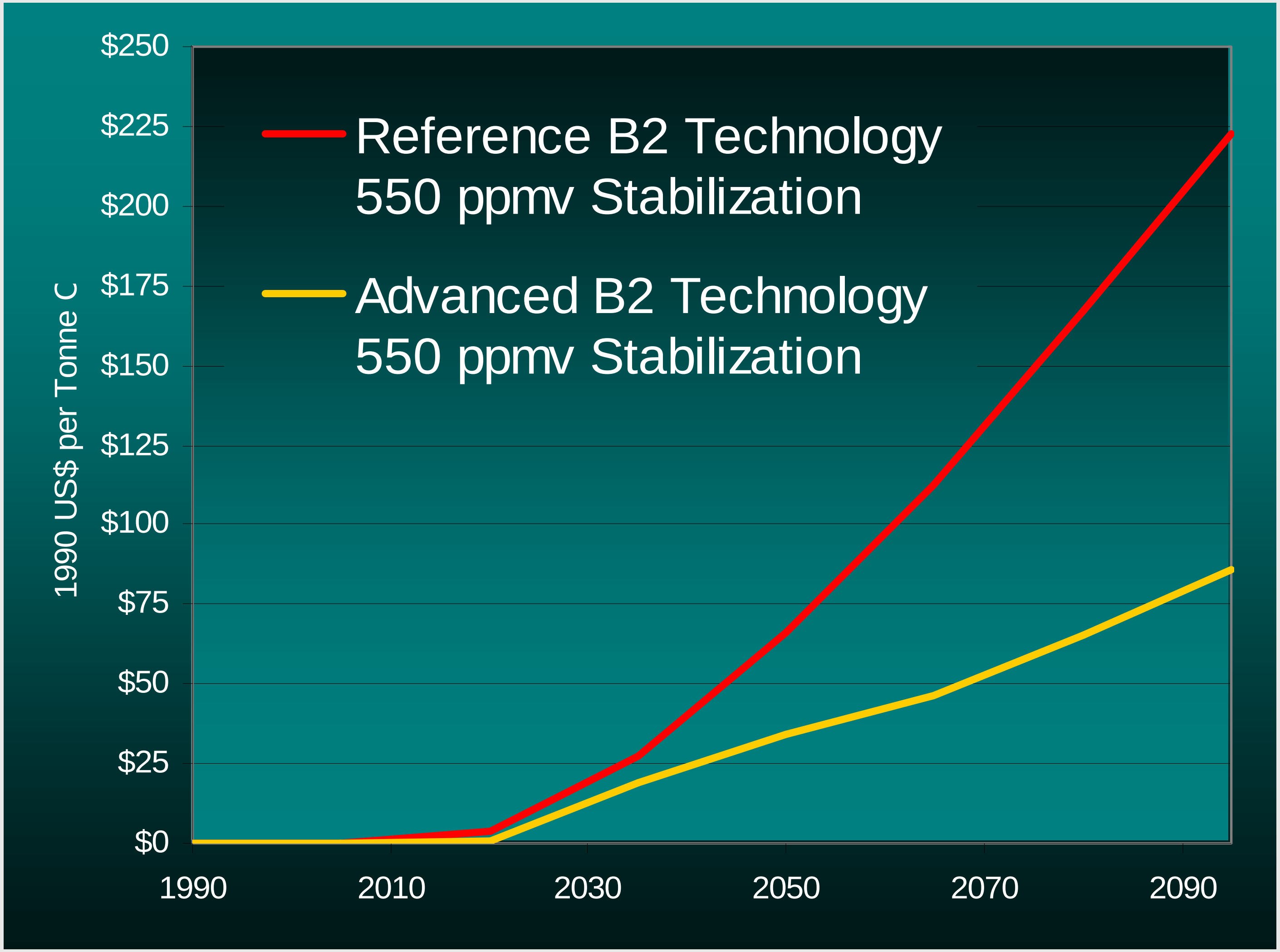
Source: IIASA

Energy Related Emissions



550 ppmv Stabilization—Carbon Tax

- Carbon Tax
- Uniformly & Efficiently Applied Over Time and Space



Final Energy Use—Energy Carriers (EJ/yr)

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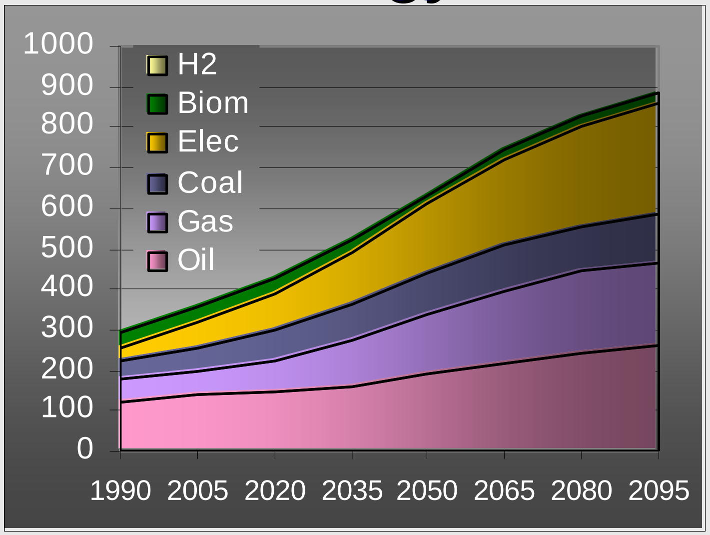

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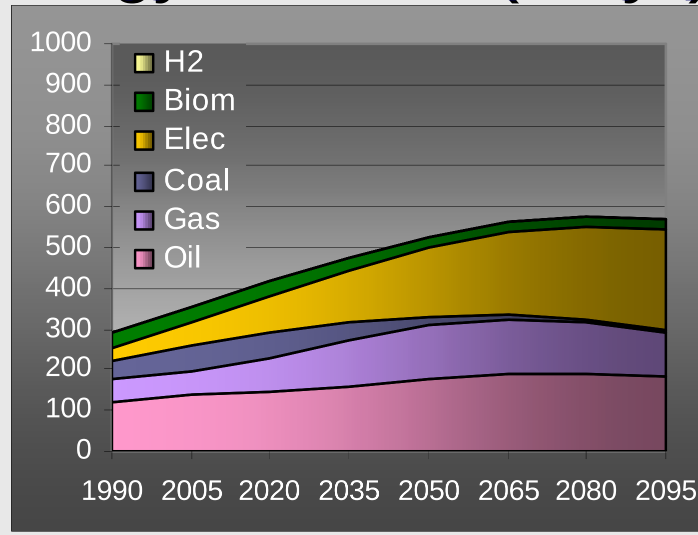

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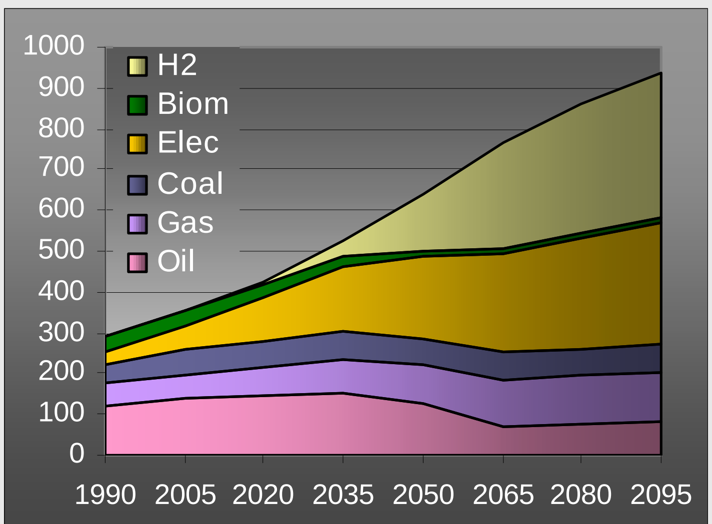

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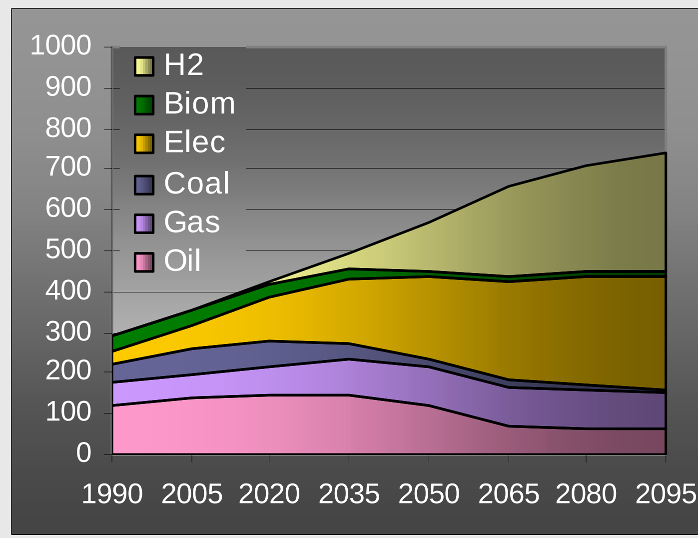

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Energy Response—Energy in Power Generation

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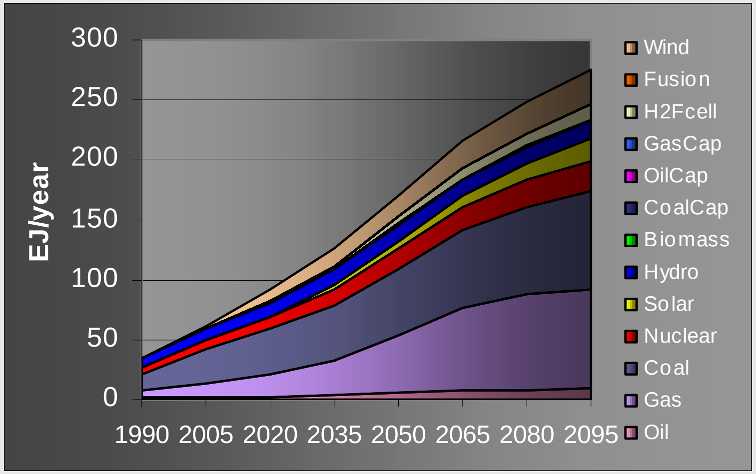

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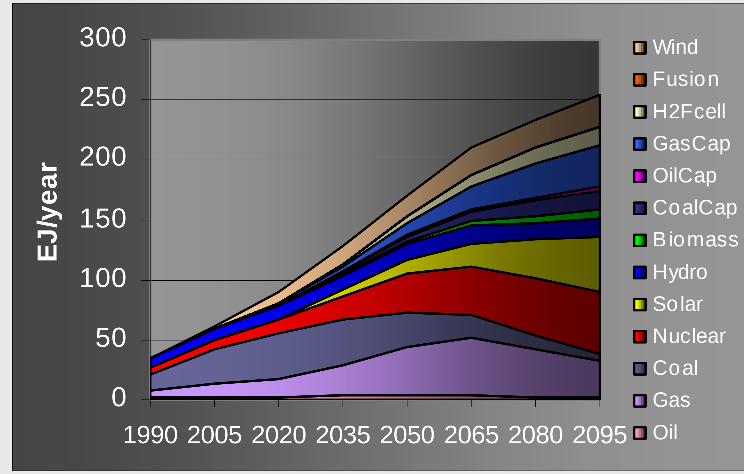

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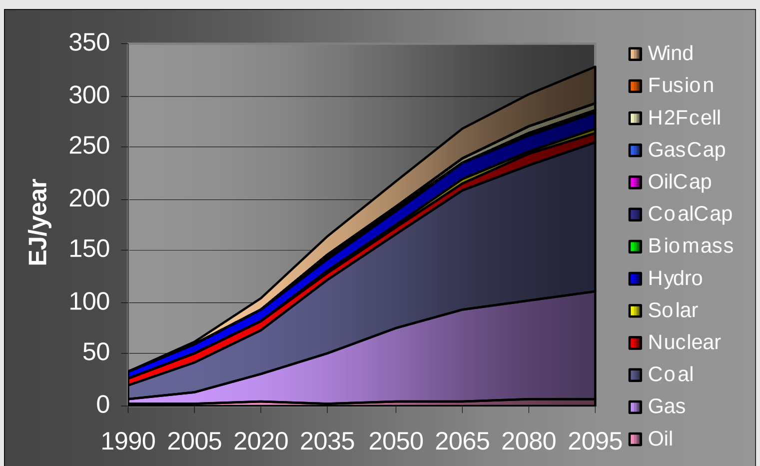

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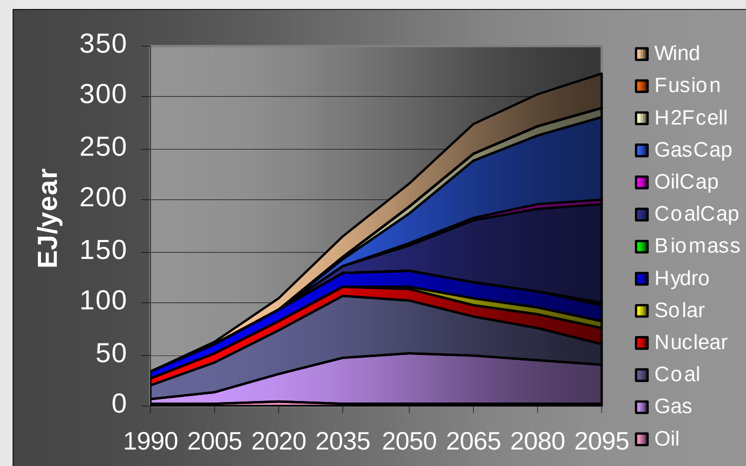

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Carbon Capture & Geologic Storage

Carbon Capture	Carbon Disposal	Carbon Sequestration
From the Energy System • ***Central plant such as power plant, refineries, etc.***	Geological Disposal • ***Depleted oil and gas fields;*** • ***Deep saline reservoirs;*** • ***Unminable coal seams.***	Terrestrial Storage • ***Soils;*** • ***Trees.***
In production of energy carriers • ***E.g. Hydrogen***	Ocean Disposal • ***Mid-depth dispersion;*** • ***Deep lake;*** • ***Hydrates.***	Ocean Carbon Capture and Sequestration • ***E.g. Fertilization***
Direct Recovery from the Atmosphere	Disposal As a Solid • ***Solid carbon;*** • ***As a mineral carbonate.***	

Carbon Capture—Annual

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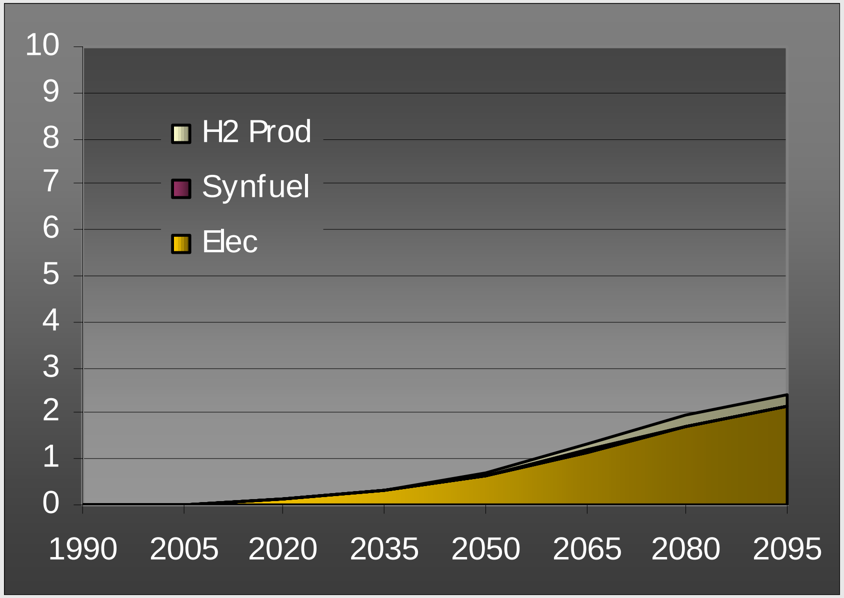

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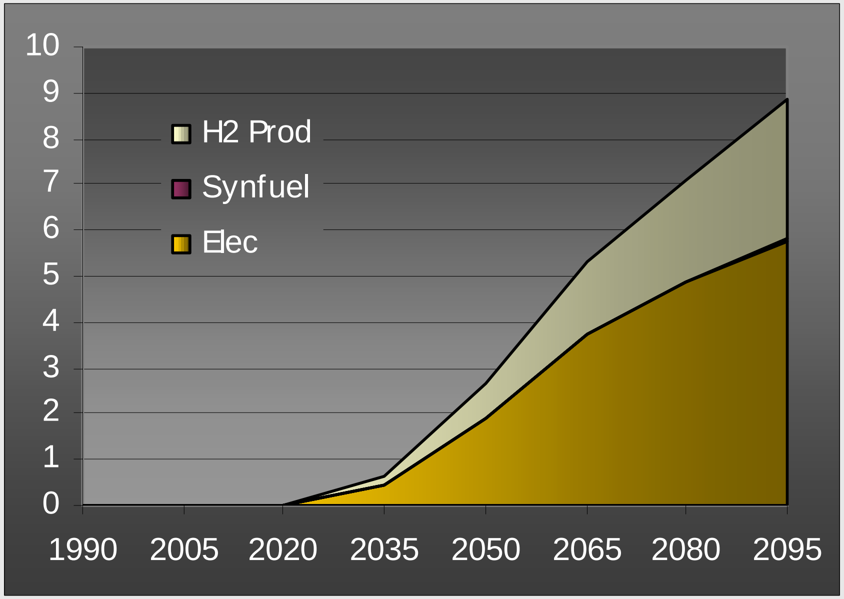

Carbon Storage Reservoir	Range (PgC)
Deep Saline Reservoirs	*87 to 2,727*
Depleted Gas Reservoirs	*136 to 300*
Depleted Oil Reservoirs	*41 to 191*
Unminable Coal	*>20*
Basalt Formations	*>1,000*
Deep Ocean	*1,400 to 27,000*

Source: Herzog et al. (1997), Freund and Ormerod (1997), PNNL (2001).

Carbon Capture—Cumulative

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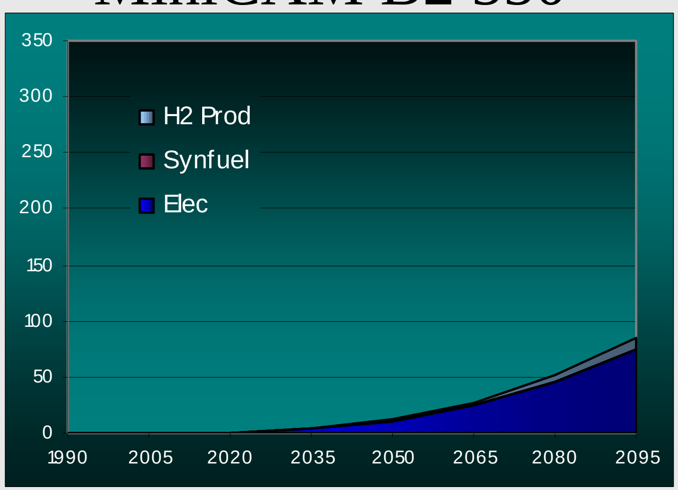

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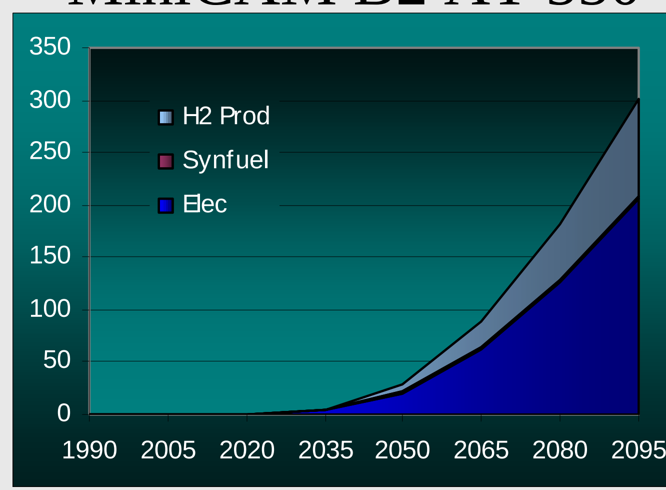
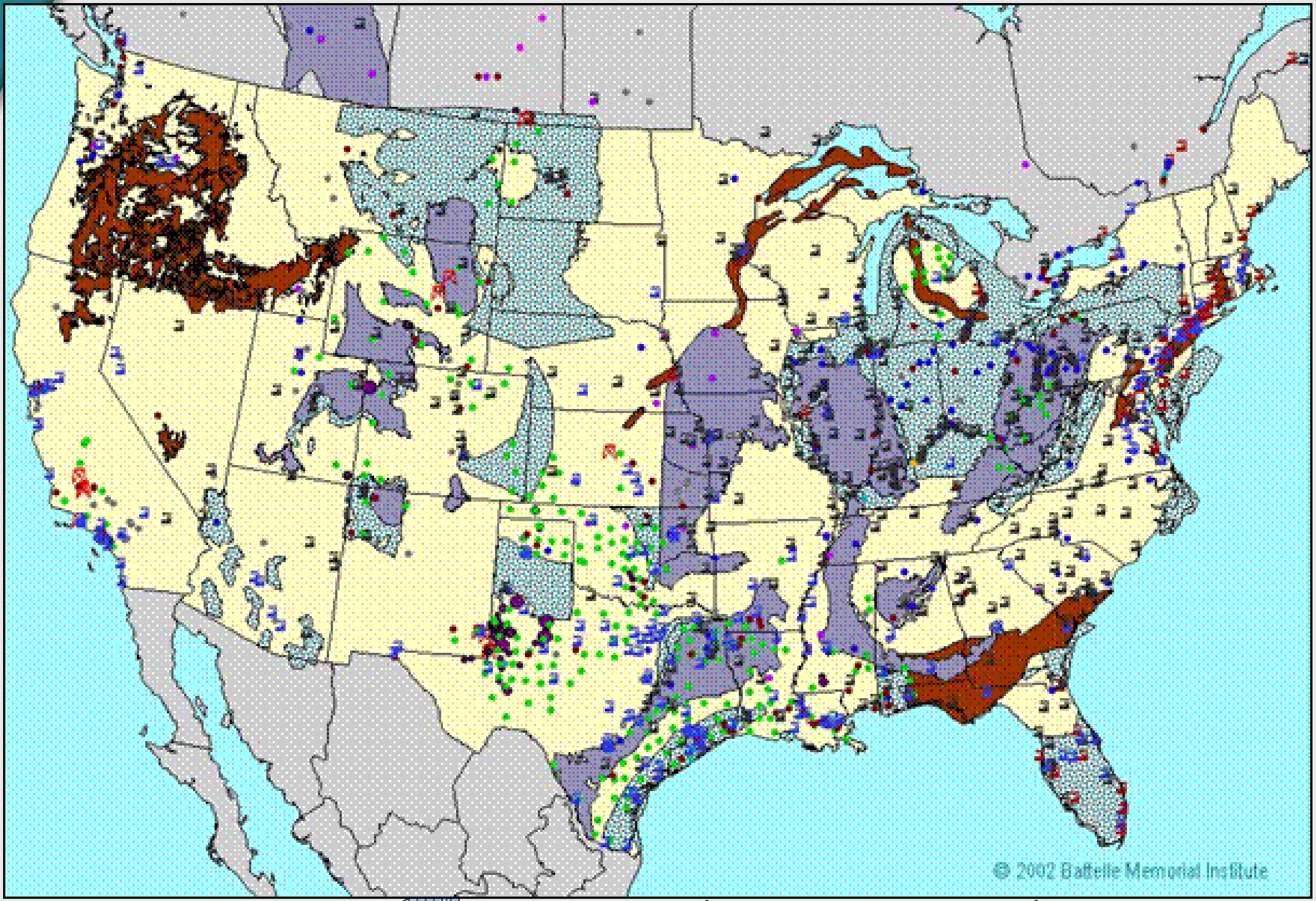


Carbon is captured and stored locally.



- 1337 Fossil Generating Units ≥ 100 MW at 589 Plants
- 453 GW Installed Capacity
- 2.27 billion tons annual CO_2 emissions
- 21 “high priority” deep saline formations
- 19 major coal basins
- 70 CO2-driven EOR projects

Carbon Disposal—Key Issues

- Retention is a high priority.
- Local Losses—A Million Tonnes of CO_2 matters if its in your house.
- Monitoring & Verification.

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The H_2 Economy?

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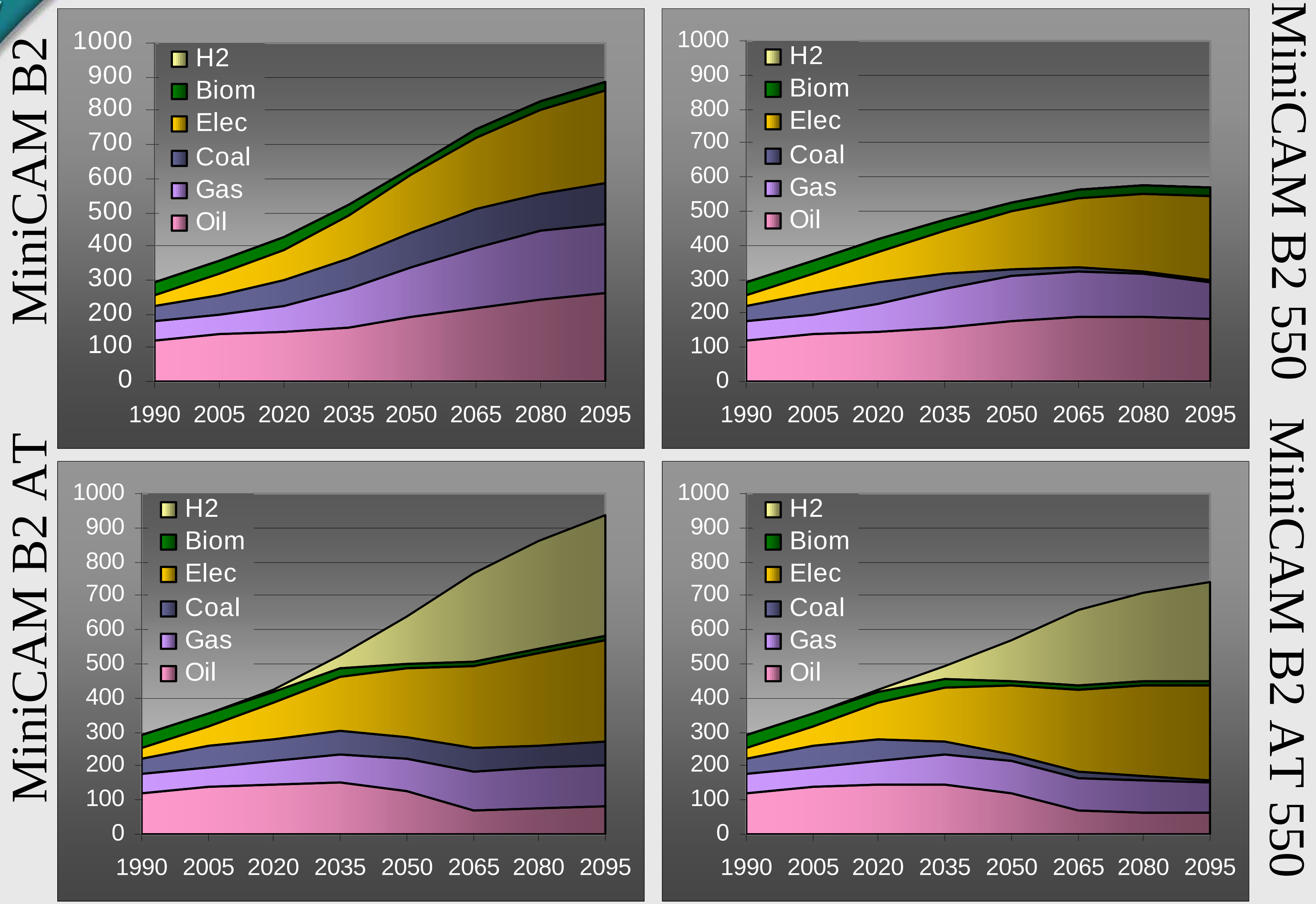
End-Use Energy (EJ/year)



Energy Related Emissions—Sources by Sector

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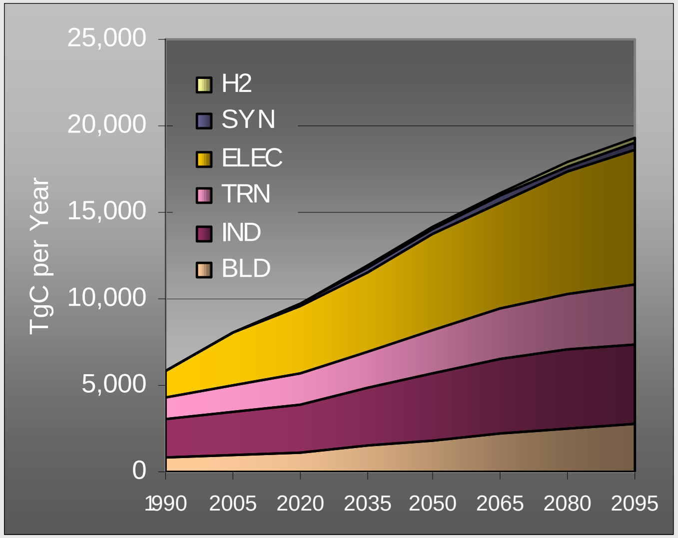

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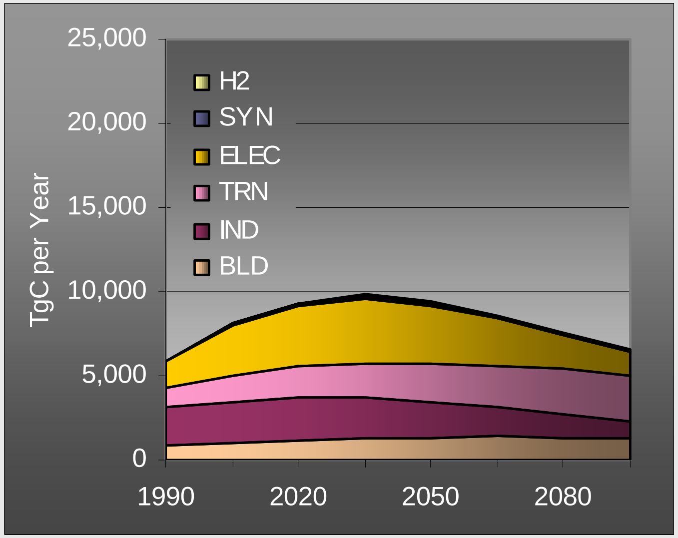

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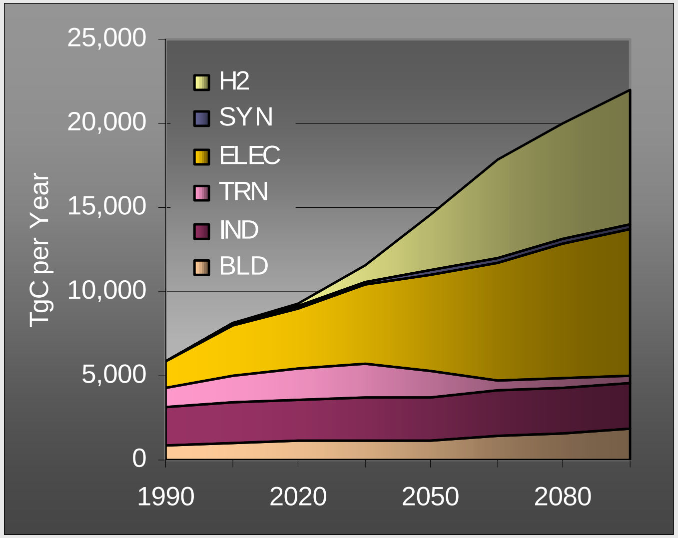

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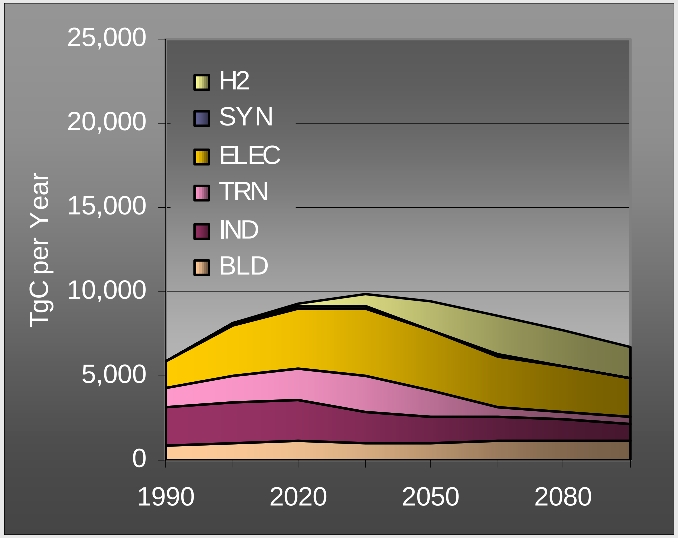

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H_2 Sources

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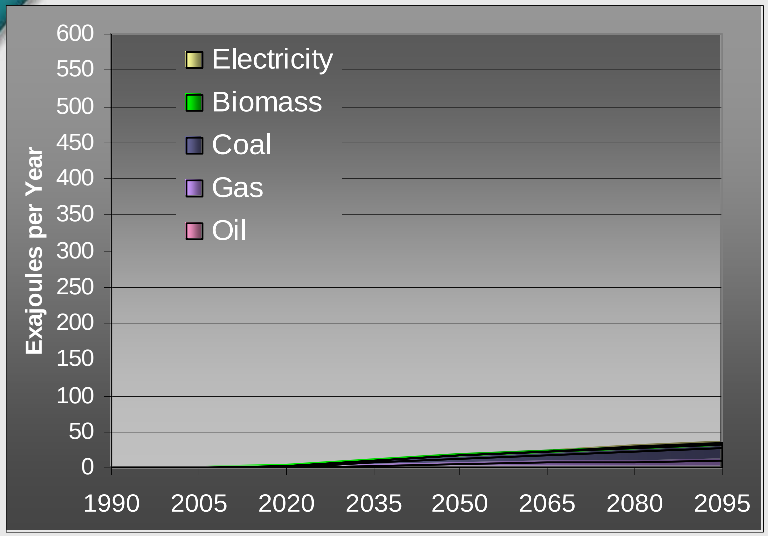

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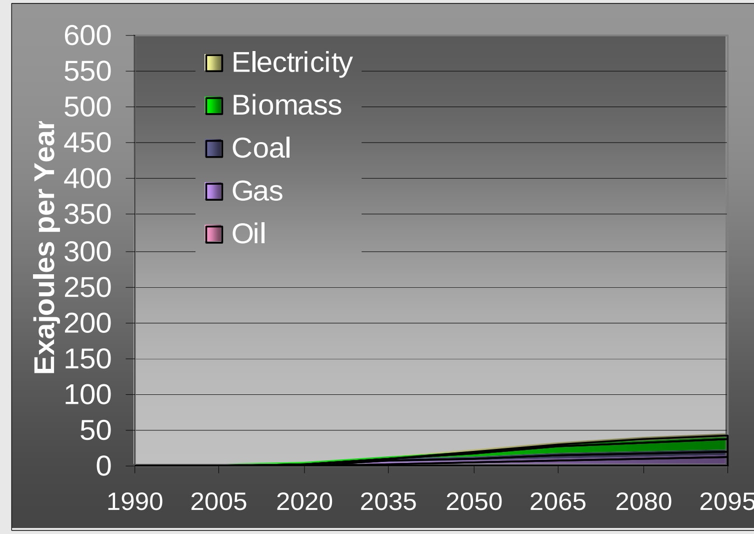

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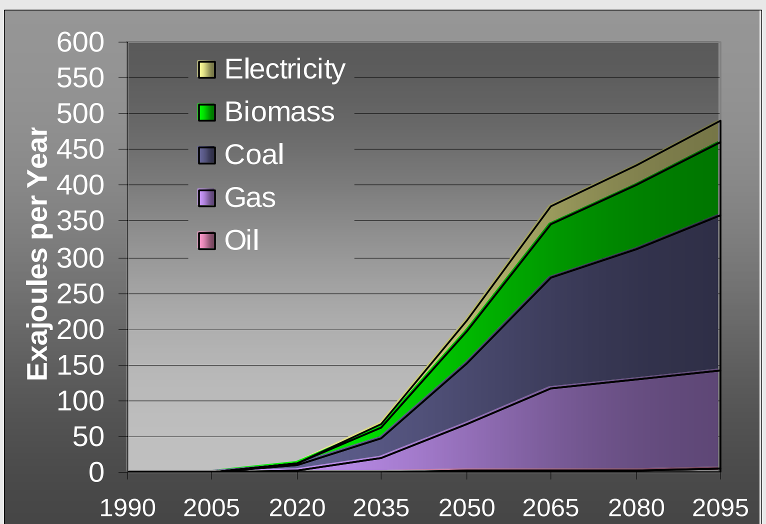

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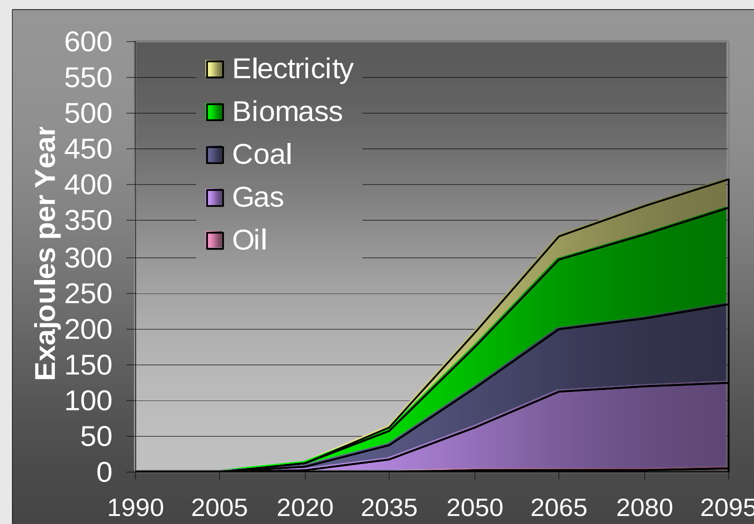

H_2 Use

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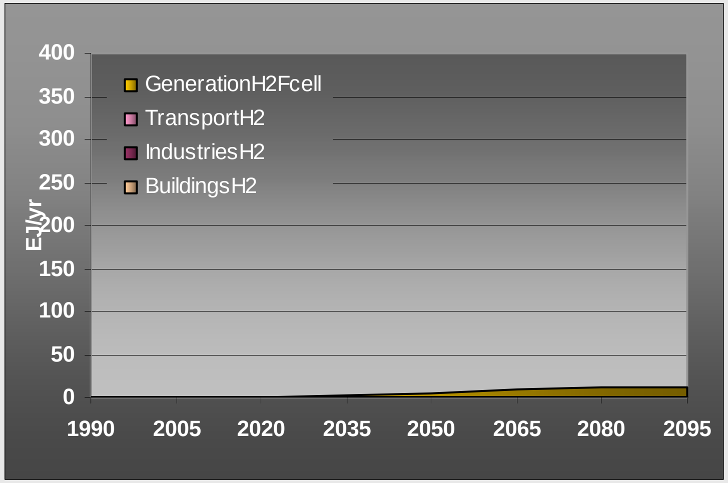

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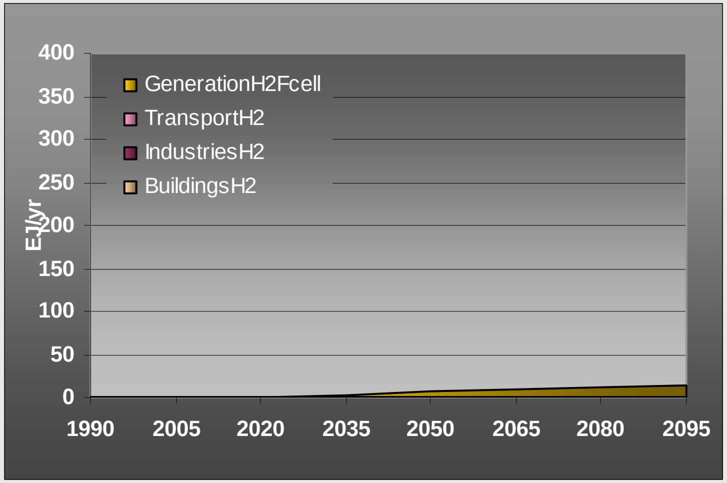

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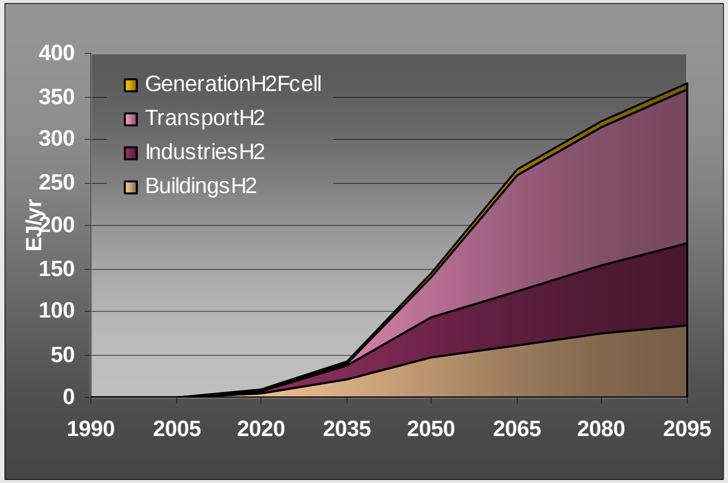

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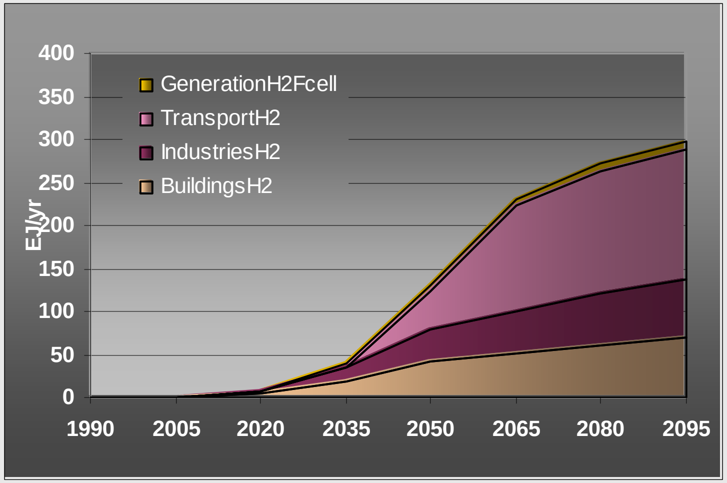

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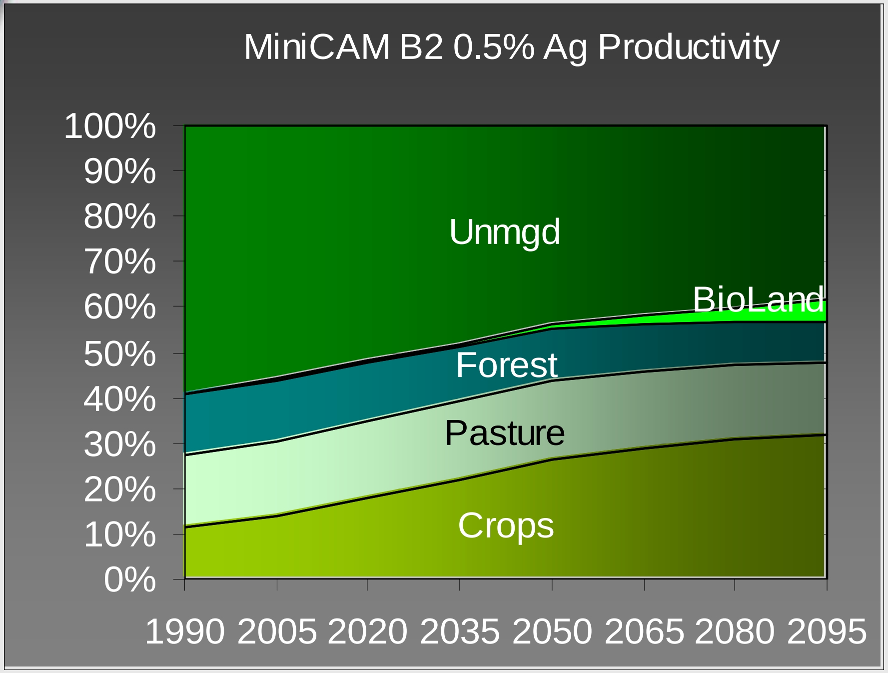
Biotech

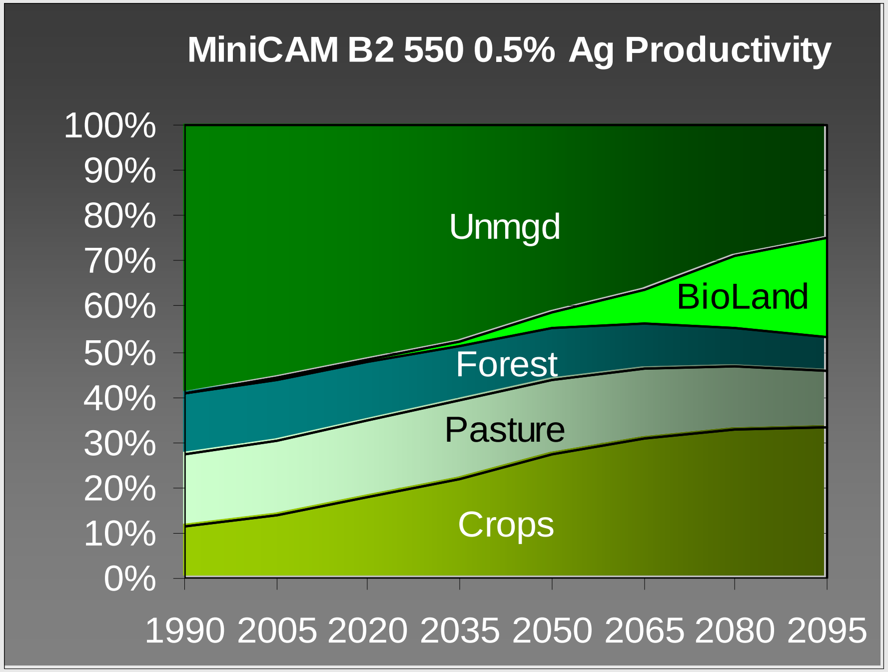
Biotechnology
A Portfolio Within a Portfolio

Biotechnology includes

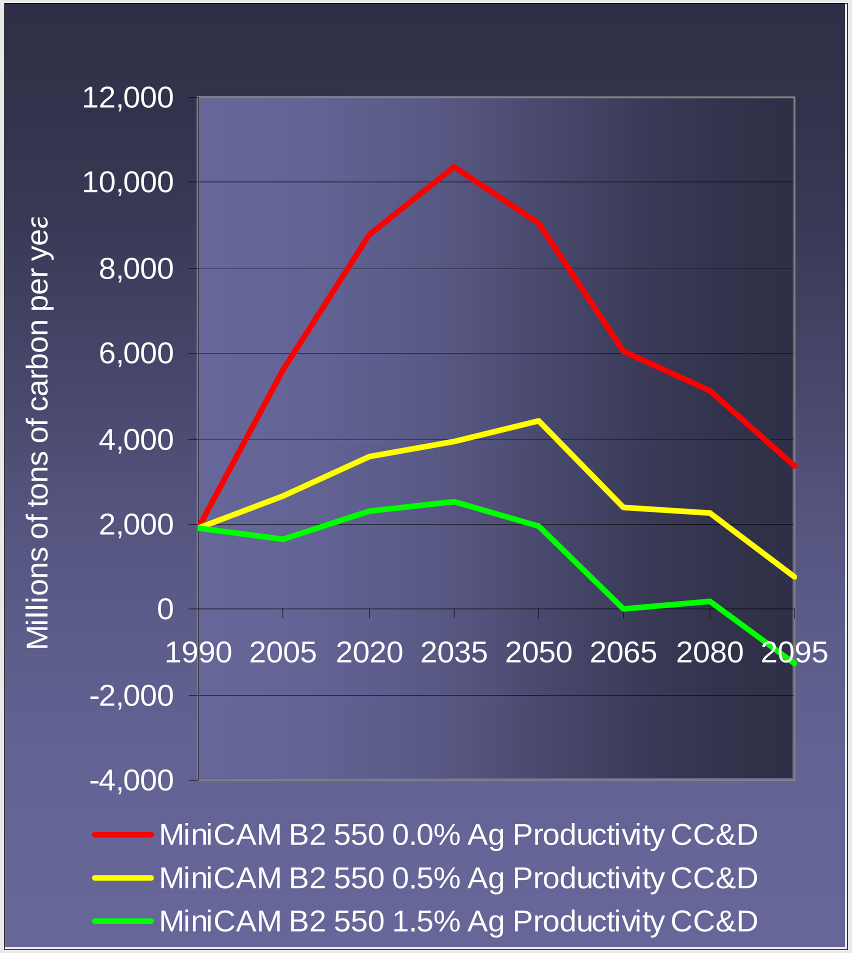
- Modern commercial biomass;
- Soil carbon;
- Afforestation, reforestation, and forest maintenance;
- Advanced concepts, e.g. single-function designer microbial communities for
  - Hydrogen production,
  - Energy end use applications
  - Carbon storage and
  - Energy transformation applications.

Biomass Could Be the Largest Land Use in the World





Implications of Agricultural Productivity for Land-Use Emissions



Avg. Annual Productivity Growth Rate	Cumulative Emissions 1990-2095 (PgC)
0%	715
0.5%	309
1.5%	134
WRE 550 1990 to 2100	1,043

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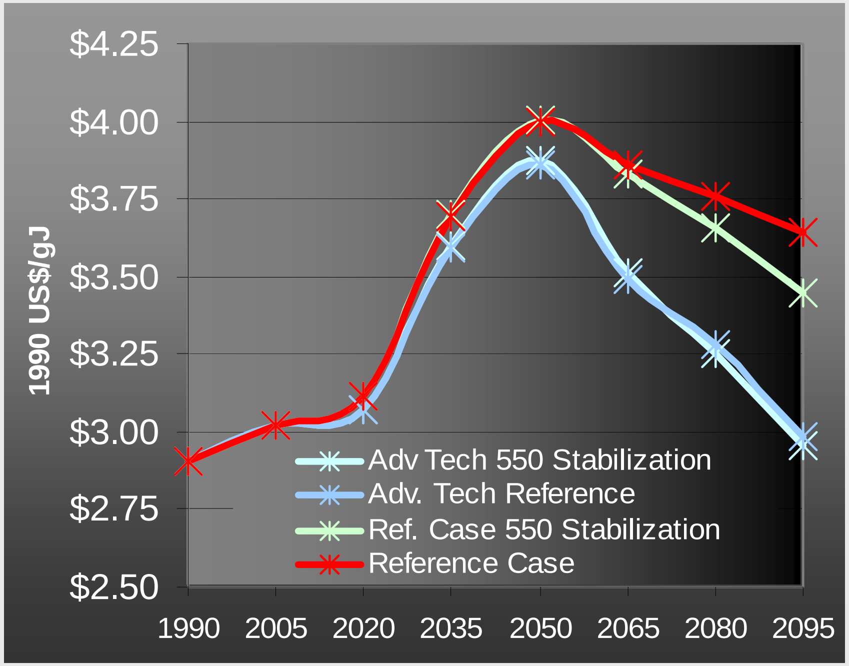
Advanced Technology and Markets

Oil Market Interactions

Price



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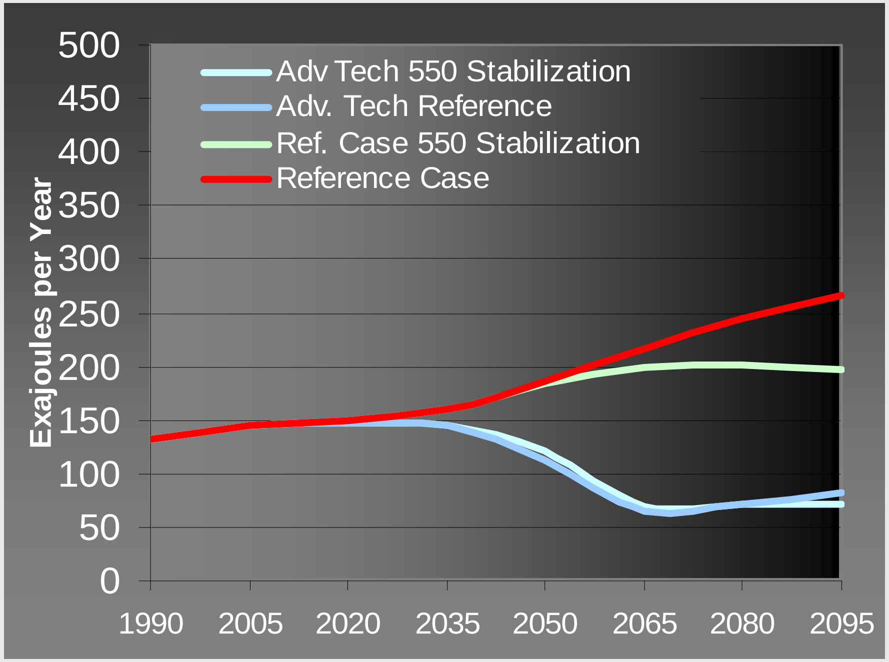

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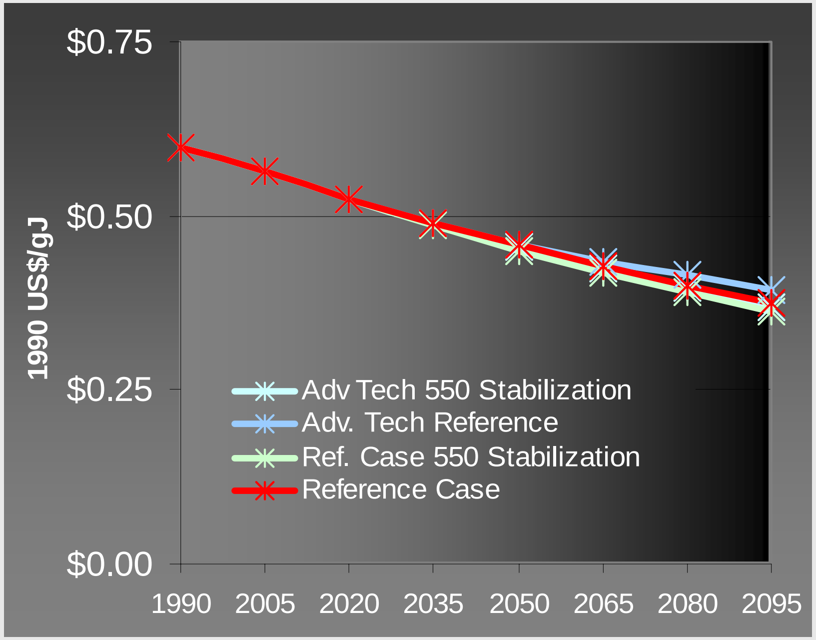
Coal Market Interactions

Price



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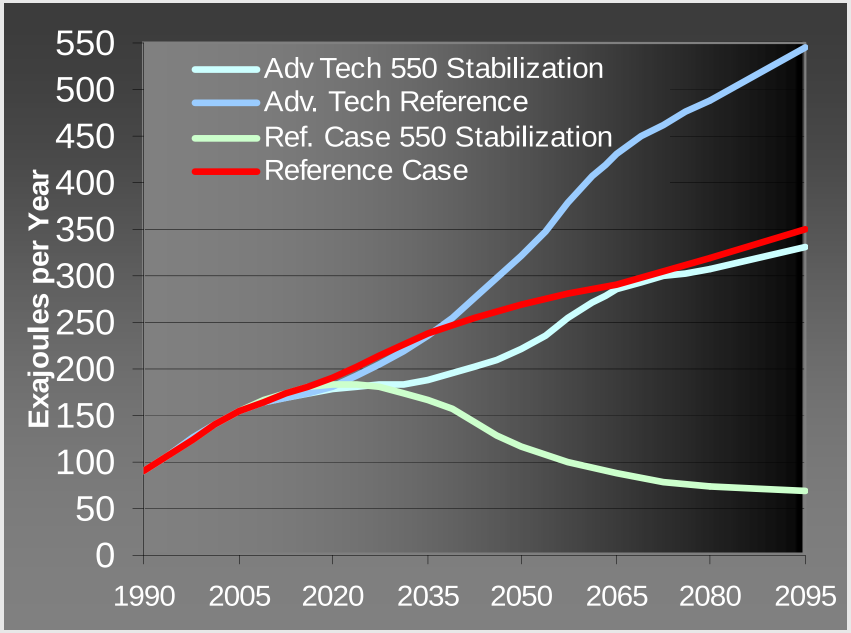
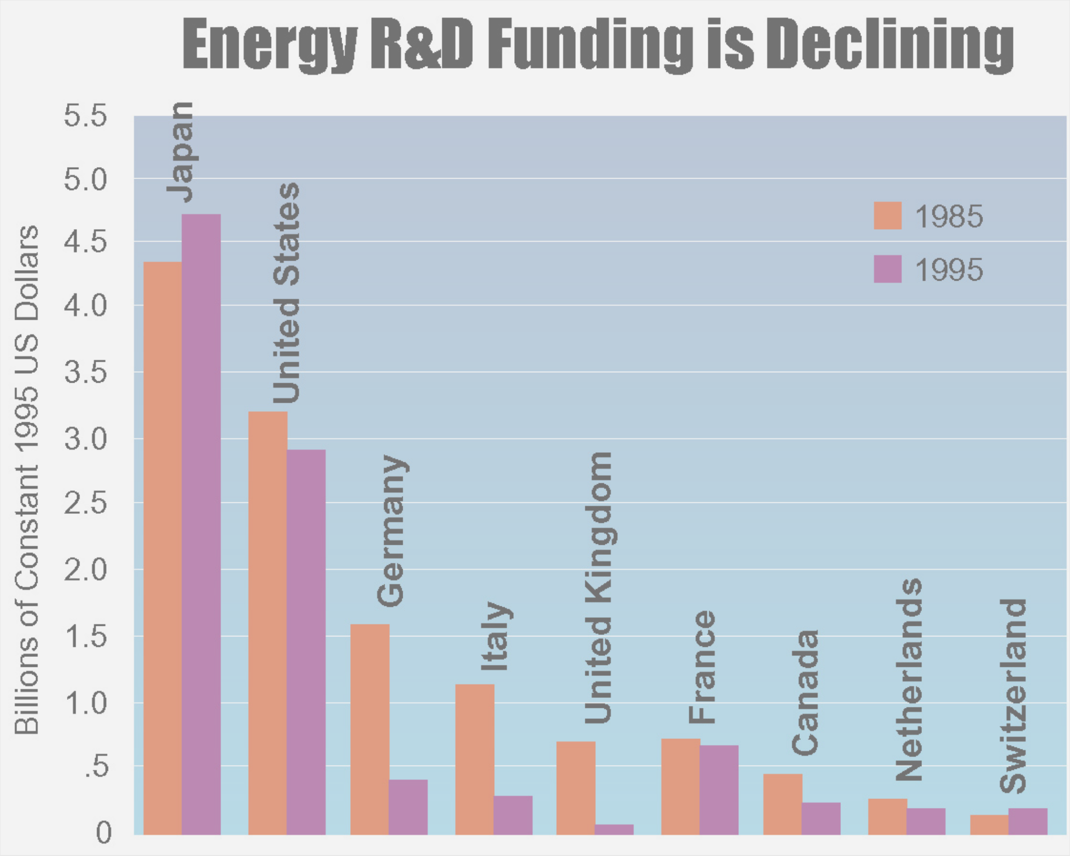


R&D

Energy R&D Investments Are Declining …



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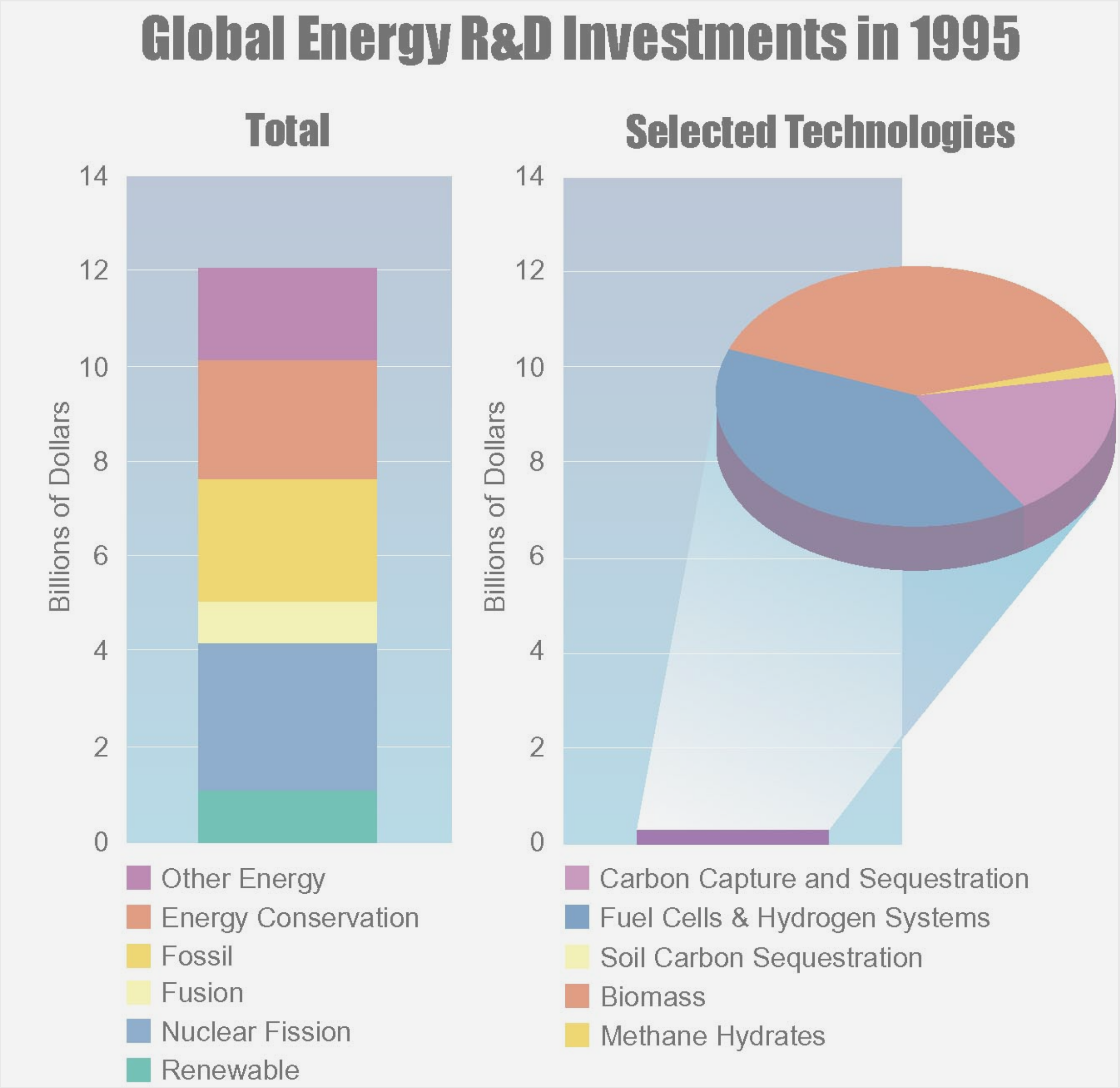
Energy R&D Investments Are Not Focused on Advanced Energy Technologies



Some Major Points

- Climate change is a long-term issue—century to millennium scale—and requires a commensurate strategy. Technology has that character.
- Technology alone will not necessarily stabilize the concentration of CO_2.
- Several potential additions to the technology portfolio could dramatically reduce the cost of stabilizing CO_2 concentrations—H_2, CC&S, biotech.
- The scale of carbon capture & storage could be HUGE.
- Deployment of advanced technologies could have significant long-term effects on energy markets.
- Energy R&D is declining and not focused on climate.

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The GTSP Web Site
www.pnl.gov/gtsp


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Since it's inception in 1998, the Global Energy Technology Strategy Program (GTSP) has been assessing the important roles that technology can play in effectively managing the long-term risks of climate change. This involves an integrated approach to fully exploring all aspects of climate change - including scientific, economic, regulatory, and social impacts - and then aligning new or existing technologies to mitigate negative consequences.

The GTSP is comprised from a core group of scientists from Battelle and the Department of Energy's Pacific Northwest National Laboratory (PNNL), as well as the Joint Climate Change Research Institute, which is a partnership between PNNL and the University of Maryland. Research is conducted in collaboration with scientists from institutions around the world. An international steering group, representing diverse perspectives and interests from government agencies, research institutions, and private industry, guides the GTSP research agenda. GTSP sponsors serve a key role in supporting research that will provide options and solutions to climate change impacts.

About the GTSP
- What is the GTSP?
- History of the GTSP
- Where we came from
- Joining the GTSP
- Contact Us

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