

Expert Meeting on Climate
Change and Sustainable
Development: 2002

Global Participation & Technology Strategies

Jae Edmonds

**Expert Meeting on Climate Change and
Sustainable Development: 2002**

**Seoul, Korea
19-20 November 2002**

Battelle

The Joint Global Change
Research Institute



UNIVERSITY OF
MARYLAND

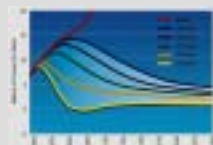
**Pacific Northwest
National Laboratory**
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U.S. Department of Energy

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support.*

Technology and Climate



Background

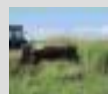
Examples of Technology Systems That Could Make A Difference



Carbon Capture & Disposal



Hydrogen & Transportation



Biotechnology

Background

background

1992 United Nations Framework Convention on Climate Change

GOAL—“...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” (Article 2)

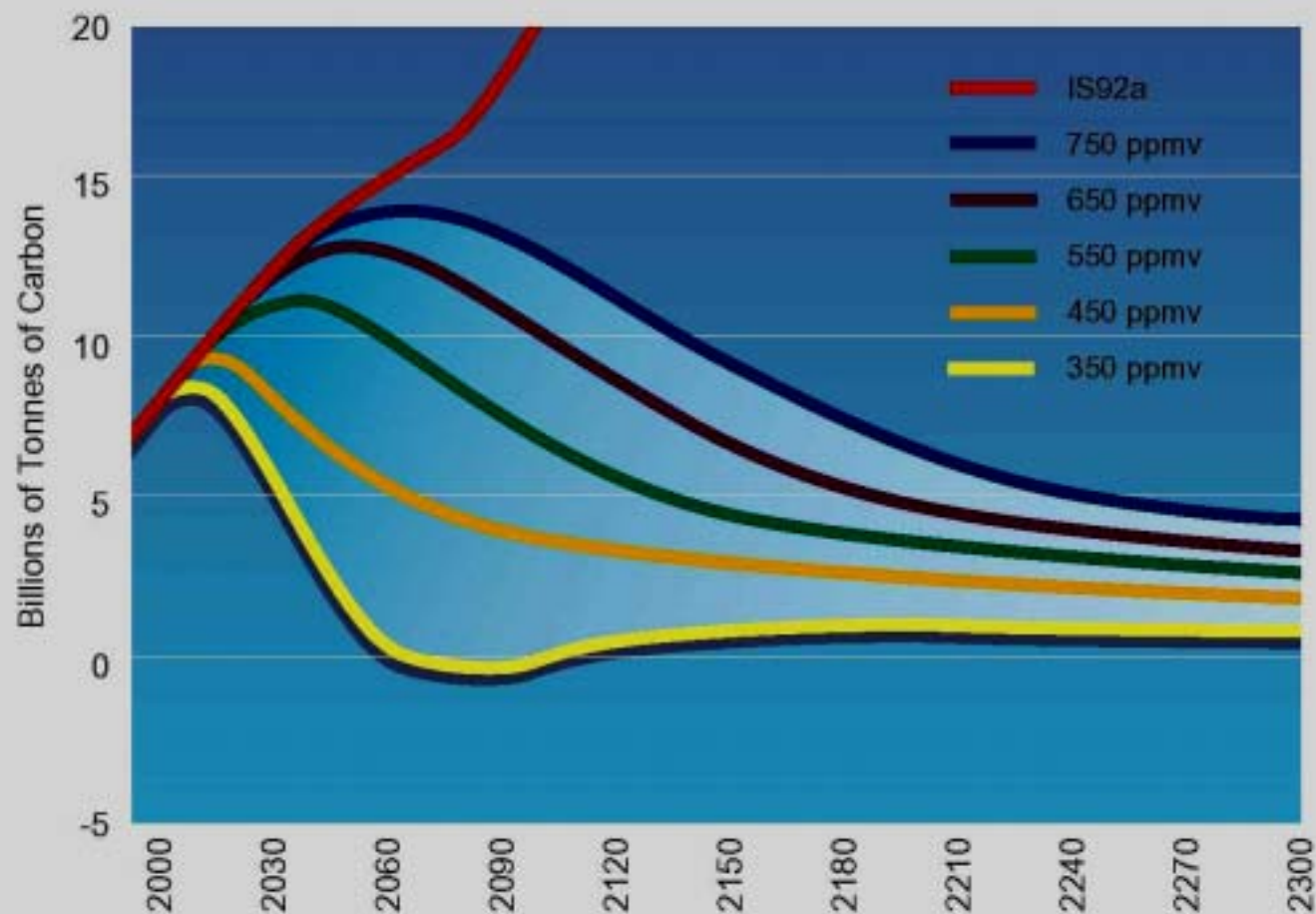
background

Four types of policy responses

- Emissions mitigation
- Adaptation
- Improvement in scientific understanding
- Technology development

background

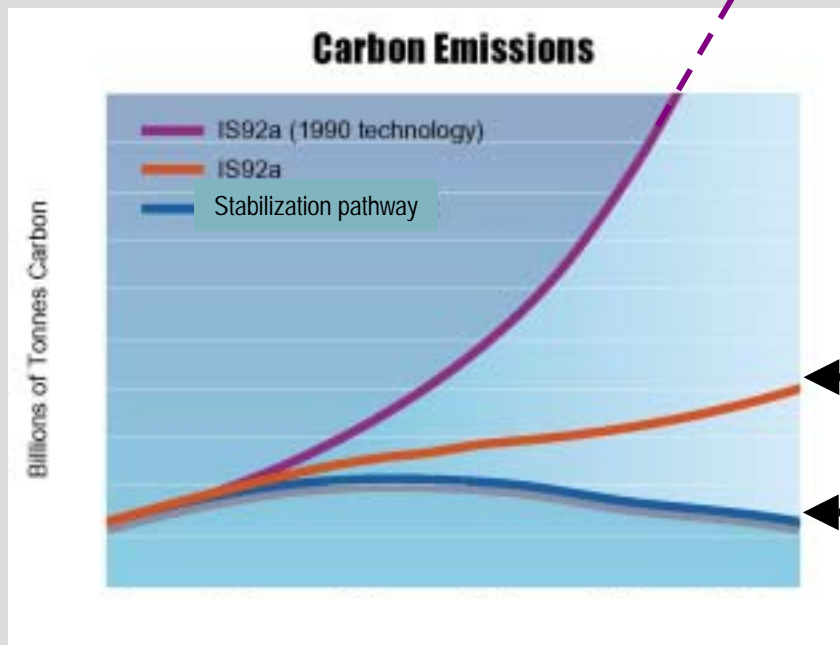
Emissions Trajectories Consistent With Various Atmospheric CO₂ Concentration Ceilings



background

Reference case technology assumptions

population and economic growth will generate increased demands for energy services



where today's technology
will take us

solar
nuclear
efficient fossil electric
advanced transportation
end use efficiency
conventional biomass

where more advanced versions of
current technologies will take us
path we need to be on to
stabilize atmospheric CO₂

Hoffert et al., 2002. Science, provided a menu of technology opportunities to stabilize the concentration of CO₂.

Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet

Martin A. Hoffert,^{1,*} Ken Caldeira,² Gregory Benford,³ David R. Criswell,⁴ Christopher Green,⁵ Howard Herzog,⁶ Atul K. Jain,⁸ Hansen S. Kleshyk,⁹ Klaus S. Lackner,¹⁰ John S. Lewis,¹¹ H. Douglas Lightfoot,¹² Wallace Manheimer,¹⁴ John C. Markink,¹⁵ Michael E. Moxel,¹¹ L. John Perkins,² Michael E. Schlesinger,² Tyler Volk,² Tom M. L. Wigley¹⁶

Stabilizing the carbon dioxide-induced component of climate change is an energy problem. Establishment of a course toward such stabilization will require the development within the coming decades of primary energy sources that do not emit carbon dioxide to the atmosphere, in addition to efforts to reduce and use energy demand. Mid-century primary power requirements that are free of carbon dioxide emissions could be several times what we now derive from fossil fuels ($\sim 10^{14}$ watts), even with improvements in energy efficiency. Here we survey possible future energy sources, evaluated for their capability to supply massive amounts of carbon emission-free energy and for their potential for large-scale commercialization. Possible candidates for primary energy sources include terrestrial solar and wind energy, solar power satellites, biomass, nuclear fusion, nuclear fission, fusion-fission hybrids, and fossil fuels from which carbon has been sequestered. Non-primary power technologies that could contribute to climate stabilization include efficiency improvements, hydrogen production, storage and transport, superconducting global electric grids, and geoeengineering. All of these approaches currently have severe deficiencies that limit their ability to stabilize global climate. We conclude that a broad range of intensive research and development is urgently needed to produce technological options that can allow both climate stabilization and economic development.

More than a century ago, Arrhenius put forth the idea that CO₂ from fossil fuel burning could raise the infrared opacity of the atmosphere enough to warm Earth (1). In the 20th century, the human population quadrupled and primary power consumption increased 35-fold (2). The fossil fuel greenhouse theory has become more credible as observations accumulate and as we better understand the links between

fossil fuel burning, climate change, and environmental impacts (3). Atmospheric CO₂ has increased from ~ 275 to ~ 370 parts per million (ppm). Unchecked, it will pass 550 ppm this century. Climate models and paleoclimate data indicate that 550 ppm, if sustained, could eventually produce global warming comparable in magnitude but opposite in sign to the global cooling of the last Ice Age (4).

The United Nations Framework Convention on Climate Change aims to stabilize greenhouse gas concentrations at levels that avoid "dangerous anthropogenic interference with the climate system" (5). Atmospheric CO₂ stabilization targets as low as 450 ppm could be needed to forestall coral reef bleaching, thermohaline circulation shutdown, and sea level rise from disintegration of the West Antarctic Ice Sheet (6). Wigley and colleagues developed emission scenarios to stabilize atmospheric CO₂ at 350, 450, 550, 650, or 750 ppm (7). They minimized early emission controls by initially following a business-as-usual scenario that continues economic growth of 2 to 3% year⁻¹ with a sustained decline of 1% year⁻¹ in energy intensity (energy use per gross domestic product). Much larger cuts than those called for in the Kyoto Protocol are needed later, because the levels at which CO₂ stabilize depend approximately on total emissions. Targets of cutting to 450 ppm and, certainly, 350 ppm, could require Herculean

effort. Even holding at 550 ppm is a major challenge.

Primary power consumption today is ~ 12 TW, of which 85% is fossil-fueled. Stabilization at 350, 450, and 550 ppm CO₂ by Wigley *et al.* scenarios require emission-free power by mid-century of 15, 25, and >30 TW, respectively (7). Attaining this goal is not easy. CO₂ is a combustion product vital to how civilization is powered; it cannot be regulated away. CO₂ stabilization could prevent developing nations from basing their energy supply on fossil fuels (8). Hansen *et al.* call for reductions in methane and black soot, which also cause warming (9). Such reductions are desirable but do not address fossil fuel greenhouse warming. The Kyoto Protocol calls for greenhouse gas emission reductions by developed nations that are 5% below 1990 levels by 2008 to 2012. Paradoxically, Kyoto is too weak and too strong: Too strong because its initial cuts are perceived as an economic burden by some (the United States withdrew for this stated reason); too weak because much greater emission reductions will be needed, and we lack the technology to make them.

Arguably, the most effective way to reduce CO₂ emissions with economic growth and equity is to develop revolutionary changes in the technology of energy production, distribution, storage, and conversion (6). The need to intensify research on such technologies now is by no means universally appreciated. Present U.S. policy emphasizes domestic oil production, not energy technology research (10). Misperceptions of technological readiness also appear in the latest "Summary for Policymakers" by the "Mitigation Working Group of the Intergovernmental Panel on Climate Change (IPCC): "... known technological options could achieve a broad range of atmospheric CO₂ stabilization levels, such as 550 ppm, 450 ppm or below over the next 100 years or more. ... Known technological options refer to technologies that exist in operation or pilot plant stage today. It does not include any new technologies that will require drastic technological breakthroughs. ..." (11)

This statement does not recognize the CO₂ emission-free power requirements implied by the IPCC's own reports (3, 6) and is not supported by our assessment. Energy

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Technology

Today's Discussion

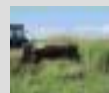
Examples of Advanced Technologies That Could
Make A Difference



Carbon Capture & Disposal (CC&D)



Hydrogen & Transportation



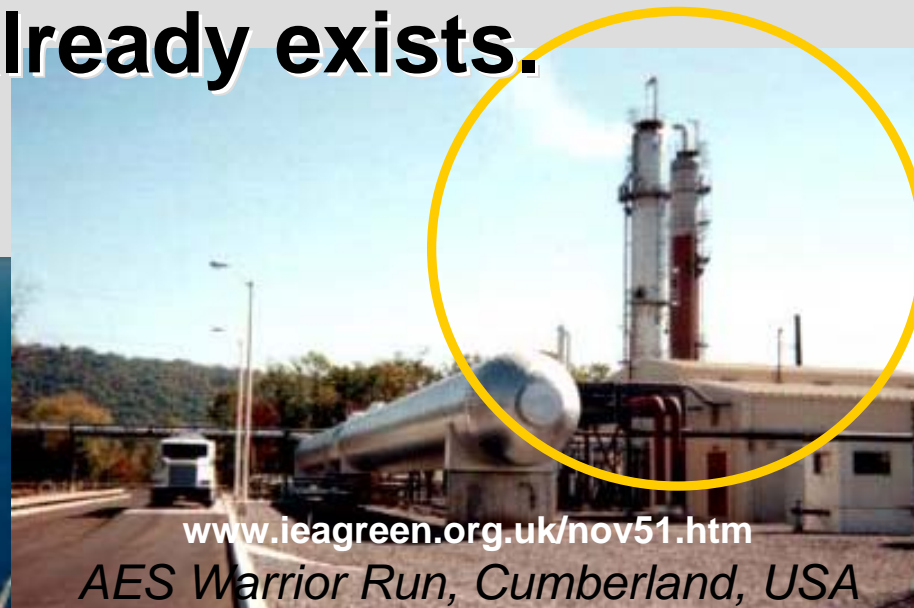
Biotechnology

Carbon capture already exists.

www.ieagreen.org.uk/nov51.htm
Sleipner, North Sea

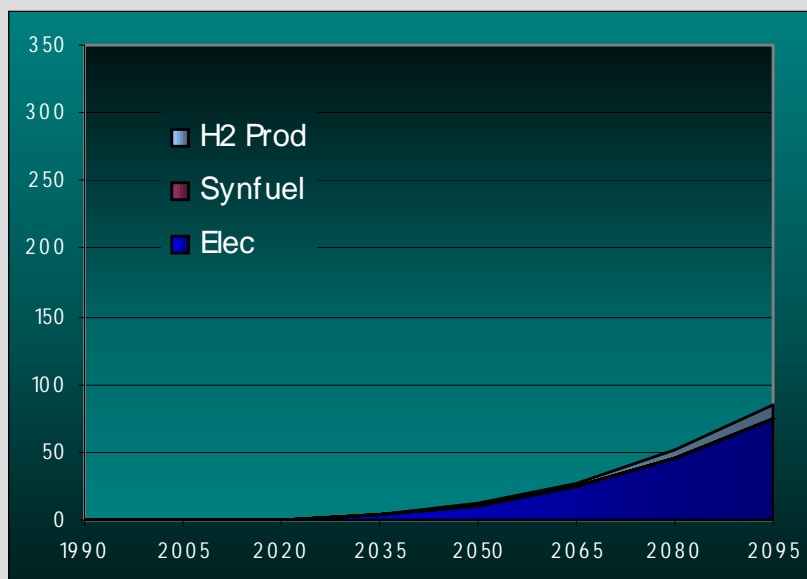


www.ieagreen.org.uk/nov51.htm
AES Warrior Run, Cumberland, USA

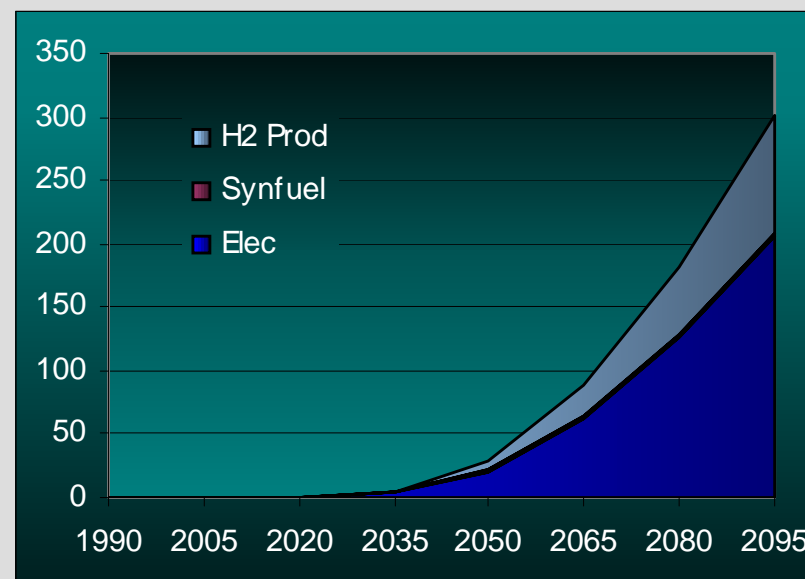


Cumulative Carbon Capture

MiniCAM B2 550



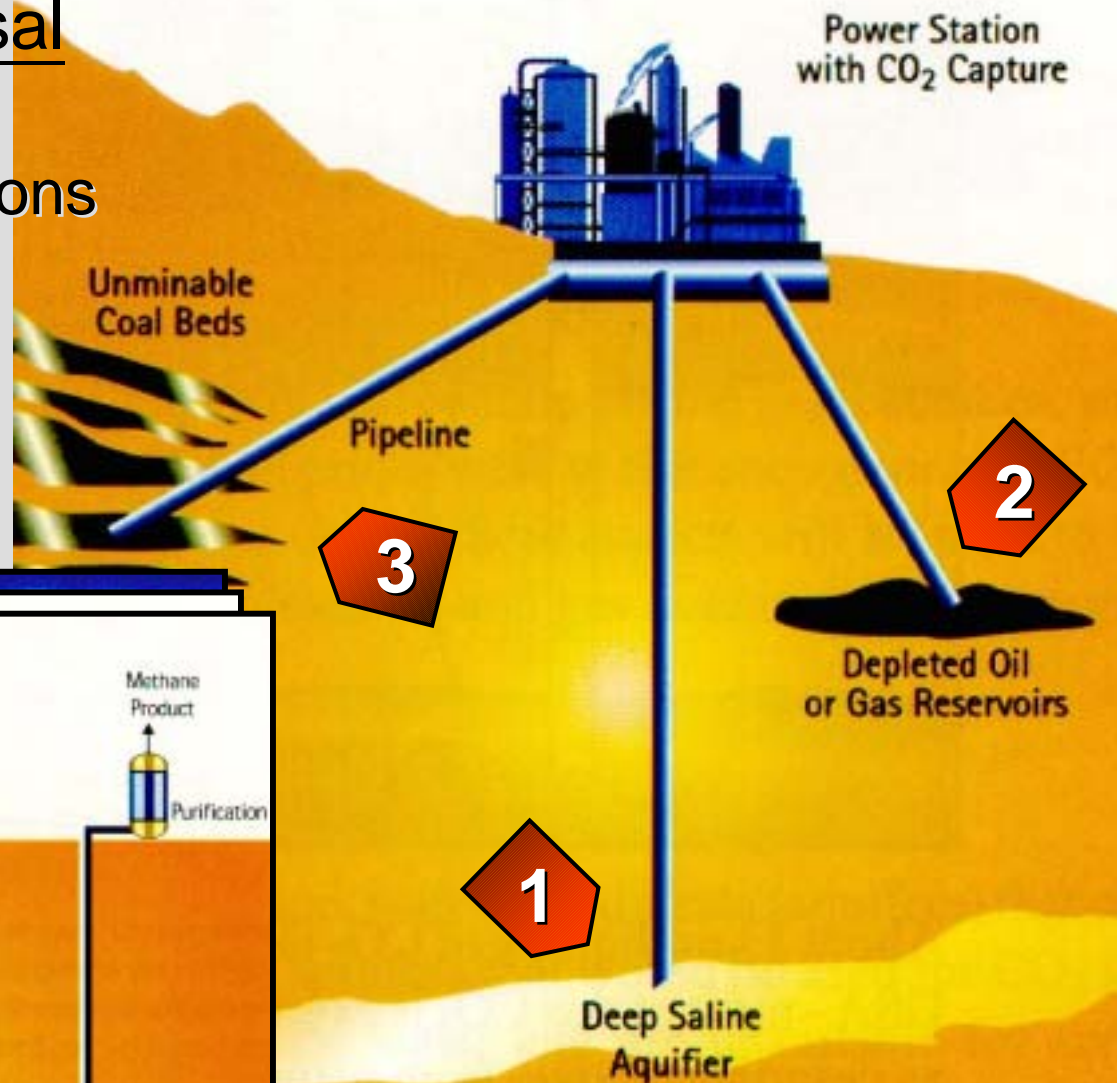
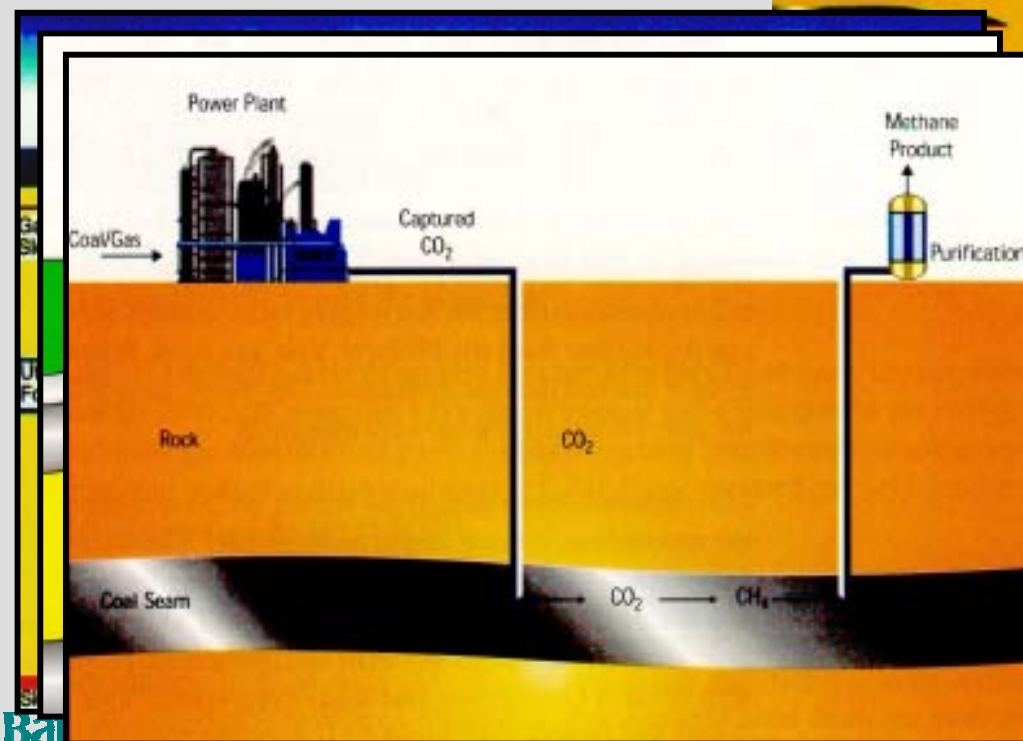
MiniCAM B2 AT 550



... where to put 300 Billion Tons of Carbon?

Geologic Disposal

1. Deep saline formations
2. Oil & gas reservoirs
3. Unmined coal beds



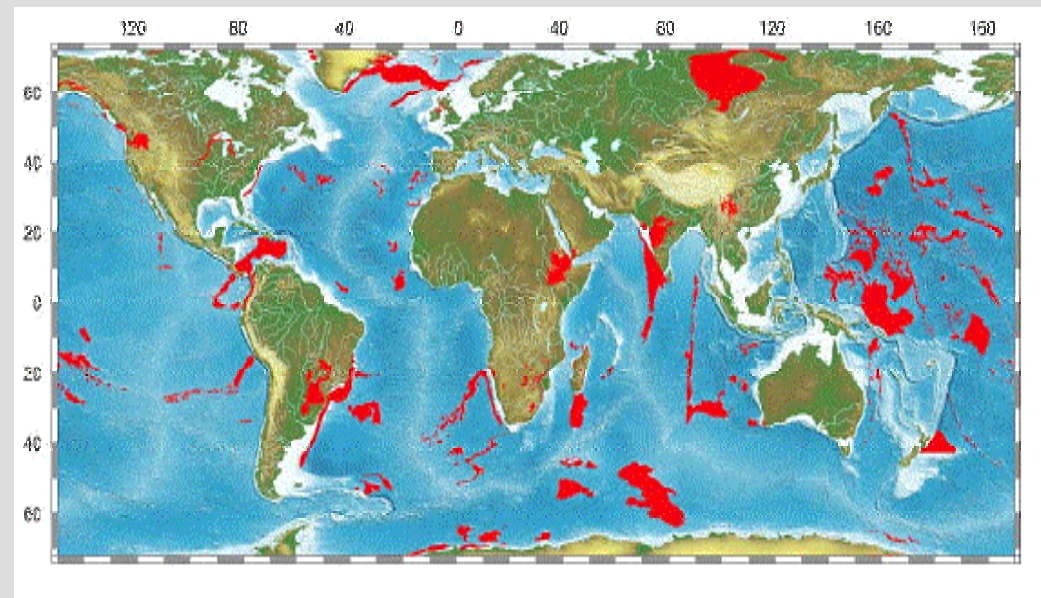
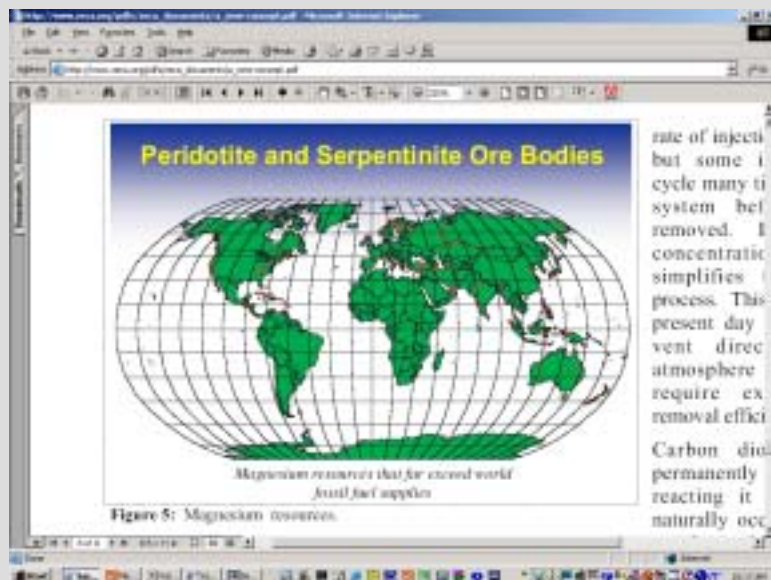
(IEA Greenhouse R&D Programme, 2001)

Geologic Disposal

There are other reservoirs that need to be explored...

Deep Basalt Flows

Ex situ
Mineralization

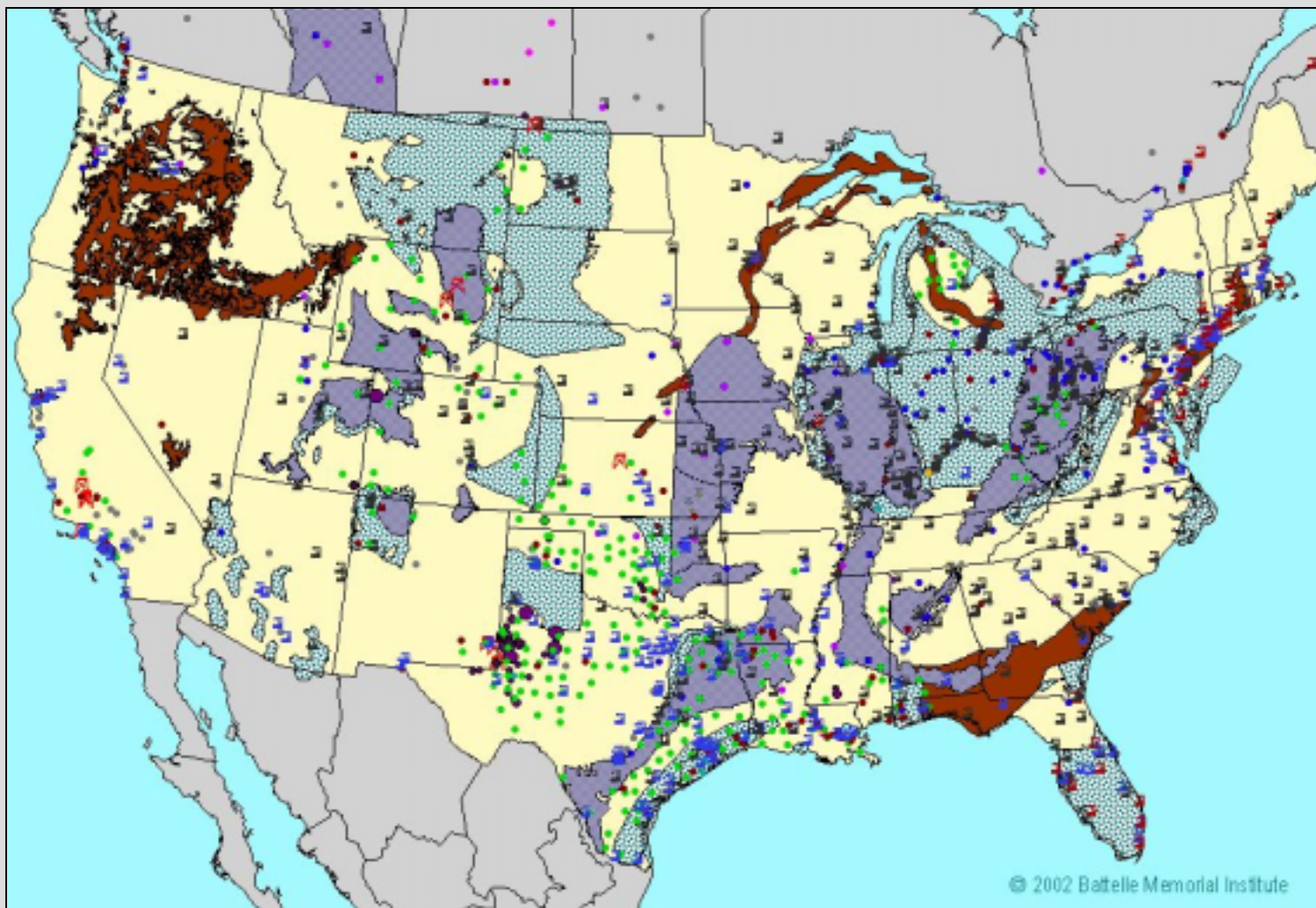


Ocean Disposal

Global Carbon Storage Reservoirs

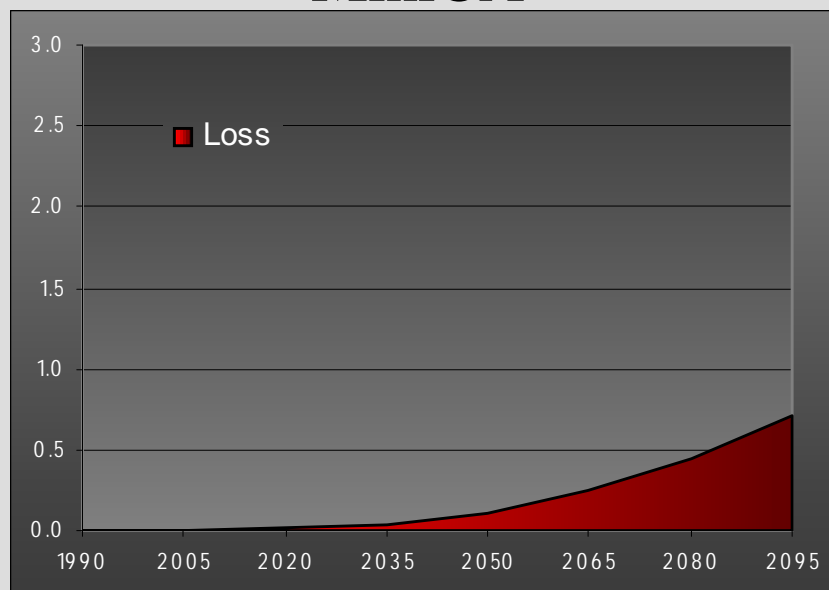
Carbon Storage Reservoir	Range (PgC)
<i>Deep Saline Reservoirs</i>	87 to 2,727
<i>Depleted Gas Reservoirs</i>	136 to 300
<i>Depleted Oil Reservoirs</i>	41 to 191
<i>Unminable Coal</i>	>20
<i>Basalt Formations</i>	>1,000
<i>Deep Ocean</i>	1,391 to 27,000
Source: Herzog et al. (1997), Freund and Ormerod (1997), PNNL (2001).	

Carbon is captured and stored locally.

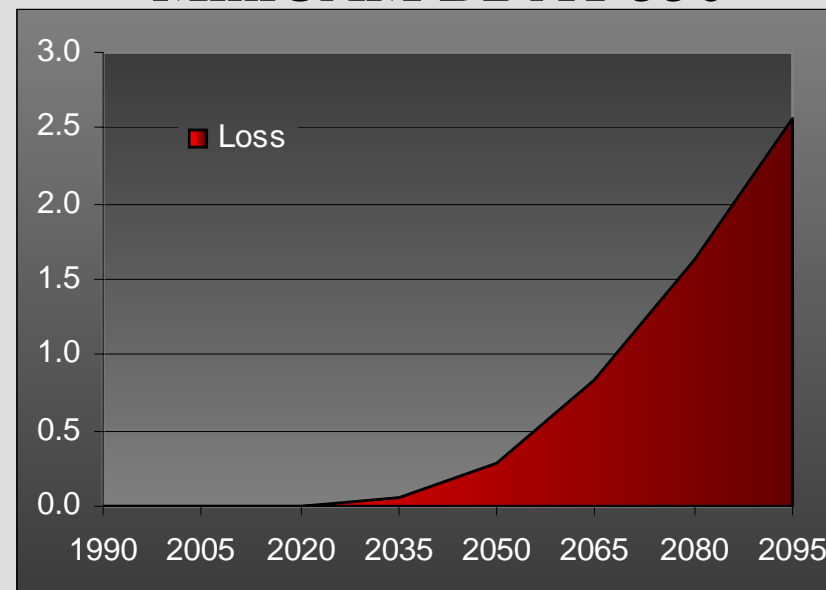


Aggregate Losses From 1% Annual Release Rate

MiniCA



MiniCAM B2 AT 550



Year 2100 Emissions (PgC/Year)

WRE 350	WRE 450	WRE 550	WRE 650	WRE 750
0	3.6	6.8	10.0	12.5

Key Issues

- Macro-scale Losses—1% is a BIG number!
- Local Losses—A Million Tonnes of CO₂ matters if its at your house.
- Monitoring & Verification Loom Large.
- General dispersion in oceans probably has high loss rates.

Today's Discussion

Examples of Advanced Technologies That Could Make A Difference



Carbon Capture & Disposal



Hydrogen & Transportation (H2)



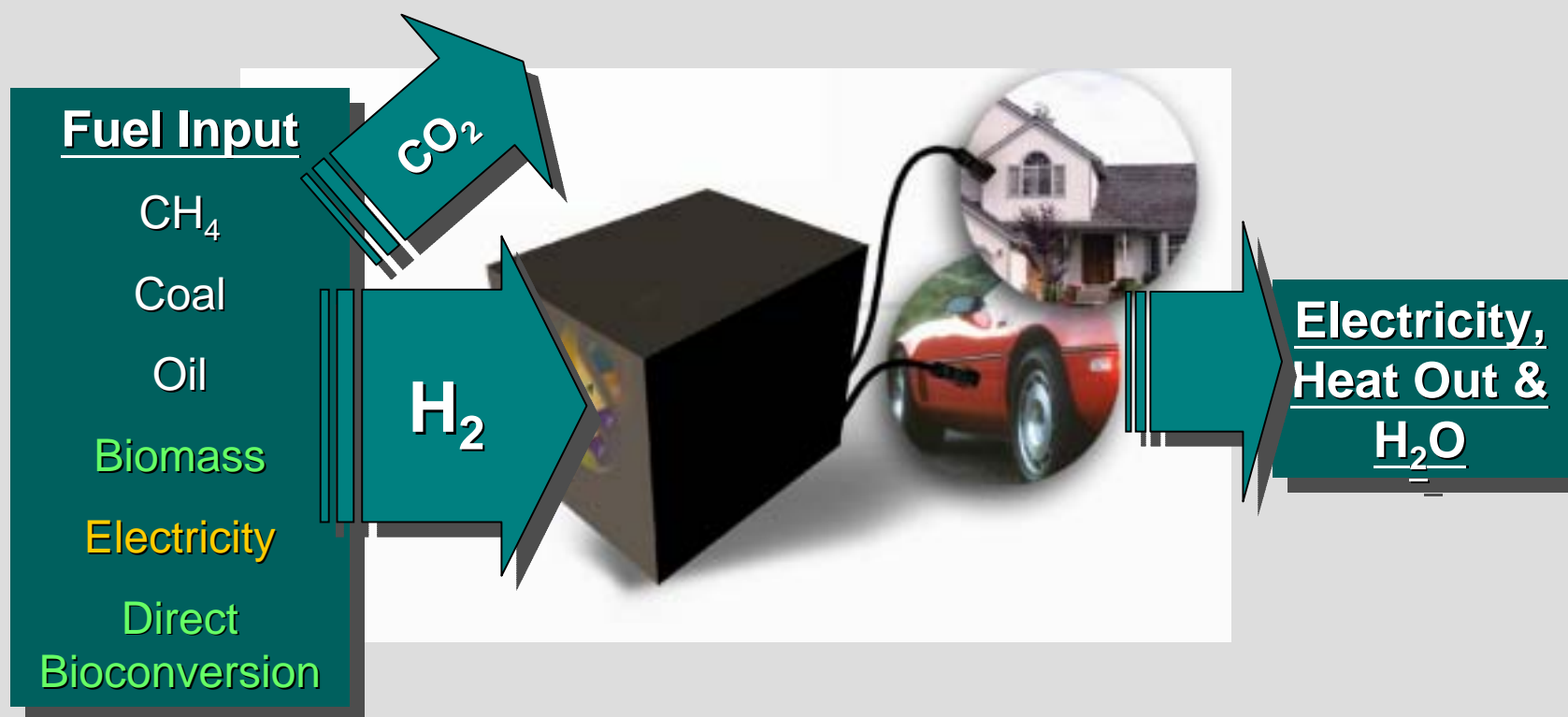
Biotechnology

Transport Emissions Are All About Technology

- 1990 Fuel is 9% of total passenger transport cost.
- 2100 Fuel is 4% of total passenger transport cost with \$200/ton carbon value.

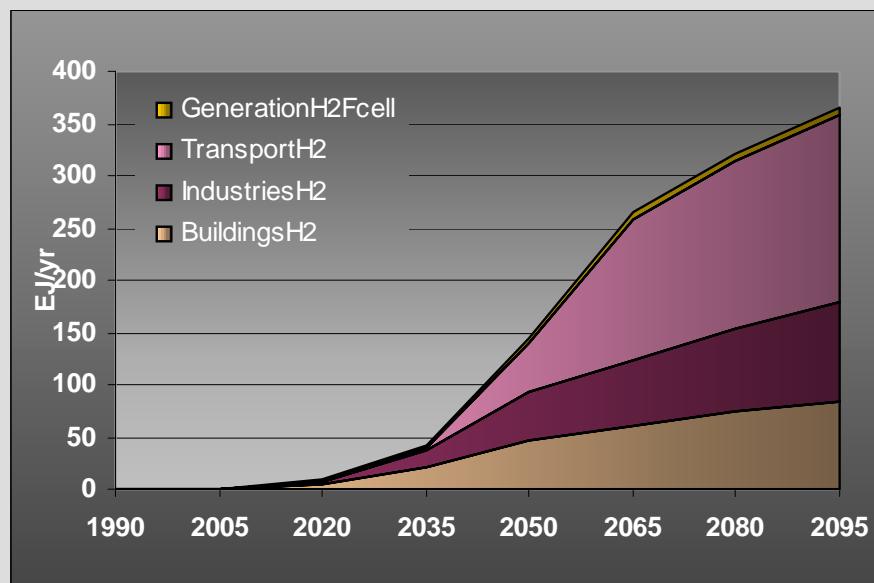
Fuel Cells

...for the H₂ economy.

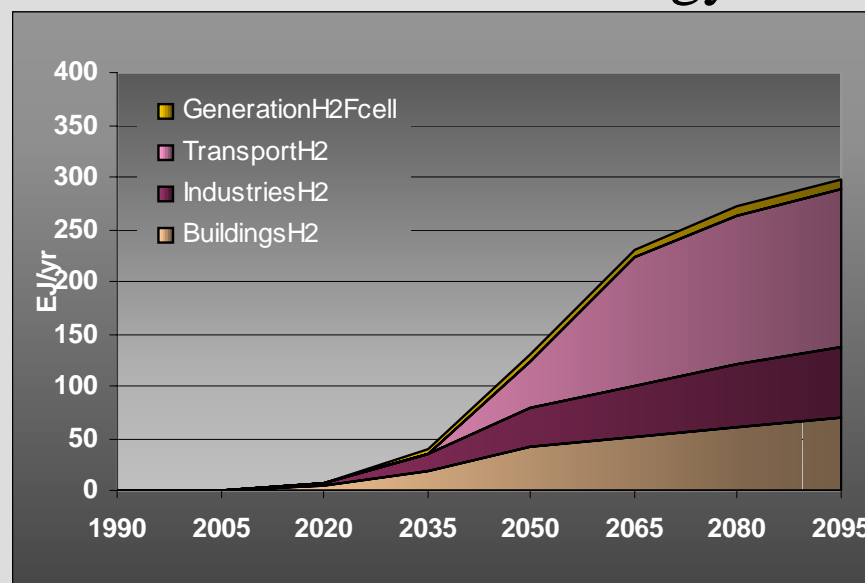


Hydrogen could provide stationary heat and power, then penetrates the transportation sector.

MiniCAM B2
Advanced Technology



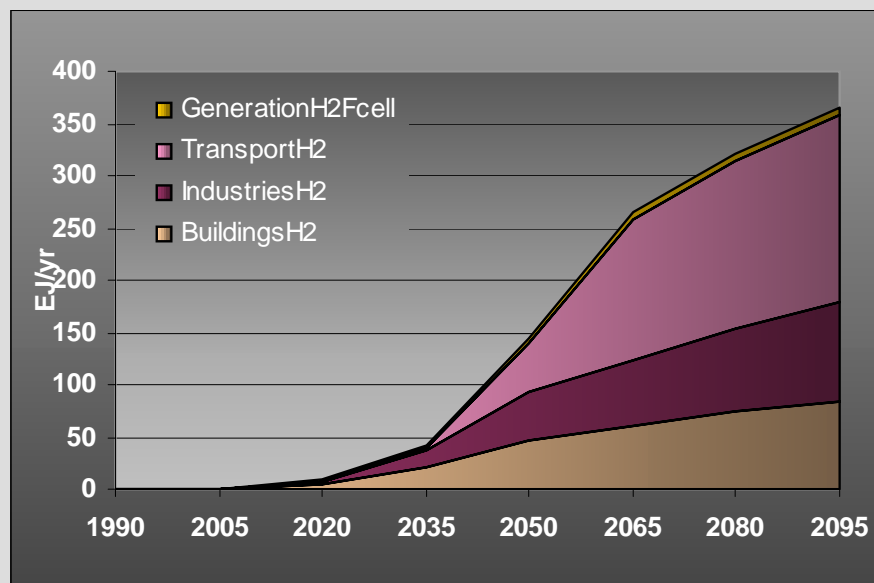
MiniCAM B2 550
Advanced Technology



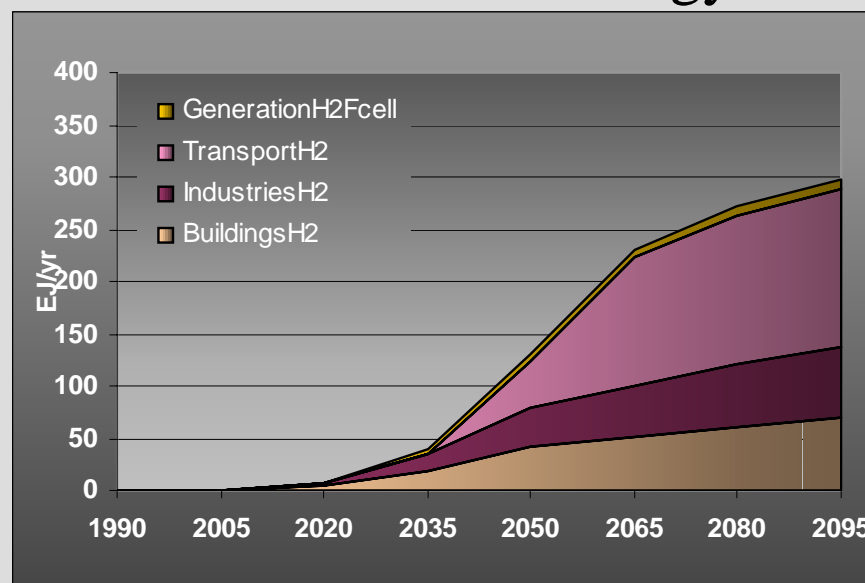
H₂ Use—Exajoules/year

Even with rapid technology improvement,
significant market penetration is decades in the
future.

MiniCAM B2
Advanced Technology



MiniCAM B2 550
Advanced Technology



H₂ Use—Exajoules/year

Today's Discussion

Examples of Advanced Technologies That Could Make A Difference



Carbon Capture & Disposal



Hydrogen & Transportation



Biotechnology

Biotechnology

...modern
commercial
biomass energy



e.g. Switchgrass

www.scientecmatrix.com/.../02E6A08F3A385394C1256B5A0028FFFF



Biorefining

ens.lycos.com/ens/aug2001/2001L-08-21-01.html

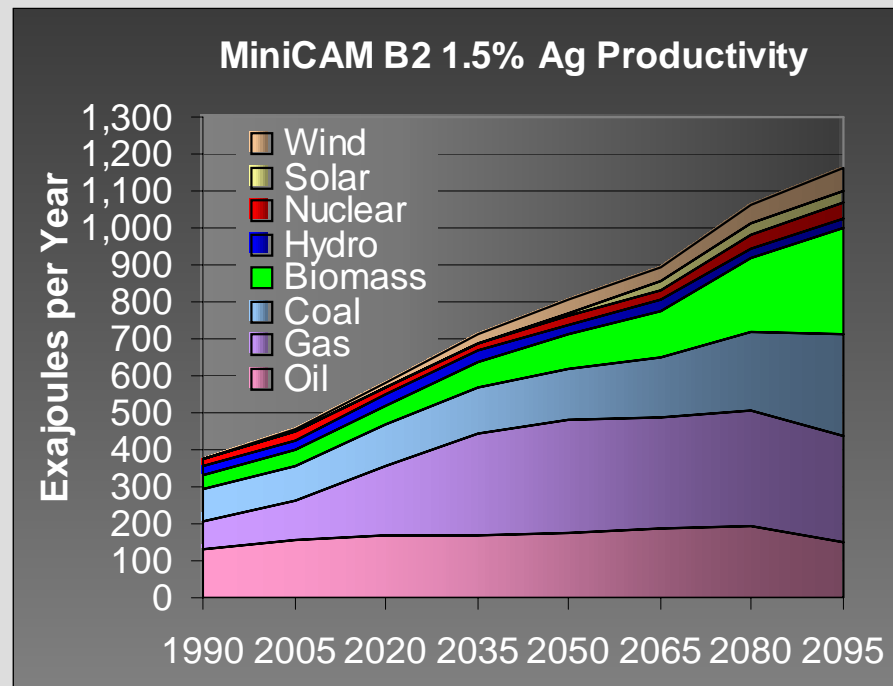
Bio
Fuels
Gas
Solids

...bio-hydrogen

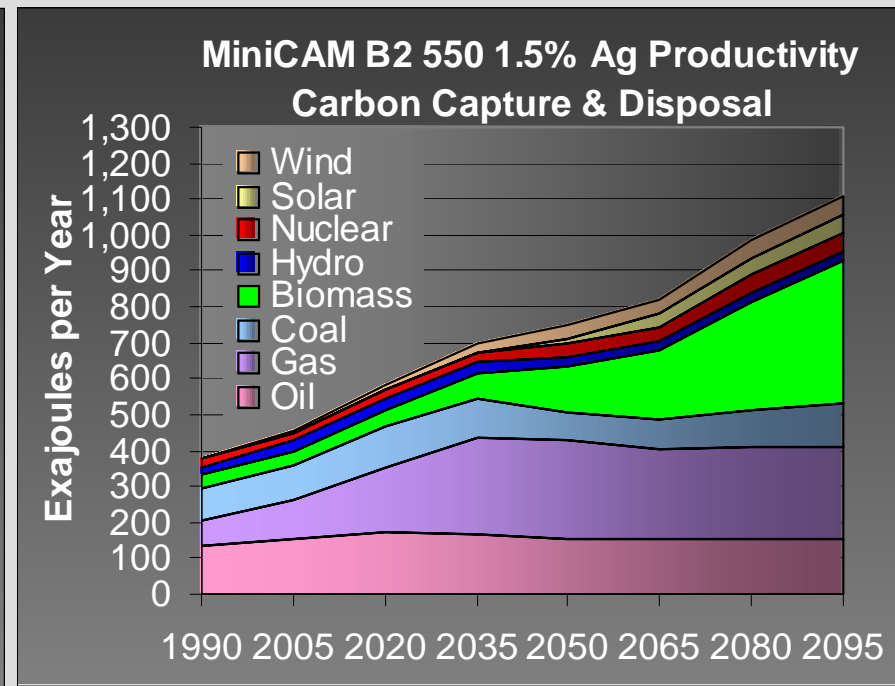
Stabilization implies significant growth in modern commercial biomass.

Primary Energy (EJ/year)

MiniCAM B2 Reference

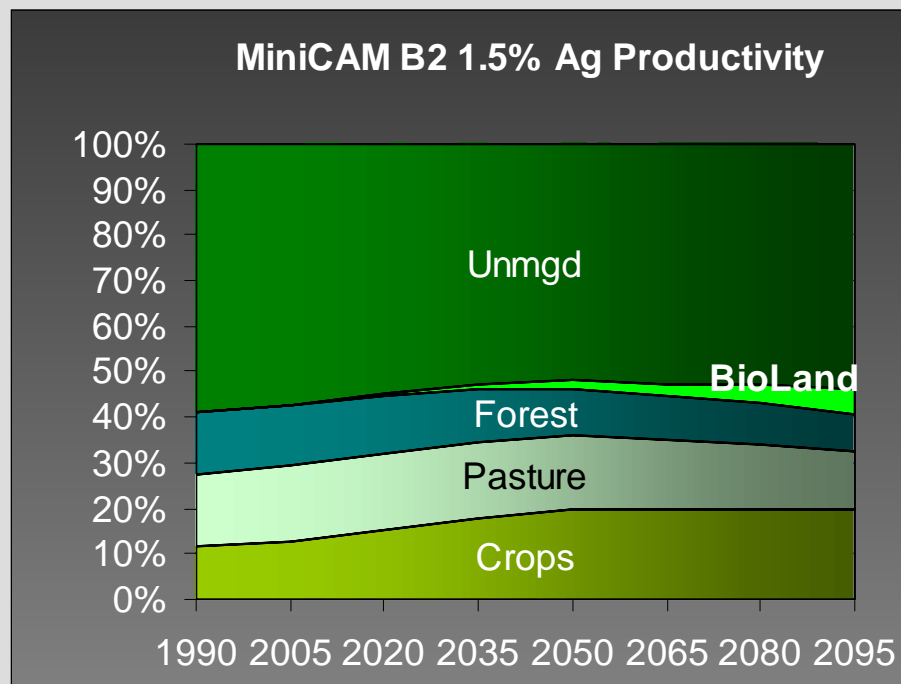


MiniCAM B2 550 Stabilization

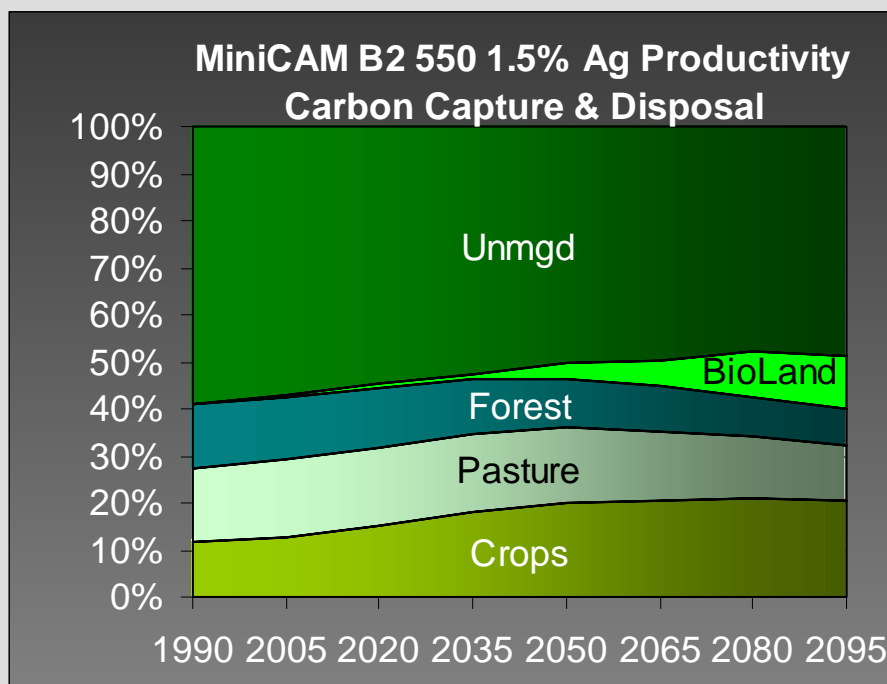


Stabilization could dramatically change land use.

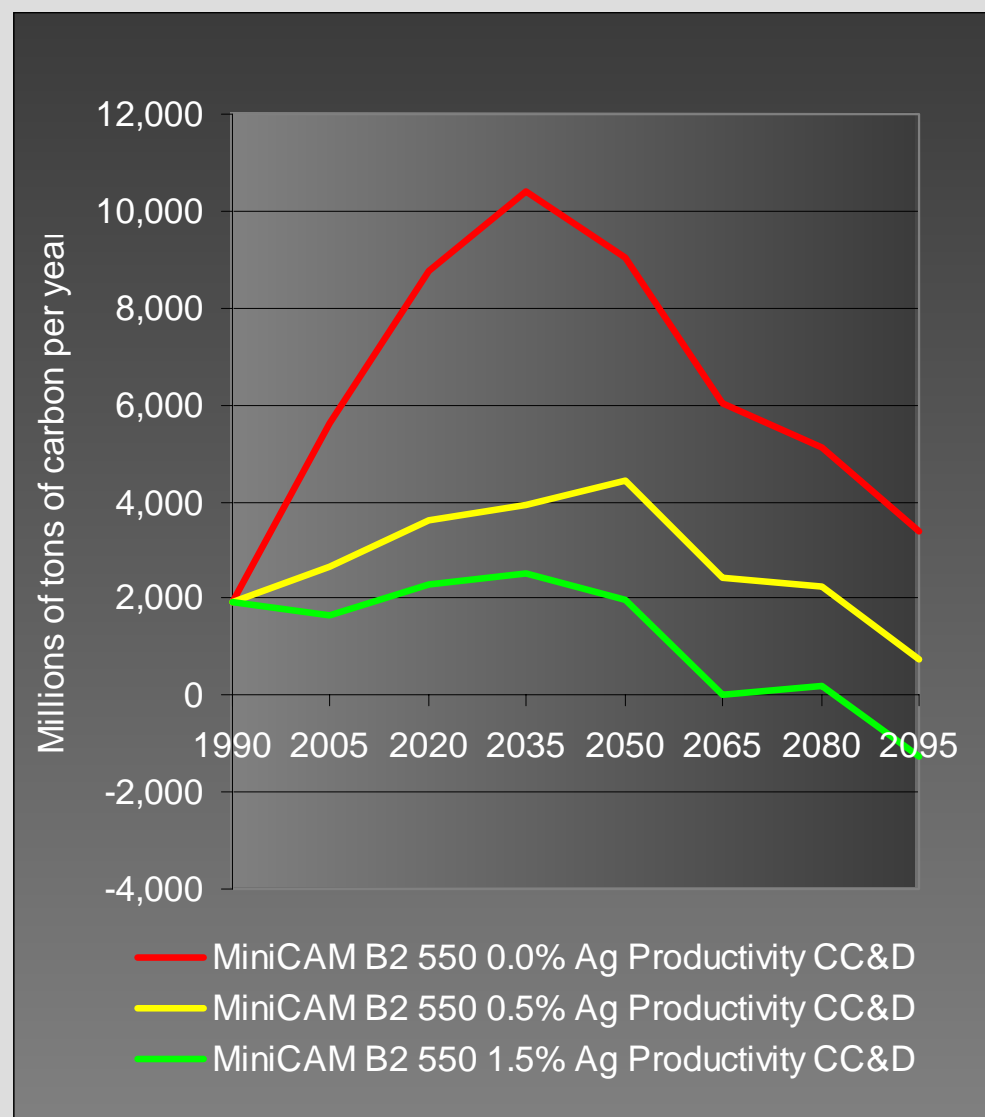
MiniCAM B2 Reference



MiniCAM B2 550 Stabilization



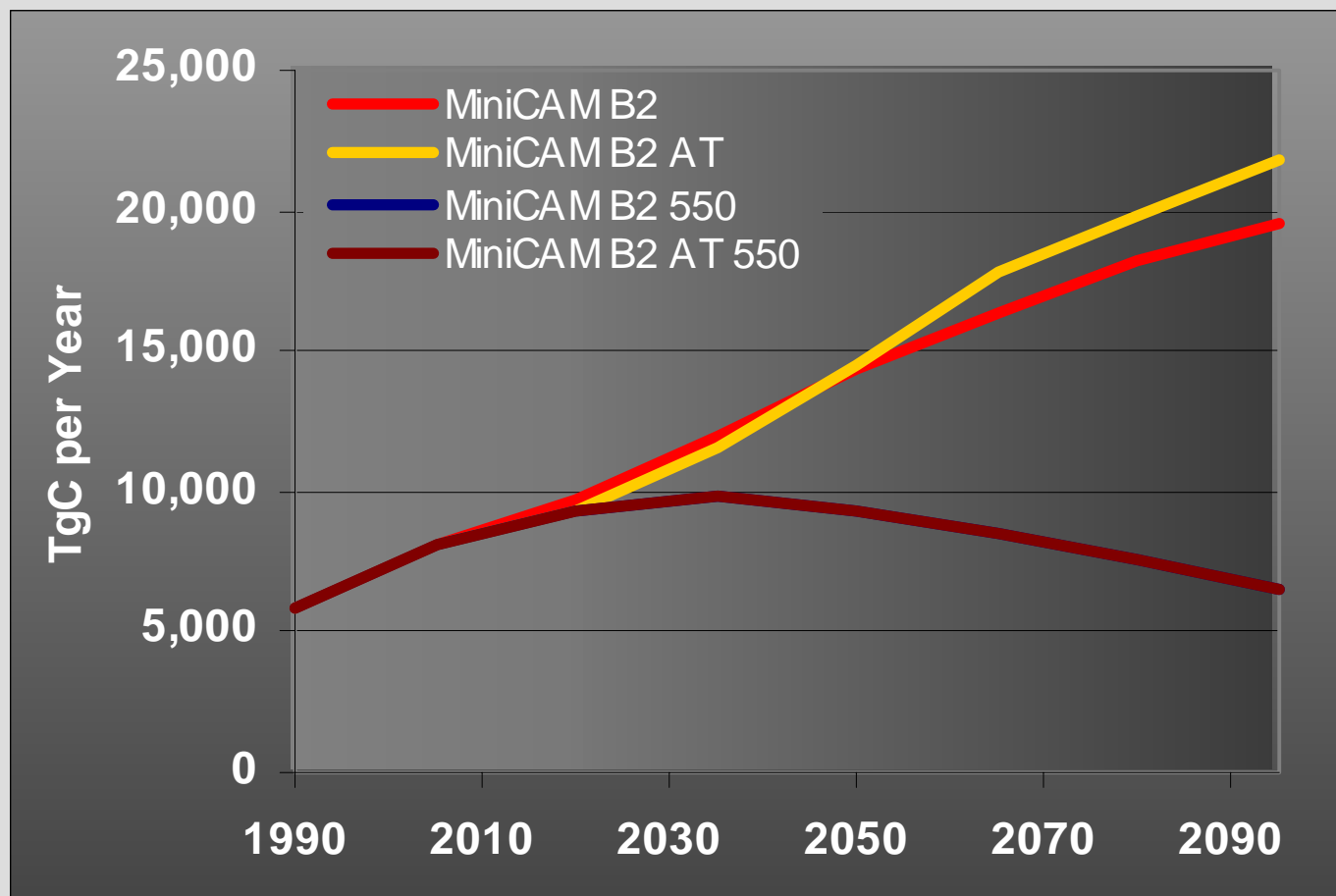
Increasing
agricultural
productivity
dramatically
reduces
land-use
emissions.



Technology & Policy

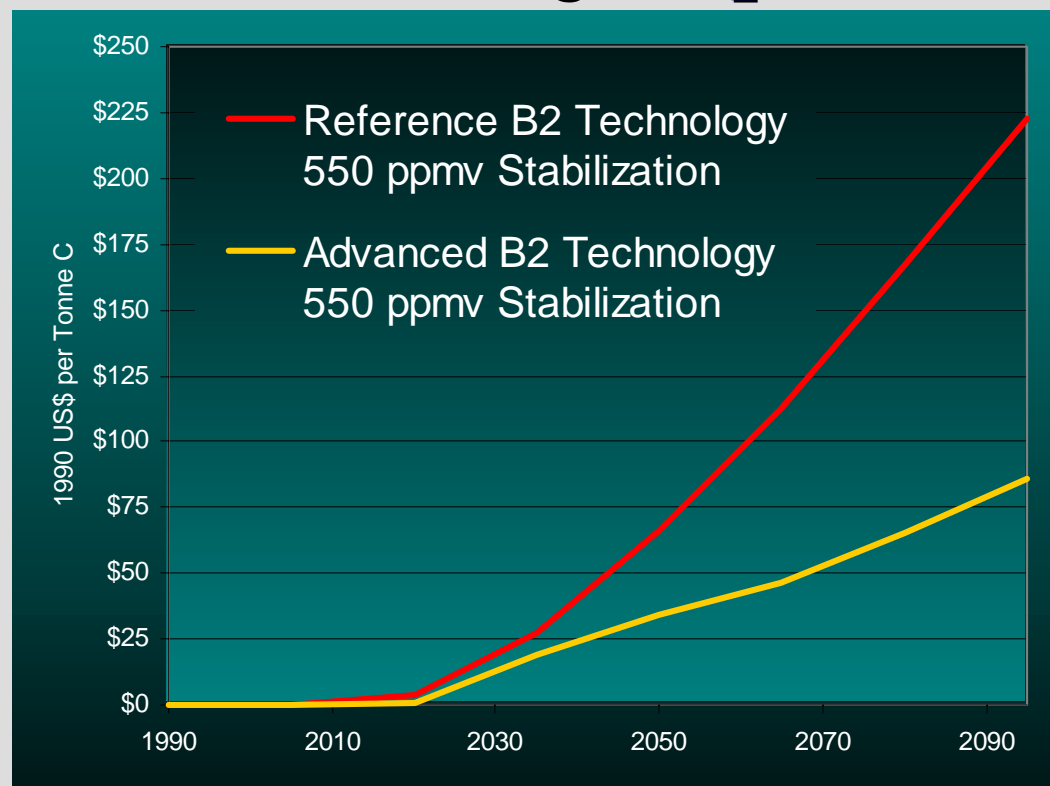
technology & policy

Technology alone may not stabilize
CO₂ concentrations.



technology & policy

However, technology can dramatically lower the cost of stabilizing CO₂ concentrations.



Carbon value (1990\$/tonC)

Final Thoughts

- **Technology Performance Is Critical**

The development and deployment of cost-effective advanced energy technologies could cut costs of stabilizing CO₂ concentrations by more than half.

- **While advanced technology development holds great promise, these technologies are not yet significant components of the global energy system.**

- **Technology Alone May or May NOT Stabilize CO₂ Concentrations**

Emissions may rise with enhanced technology. To stabilize CO₂ concentrations, cumulative emissions must be limited.