



Two-Degrees of Climate Change

a presentation to

Avoiding Dangerous Climate Change

A Scientific Symposium on Stabilisation of Greenhouse Gases

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02 February 2005

Met Office

Exeter, United Kingdom

Battelle



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Acknowledgements

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Colleagues

Tom Wigley, Steve Smith

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Key Question for Today

What are the energy technology implications of stabilizing climate change at 2°C relative to preindustrial—not just CO₂ concentrations

This limit does NOT reflect a determination as to a change that avoids dangerous anthropogenic interference with the climate system.

- Interactions with uncertainty in technology developments.
- Interactions with uncertainty in biogeochemical parameterization;

The MiniCAM

Integrated Assessment Model

- ▶ *Anthropogenic emissions*
 - *Energy-agriculture-economy market equilibrium*
 - *15 gaseous emissions—linked to associated human activities*
 - *14 global regions*
 - *2095 time horizon*
 - *Demographics module*
 - *Land resource constraints*
 - *Energy technology detail*
- ▶ *Natural system model (MAGICC)*
 - *Carbon cycle,*
 - *Air chemistry &*
 - *Climate*

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MiniCAM B2

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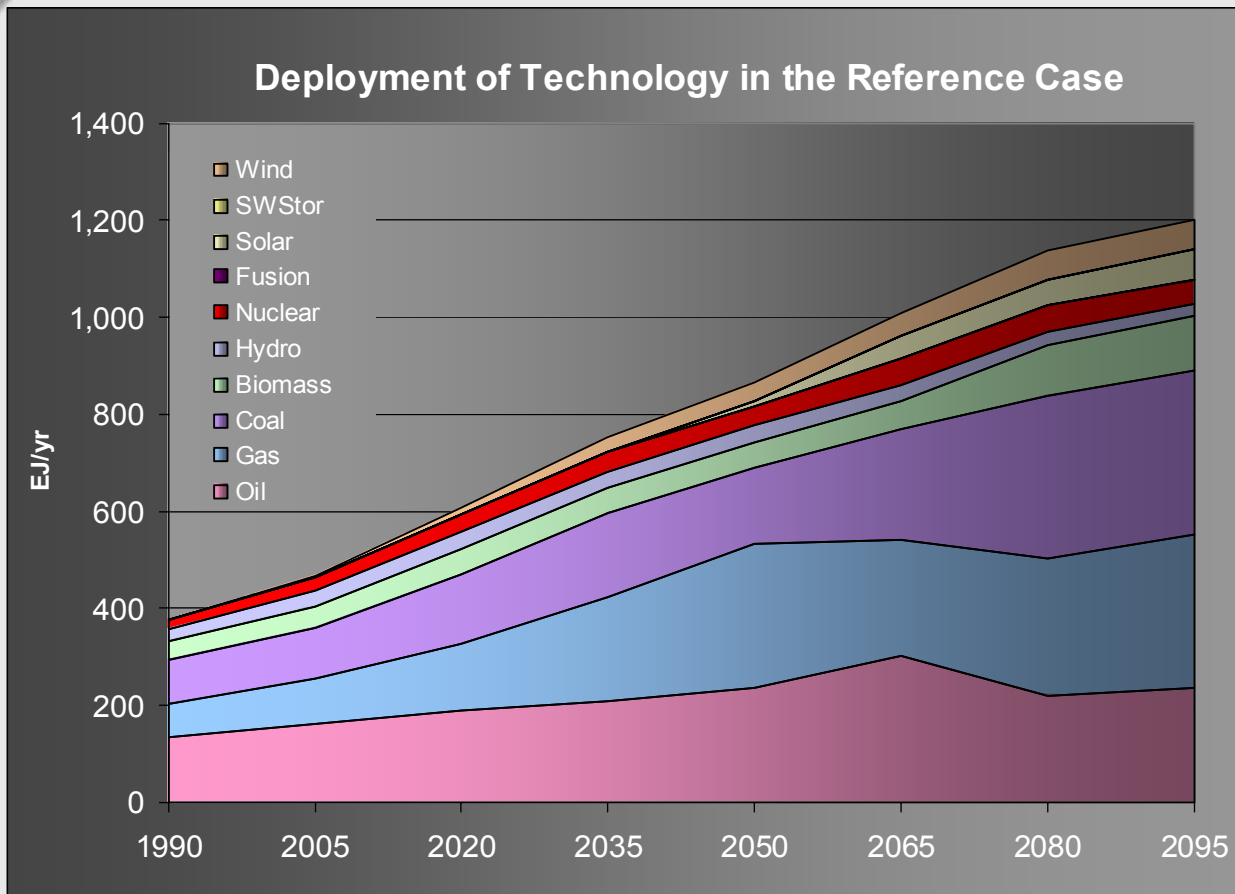
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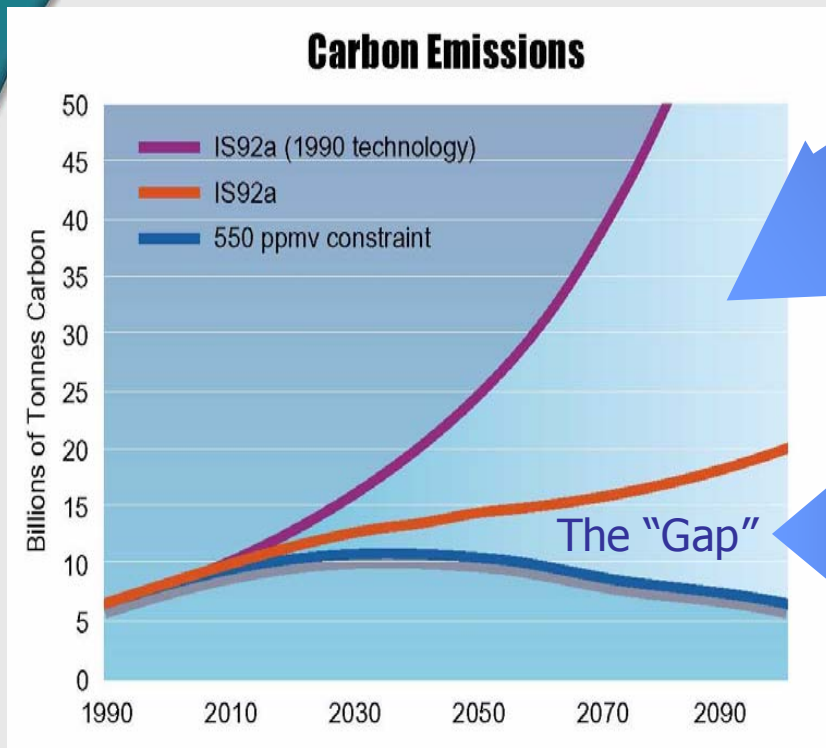
The Reference Primary Energy System SRES MiniCAM B-2



The Reference Case Technology

Assumed Advances In

- Fossil Fuels
- Energy intensity
 - Nuclear
- Renewables



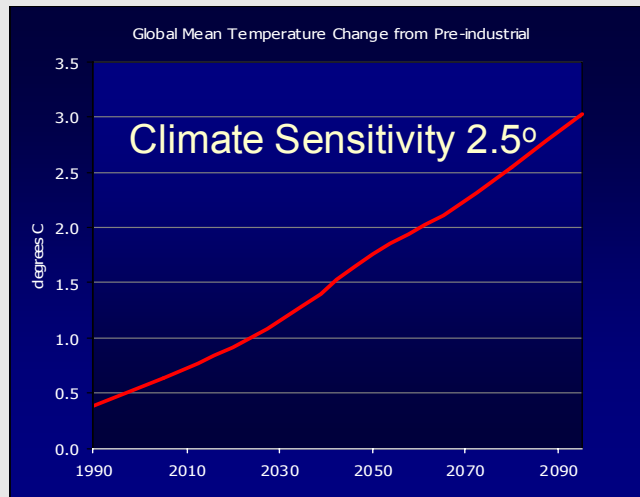
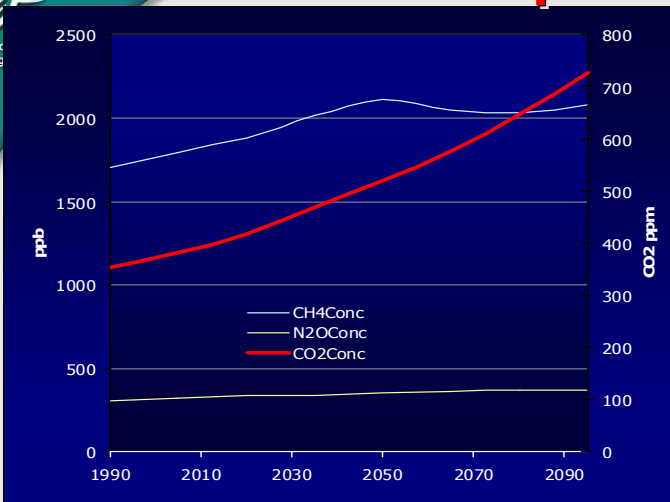
Gap technologies

- Improved performance of ref tech.
- Carbon capture & disposal
 - Adv. fossil
- H2 and Adv. Transportation
- Biotechnologies
 - Soils, Bioenergy, adv. Biological energy



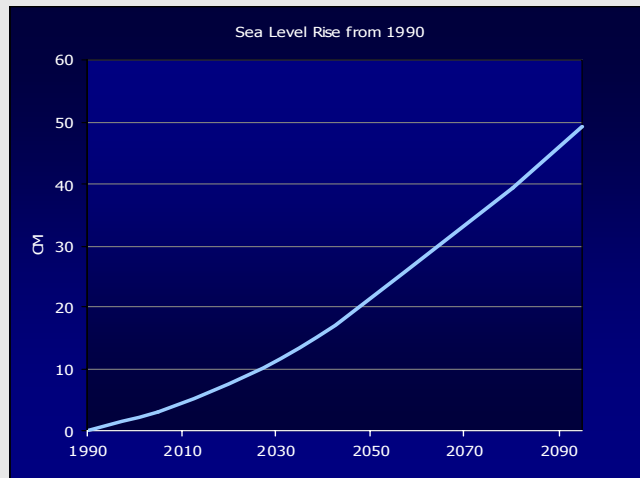
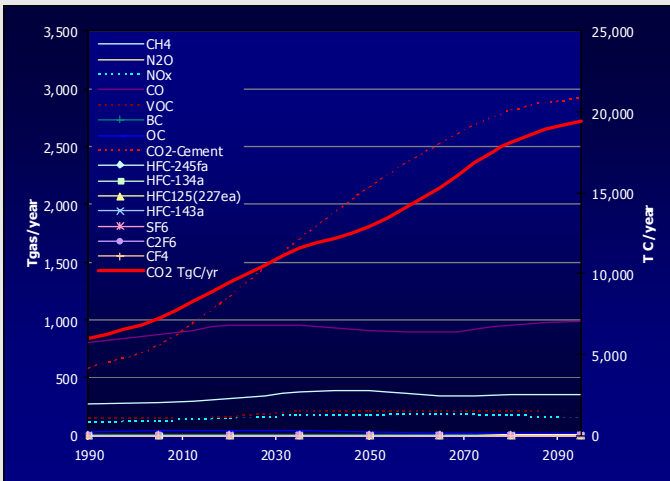
Greenhouse Gas Emissions, Concentrations, Temperature Rise & Sea Level Rise

Concentrations



Global Mean
Temperature Change

Emissions



Sea Level Rise

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Climate Stabilization

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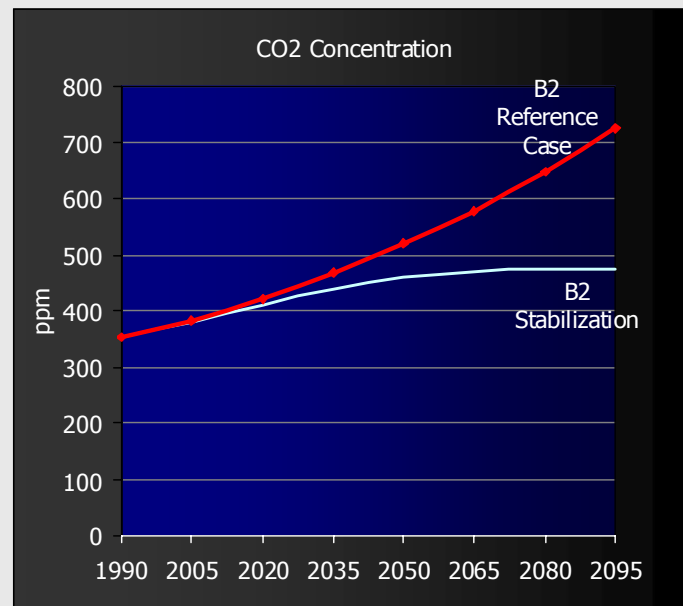
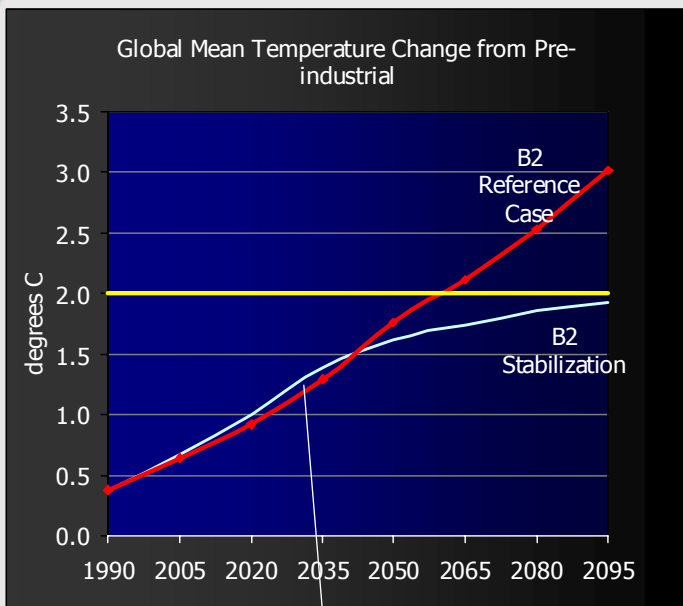
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Approach

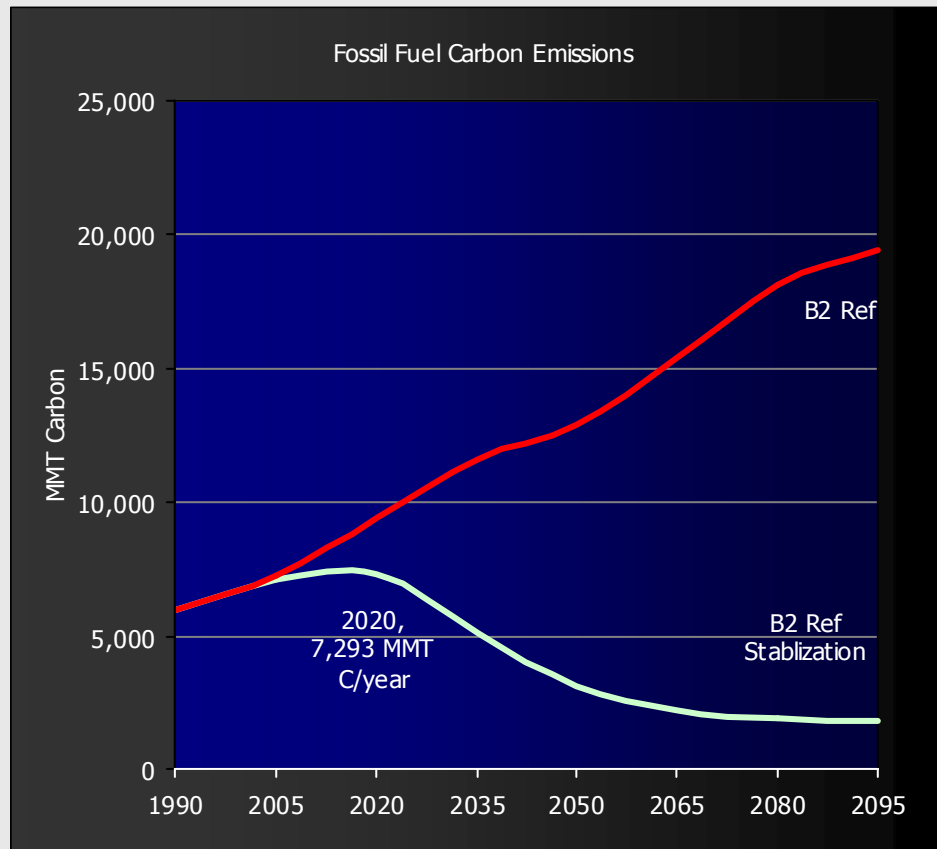
Minimize the cost of stabilizing
climate change

Reference B2 and Stabilization with Reference Technology and Physical Parameters

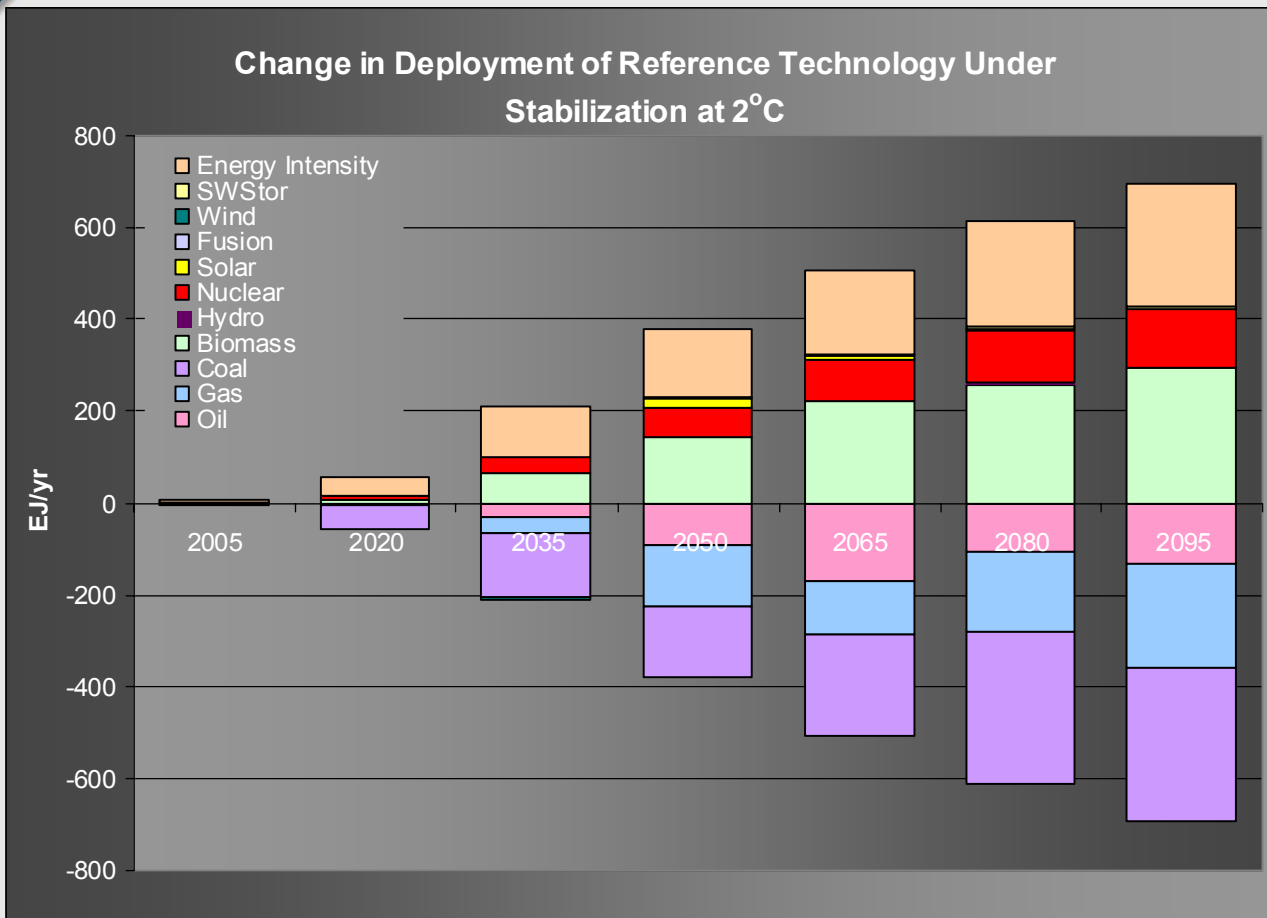


The aerosol effect

CO₂ Emissions

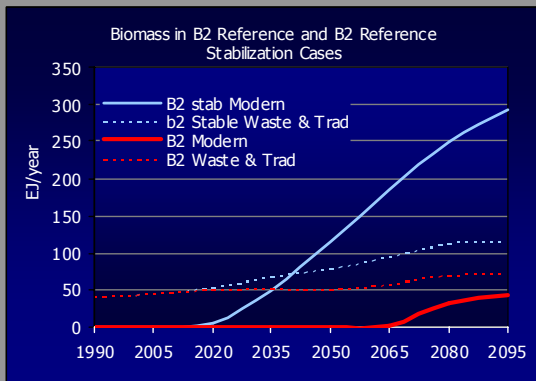


Energy and Stabilization

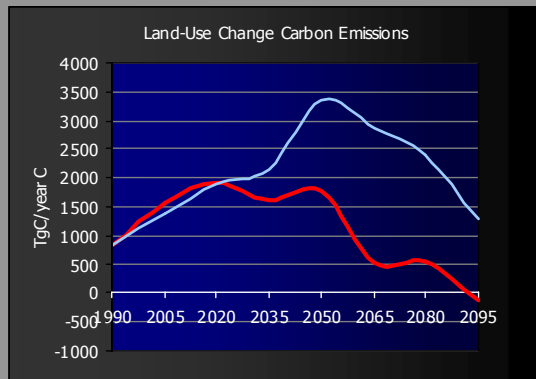


Biomass and Land-Use Change Emission

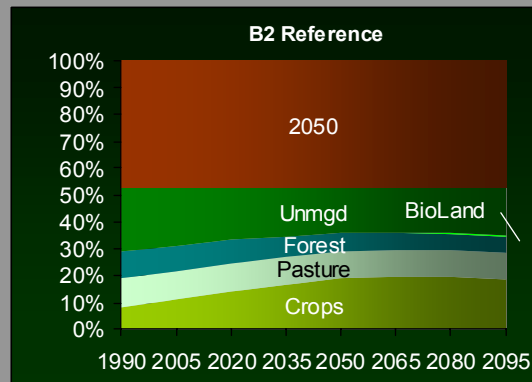
Energy



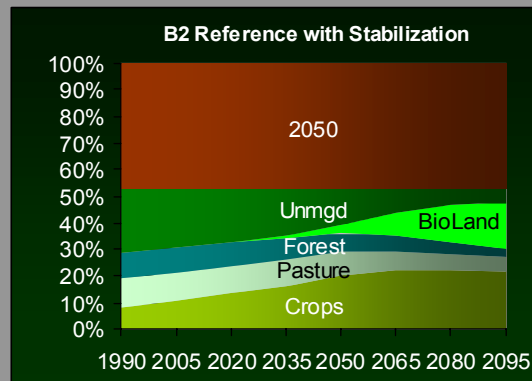
Land-use Emissions



B2 Reference



B2 Reference with
Climate
Stabilization



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Physical Parameter Uncertainty & Climate Stabilization

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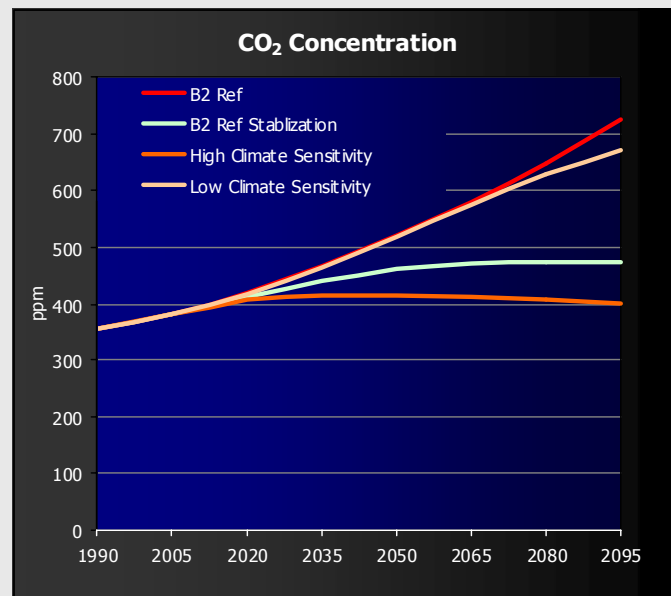
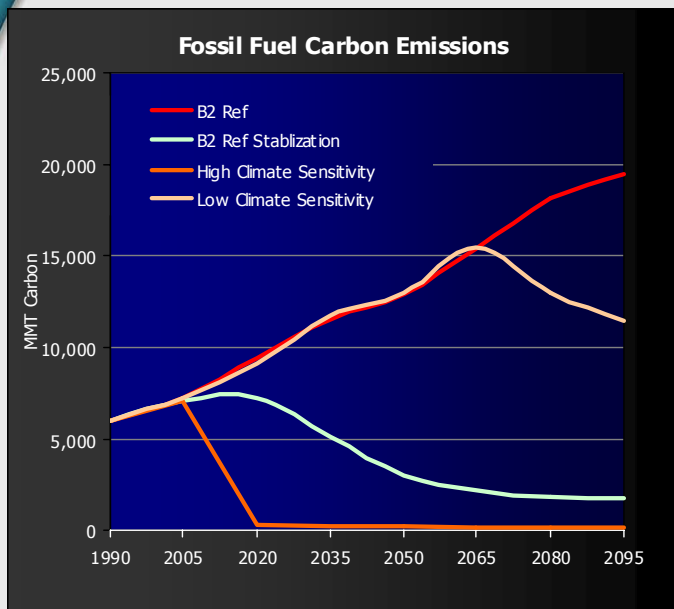
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Carbon and GMST Change Stabilization at $\Delta T < 2^\circ\text{C}$



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Technology Availability & Climate Stabilization

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Technology Performance

**Reference
technological change
case**

**Accelerated
improvements**

- ▶ Wind & solar
- ▶ Biotechnology
- ▶ CO₂ capture & storage
- ▶ Energy efficiency
- ▶ Hydrogen systems

	Units	1990	Ref 2095	Adv 2095
PRIMARY ENERGY SUPPLY				
Oil	1990 US\$/gJ	\$1.13	\$7.55	\$3.27
Gas	1990 US\$/gJ	\$1.40	\$5.03	\$3.40
Coal	1990 US\$/gJ	\$0.76	\$1.42	\$1.08
Biomass	1990 US\$/gJ	\$1.63	\$1.95	\$1.89

ELECTRIC POWER GENERATION		(fuel + non-fuel cost)		
Nuclear	1990 US cents/kWh	5.8	5.8	5.8
Solar	1990 US cents/kWh	61.0	6.0	4.0
Wind	1990 US cents/kWh	8.0	4.0	4.0
Gas	1990 US cents/kWh	3.5	4.4	4.4
Coal	1990 US cents/kWh	3.8	3.8	3.8

CARBON CAPTURE & STORAGE				
Power penalty, coal	% derating	25	not available	15
Capital cost, coal	% of non-capture K	88	not available	63
Power penalty, gas	% derating	13	not available	10
Capital cost, gas	% of non-capture K	89	not available	72
Storage	1990 US\$/tC	37	not available	37
Capture efficiency	%	90	not available	90

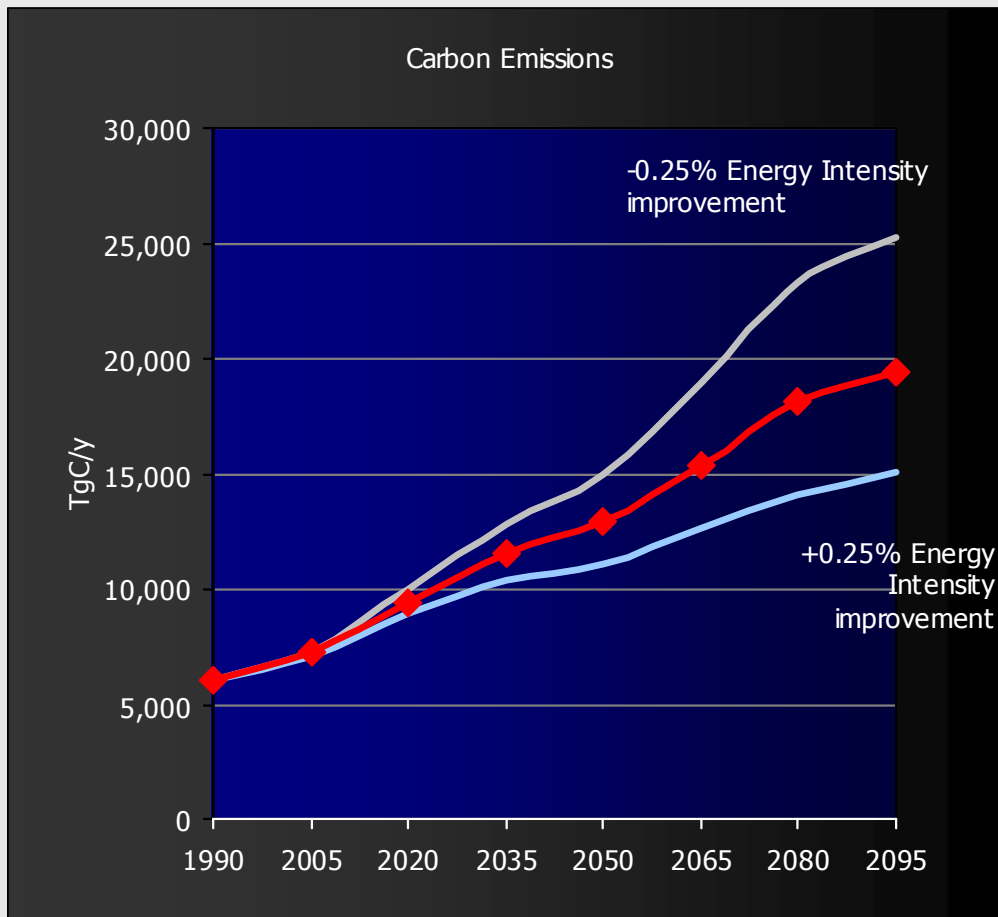
TRANSPORTATION				
US Automobile Performance	mpg	18	60	100
Fuel Cell	mpg (equivalent)	43	NA	100

AGRICULTURE & BIOMASS				
Crop & Biomass Productivity	Annual Ave		0.70%	1.10%

HYDROGEN PRODUCTION		2005	Ref 2095	Adv 2095
Gas to H2	% efficient	70%	NA	80%
Gas with C Capture, to H2	% efficient	58%	NA	71%
Coal to H2	% efficient	62%	NA	66%
Coal with C Capture, to H2	% efficient	52%	NA	58%
Electrolysis	% efficient	87%	NA	94%
Biomass	% efficient	60%	NA	80%
Gas Non-fuel Costs	1990 US\$/gJ	\$2.43	NA	\$1.55
Gas with C Capture, Non-fuel Costs	1990 US\$/gJ	\$3.16	NA	\$1.86
Coal Non-fuel Costs	1990 US\$/gJ	\$6.86	NA	\$6.86
Coal with C Capture, Non-fuel Costs	1990 US\$/gJ	\$8.91	NA	\$5.22
Electrolysis Non-fuel Costs	1990 US\$/gJ	\$5.58	NA	\$3.56
Biomass Non-fuel Costs	1990 US\$/gJ	\$5.53	NA	\$3.53

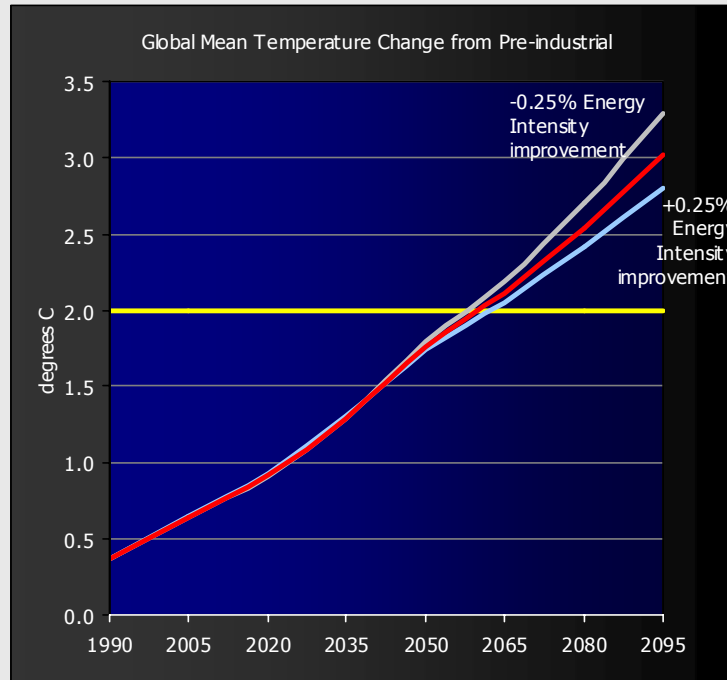
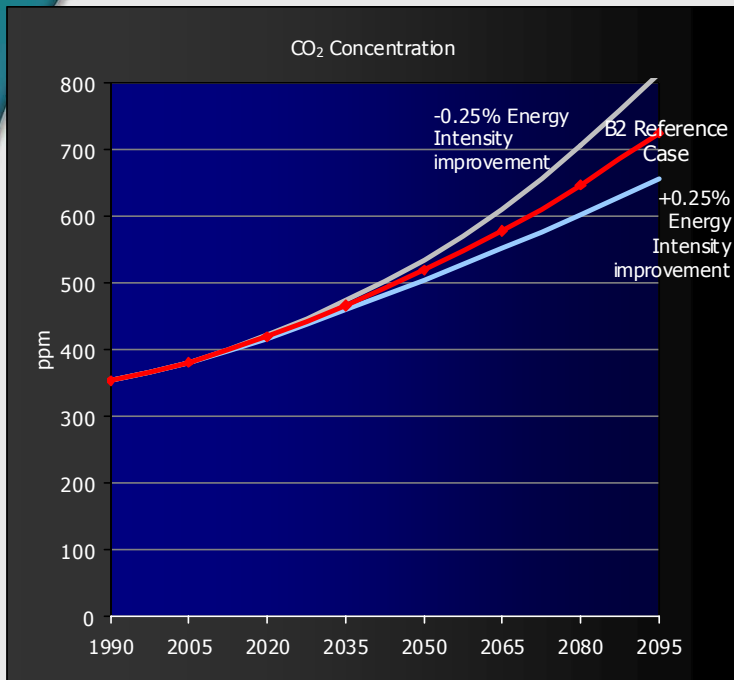


Energy Intensity

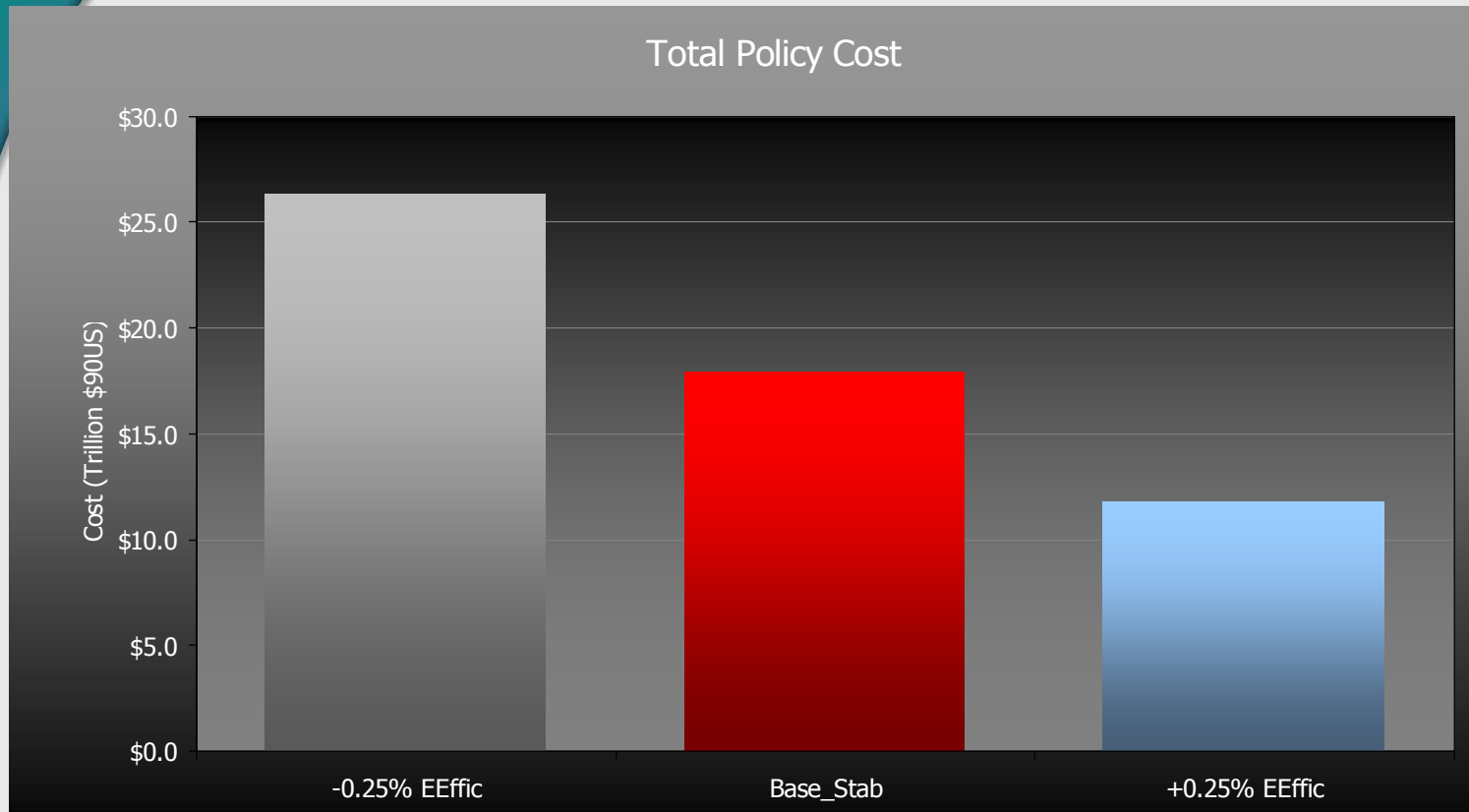


Energy Intensity

Technology Alone Doesn't Stabilize Climate

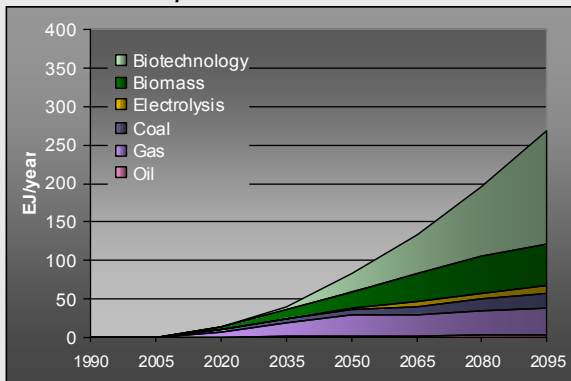


Energy Intensity and Climate Stabilization

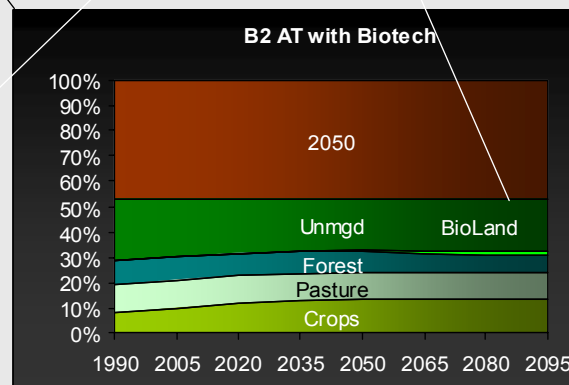
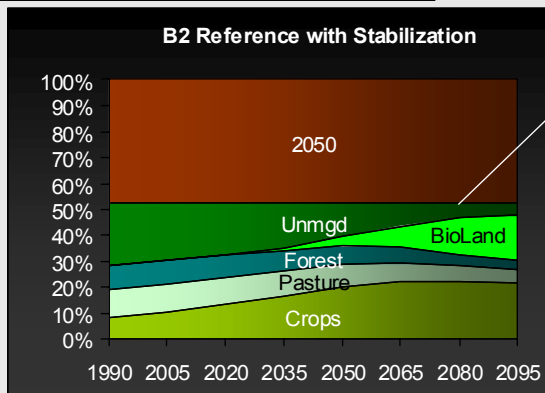
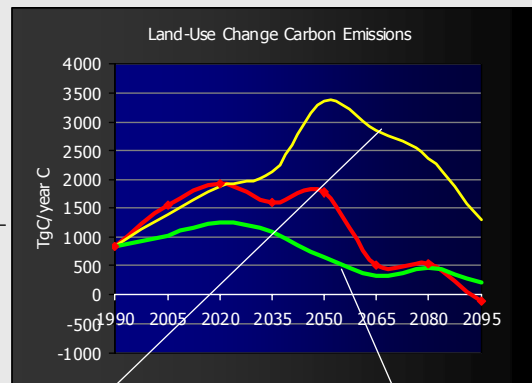


H2 and Biotech B2 AT with Stabilization

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

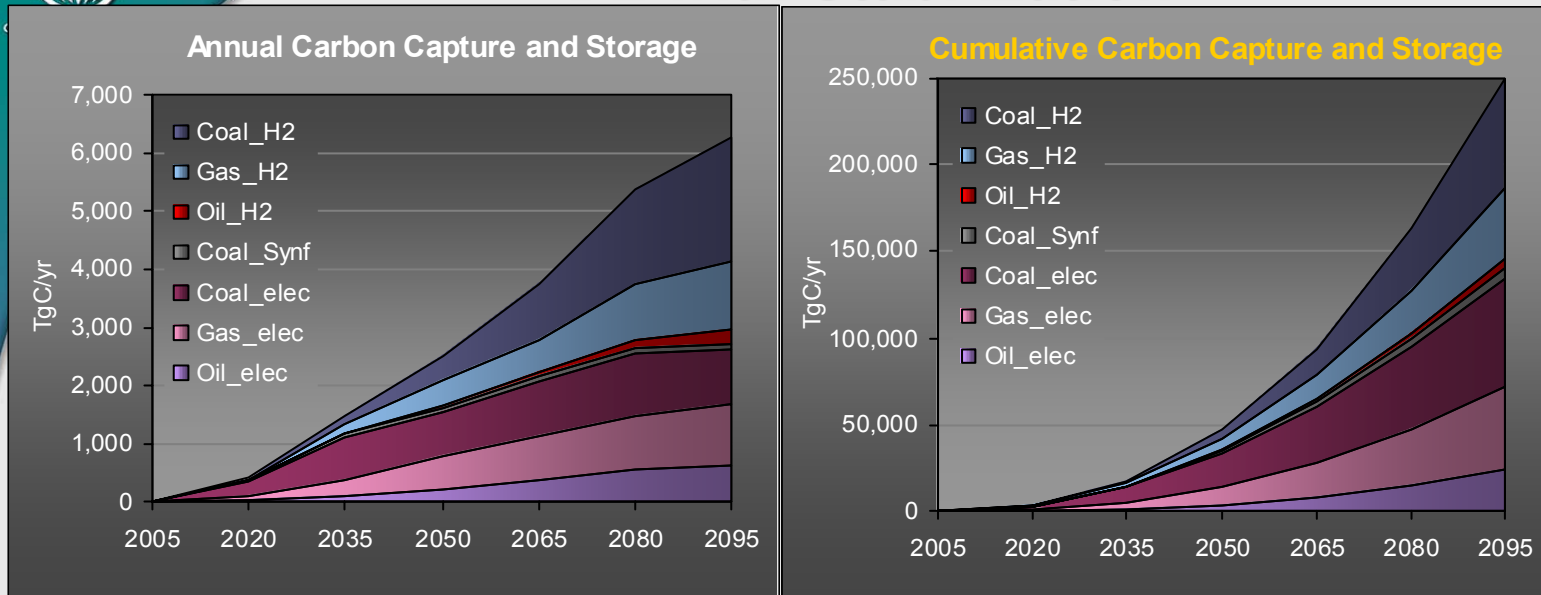


Biotechnology & Land Use





CO₂ Capture and Storage B2 with Stabilization

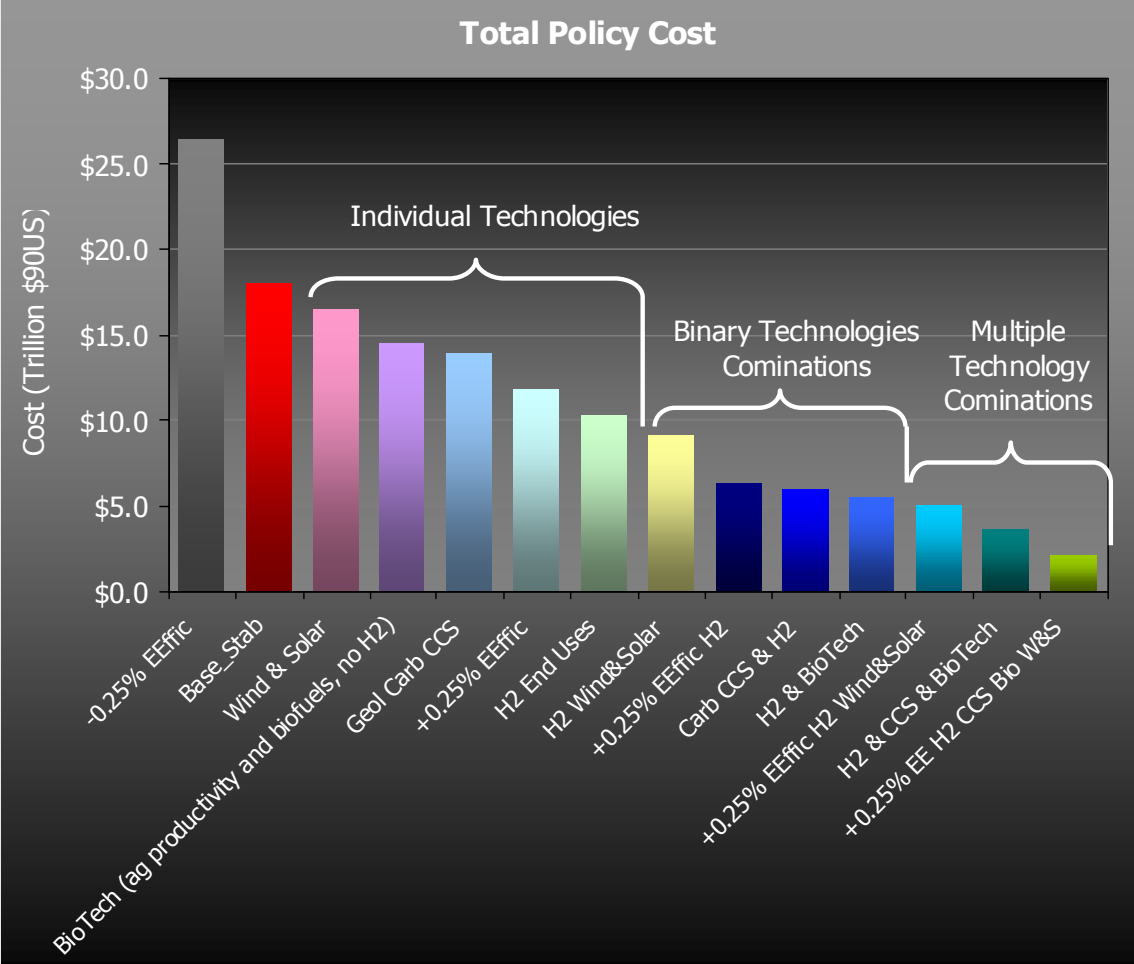


Geologic Storage Capacity Estimates, All Grades (PgC)

Coal Basins	Depleted Oil Plays	Gas Basins	Deep Saline Formation On-shore	Deep Saline Formation Off-shore	TOTAL
48	31	190	1,608	1,374	3,252

Source: Dooley, et al. 2004

Technology and Cost



Some Points

- ▶ Limiting climate change to 2°C implies stabilizing all GHG's
 - CO₂ concentrations at <500 ppm if climate sensitivity is 2.5°C.
 - Emissions peak in 2020 and decline to 3.1 PgC/year by 2095.
 - Aerosol effects are present.
 - Non-CO₂ GHG's provide important mitigation options.
- ▶ An improved technology portfolio could reduce the cost substantially—from \$17 trillion to very low levels.
- ▶ Uncertainty in climate sensitivity has huge implications for a 2°C limit on GMT change:
 - Low climate sensitivity means no mitigation until the second half of the century
 - High climate sensitivity means immediate, radical emissions mitigation.

The GTSP Web Site

www.pnl.gov/gtsp

PNNL Global Energy Technology Strategy Project (GTSP) - Mozilla

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Since its 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.

About the GTSP

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

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.

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