Global Participation & Technology Strategies

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University of Maryland

Pacific Northwest National Laboratory
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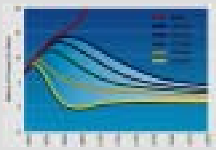
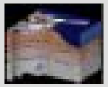
Technology and Climate



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

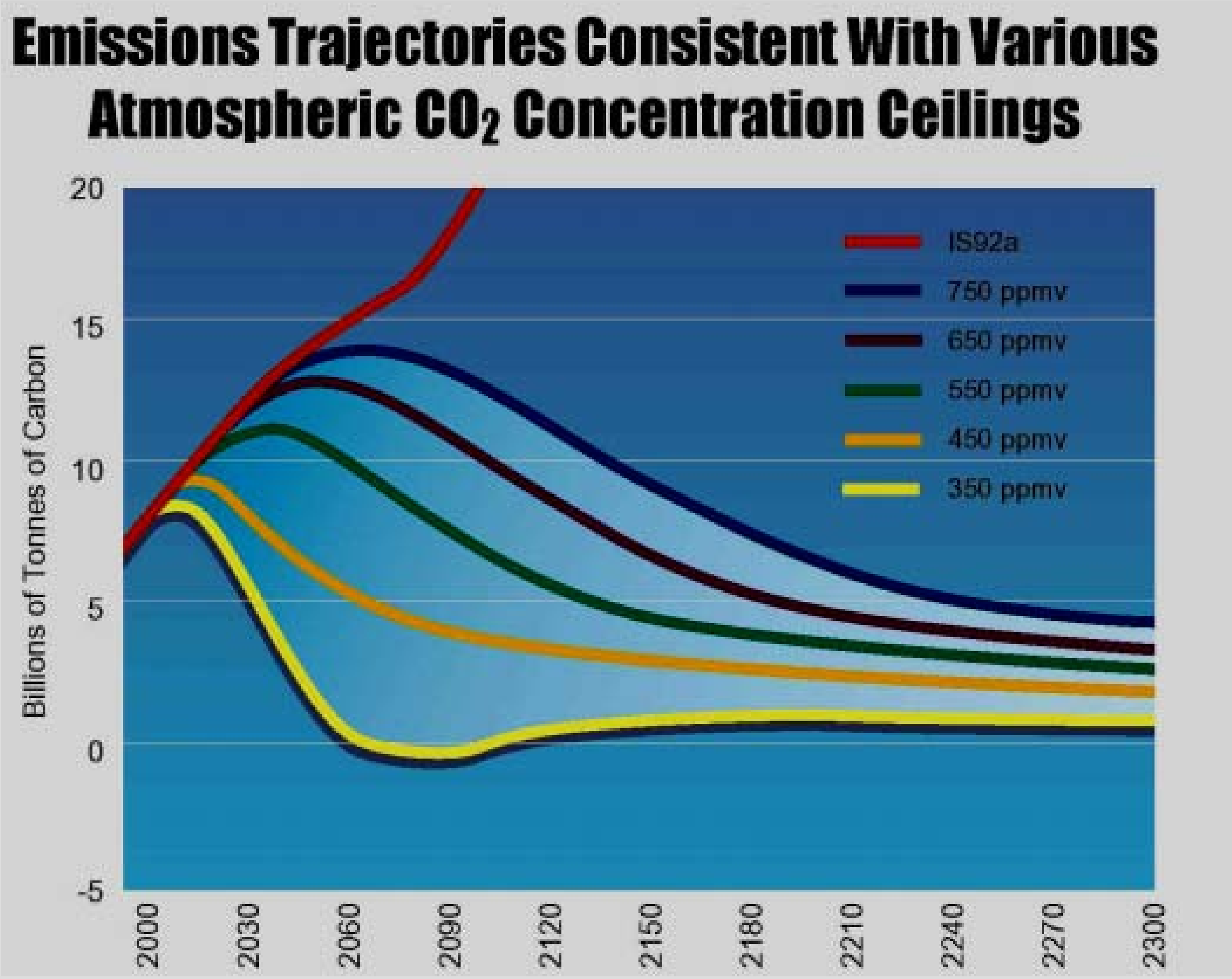
GOAL—"…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." (Article 2)

background

Four types of policy responses

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

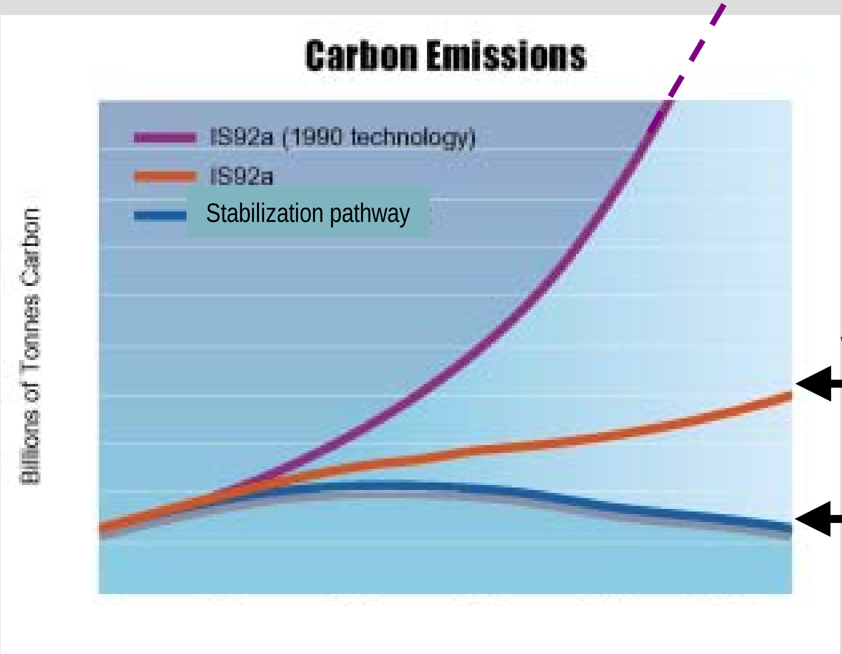
background


Emissions Trajectories Consistent With Various Atmospheric CO_2 Concentration Ceilings
Billions of Tonnes of Carbon
20
15
10
5
0
-5
2000
2030
2060
2090
2120
2150
2180
2210
2240
2270
2300
IS92a
750 ppmv
650 ppmv
550 ppmv
450 ppmv
350 ppmv

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 co_2

Hoffert et al., 2002. *Science,* provided a menu of technology opportunities to stabilize the concentration of CO_2.


SCIENCE'S COMPASS • REVIEW

REVIEW: ENGINEERING

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

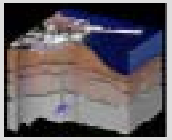
Martin I. Hoffert, Ken Caldeira, Gregory Benford, David R. Criswell, Christopher Green, Howard Herzog, Atul K. Jain, Haroon S. Kheshgi, Klaus S. Lackner, John S. Lewis, H. Douglas Lightfoot, Wallace Manheimer, John C. Mankins, Michael E. Mauel, L. John Perkins, Michael E. Schlesinger, Tyler Volk, Tom M. L. Wigley

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 end-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 (~10^{13} 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 fission, nuclear fusion, fission-fusion 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 geoengineering. 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.

Technology

Today's Discussion

Examples of Advanced Technologies That Could Make A Difference



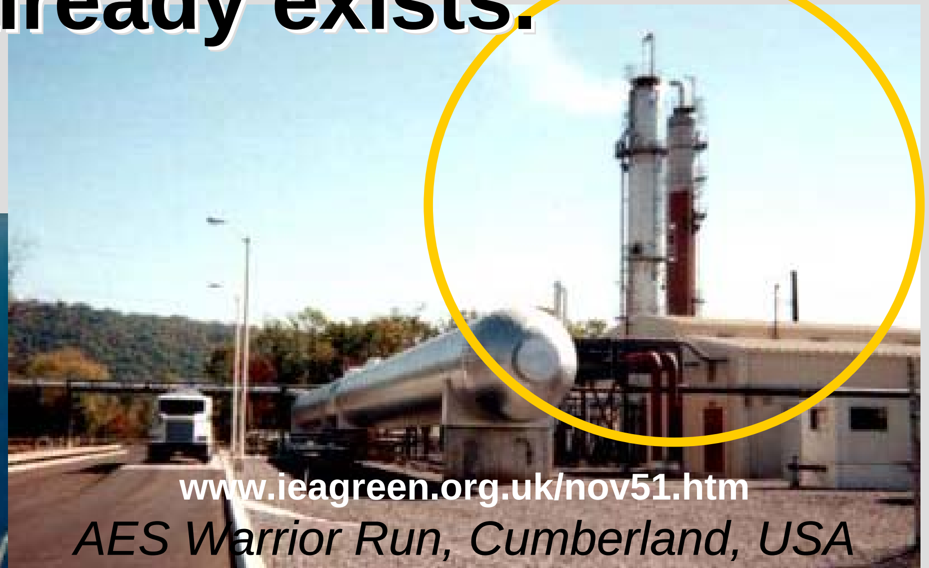
Carbon Capture & Disposal (CC&D)

Hydrogen & Transportation

Biotechnology

Carbon capture already exists.

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

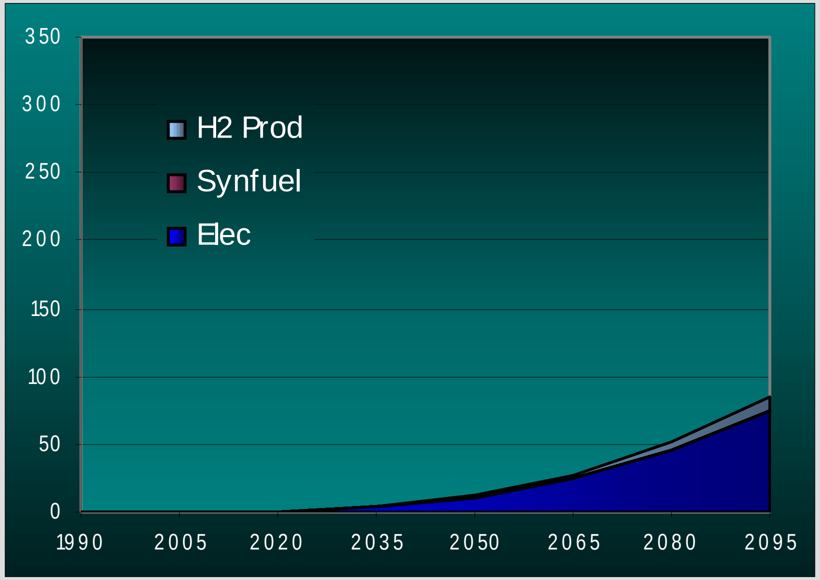


www.ieagreen.org.uk/nov51.htm
AES Warrior Run, Cumberland, USA

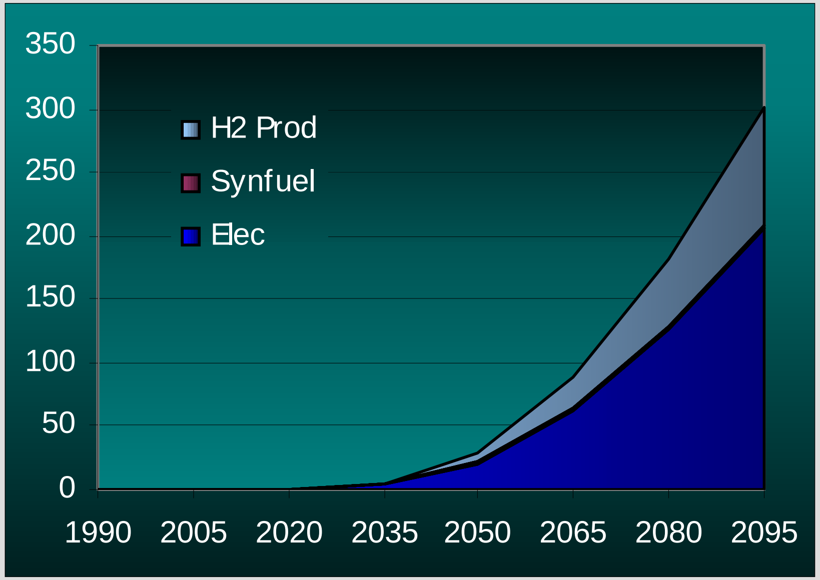
cc&d

Cumulative Carbon Capture

MiniCAM B2 550



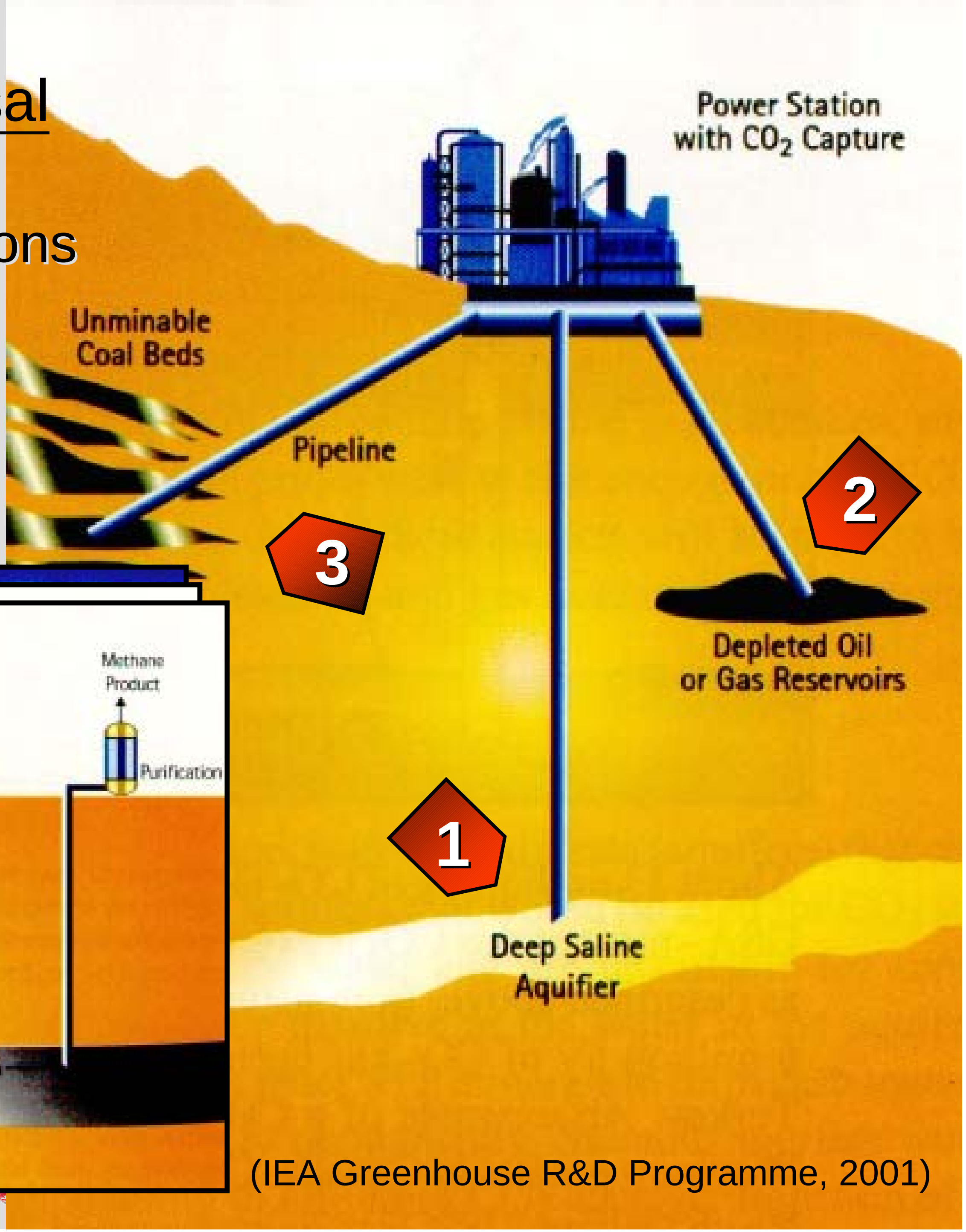
MiniCAM B2 AT 550

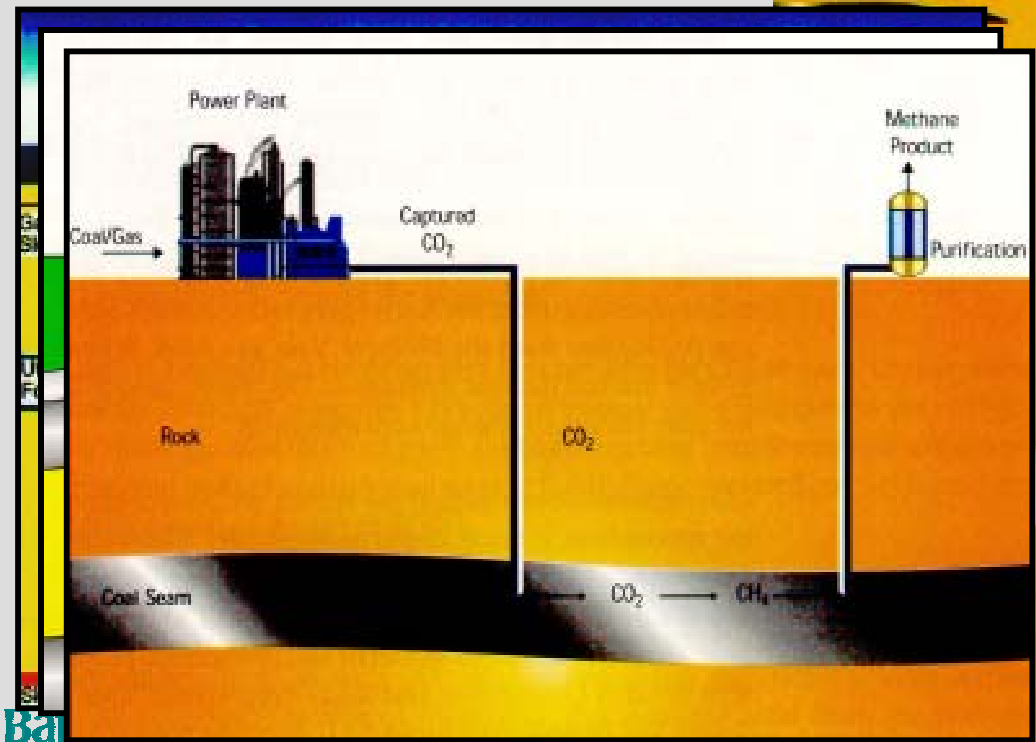


... where to put 300 Billion Tons of Carbon?

Geologic Disposal

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





(IEA Greenhouse R&D Programme, 2001)

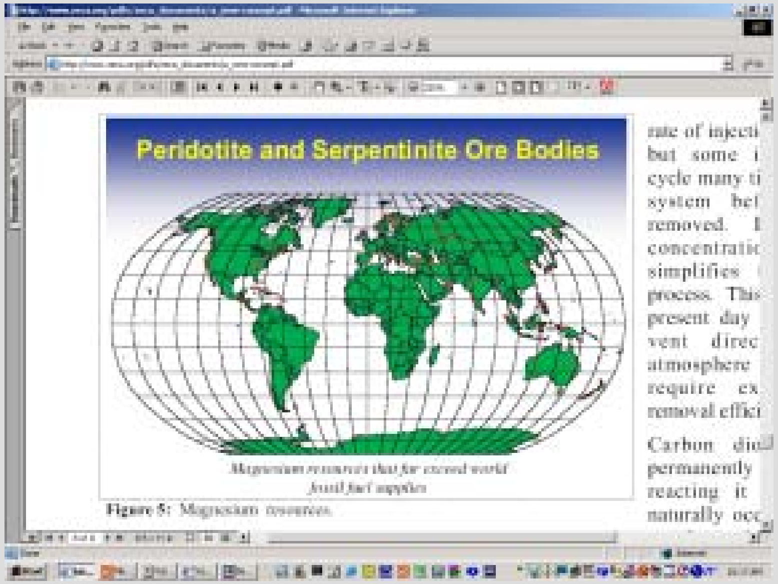
cc&d

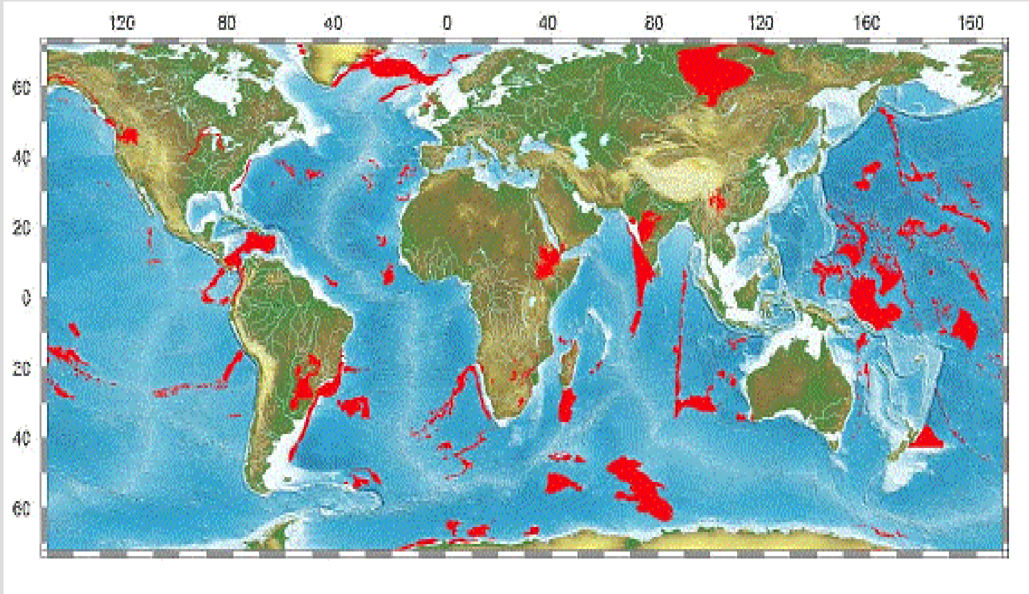
Geologic Disposal

There are other reservoirs that need to be explored…

Deep Basalt Flows

Ex situ
Mineralization





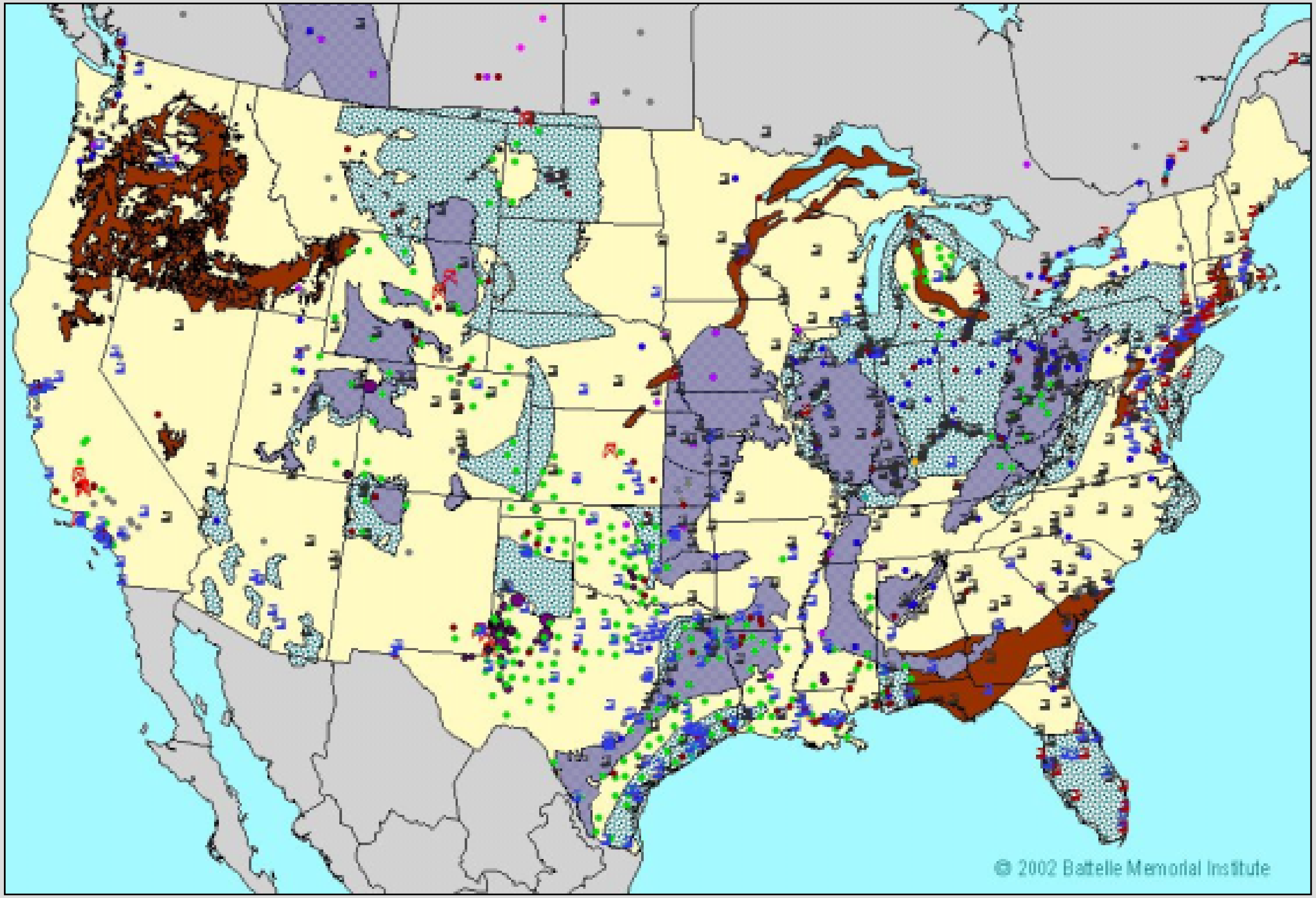
Ocean Disposal

Global Carbon Storage Reservoirs

Carbon Storage Reservoir	Range (PgC)
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	1,391 to 27,000
Source: Herzog et al. (1997), Freund and Ormerod (1997), PNNL (2001).	

cc&d

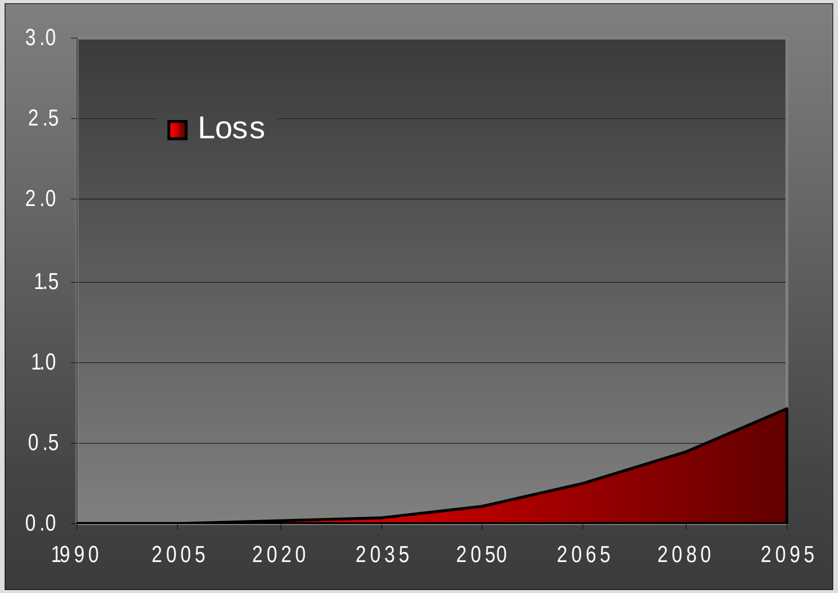
Carbon is captured and stored locally.



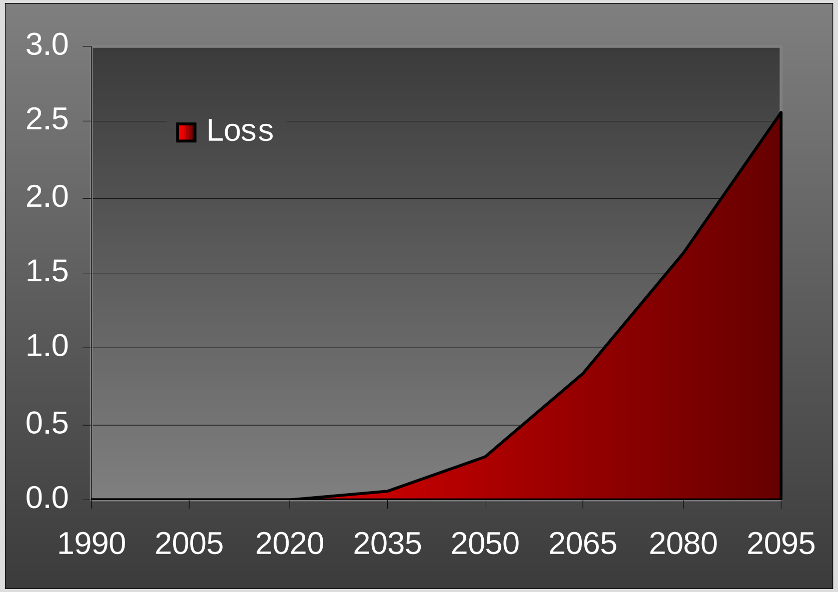
cc&d

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 CO_2 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

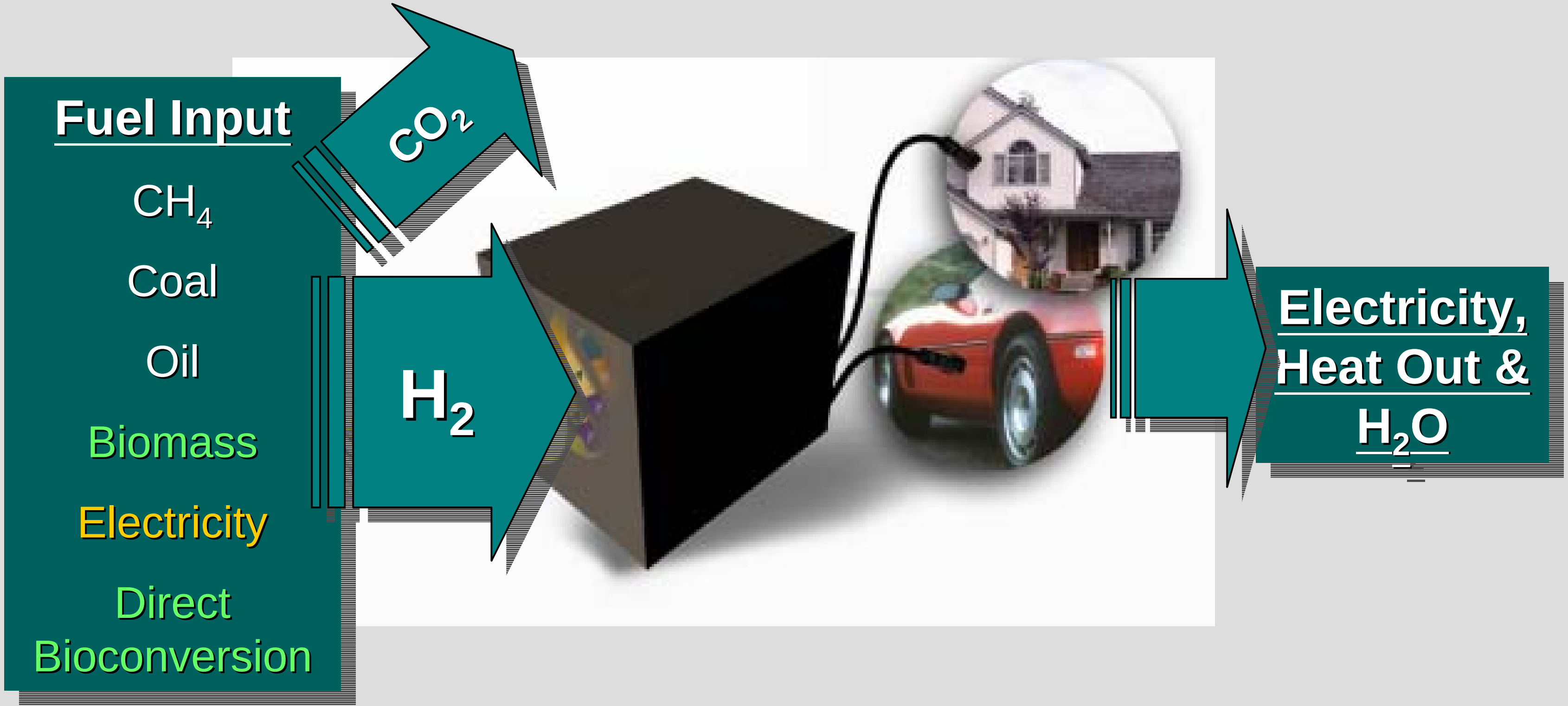
Transport Emissions Are All About Technology

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

h2

Fuel Cells

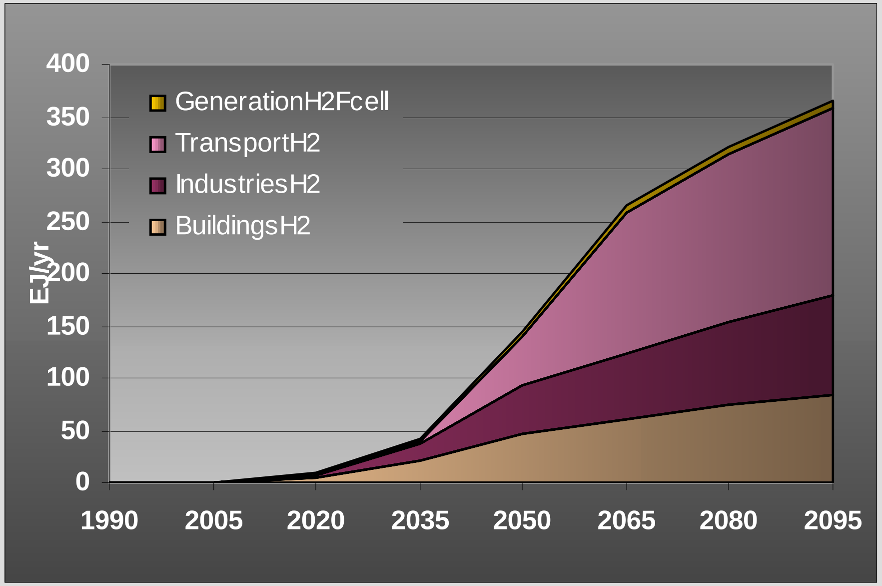
...for the H_2 economy.



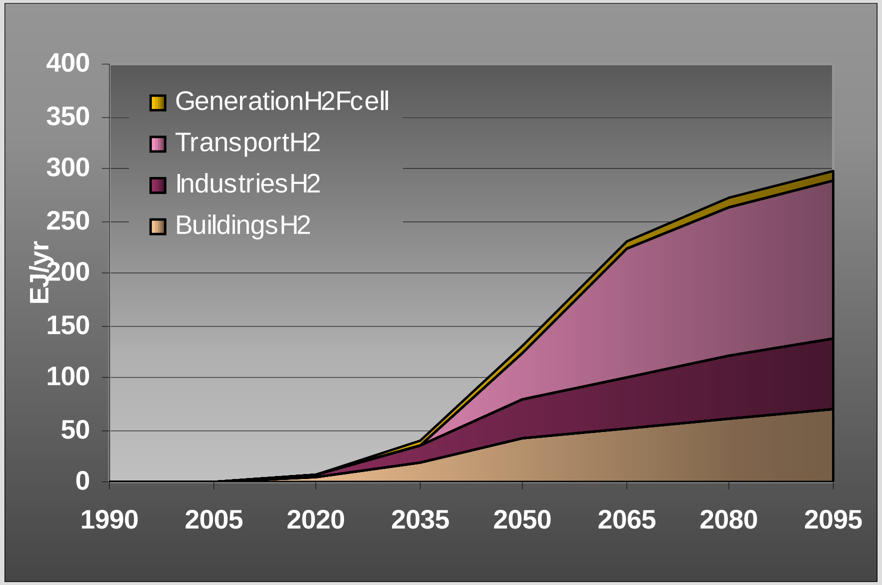
h2

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

MiniCAM B2
Advanced Technology



MiniCAM B2 550
Advanced Technology



H_2 Use—Exajoules/year

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

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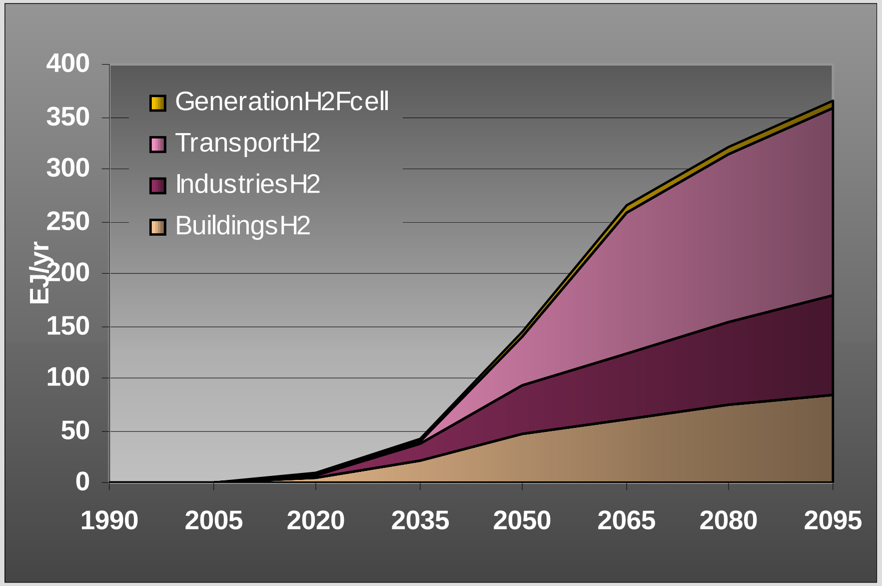
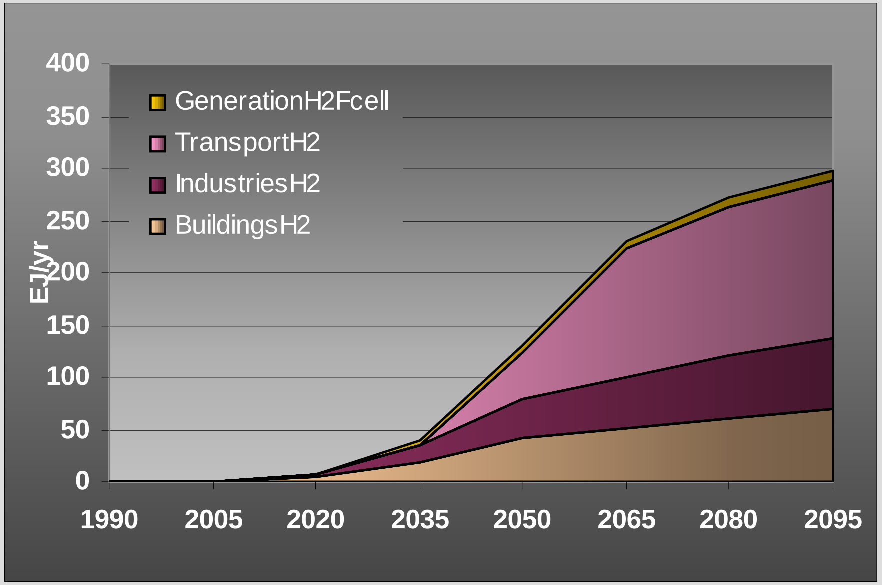
Advanced Technology



MiniCAM B2 550
Advanced Technology



H_2 Use—Exajoules/year

Today’s Discussion

Examples of Advanced Technologies That Could Make A Difference

Carbon Capture & Disposal

Hydrogen & Transportation

Biotechnology

biotech

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

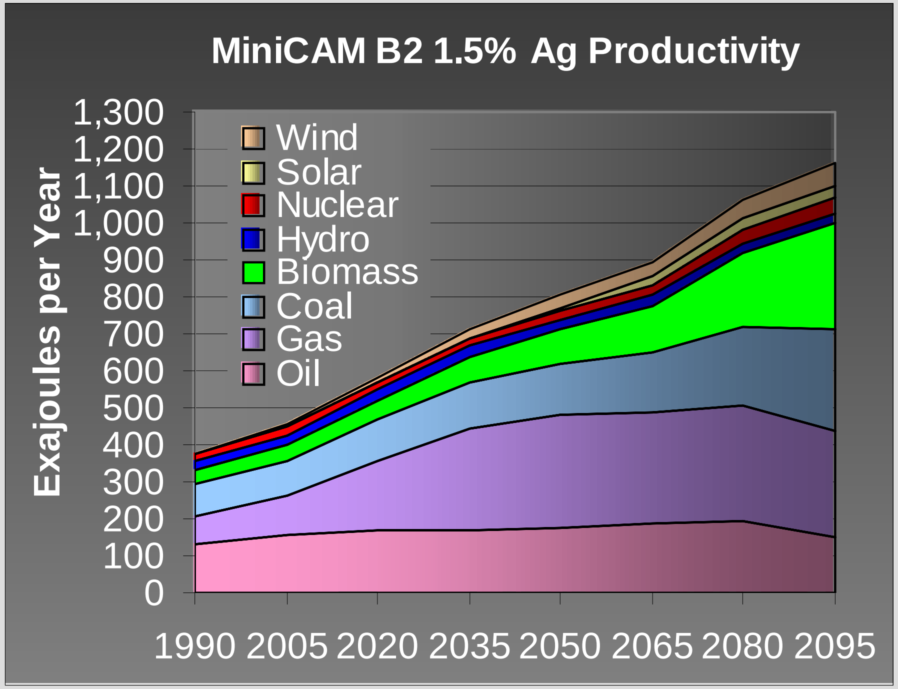
...bio-hydrogen

biotech

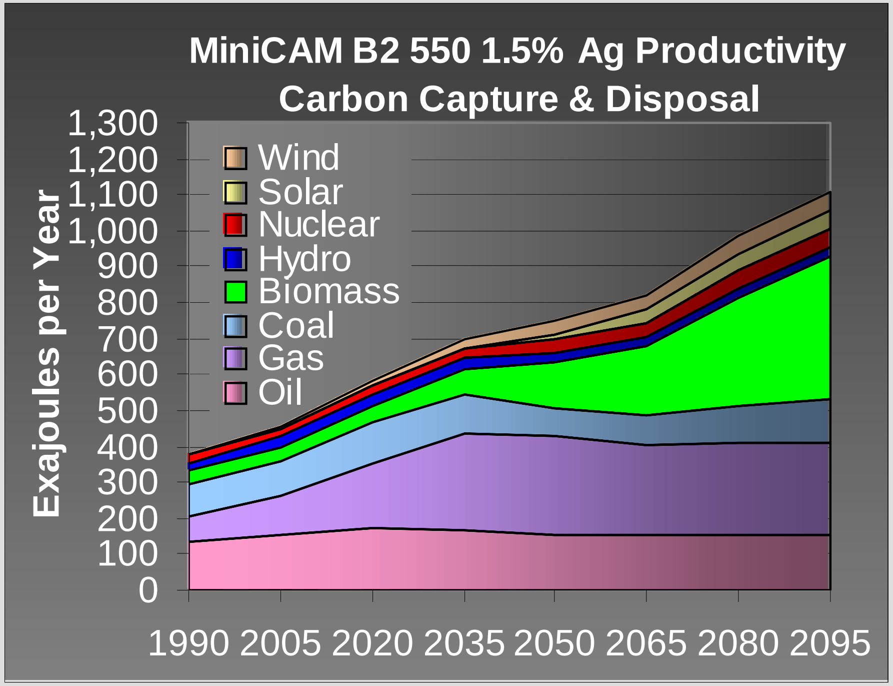
Stabilization implies significant growth in modern commercial biomass.

Primary Energy (EJ/year)

MiniCAM B2 Reference



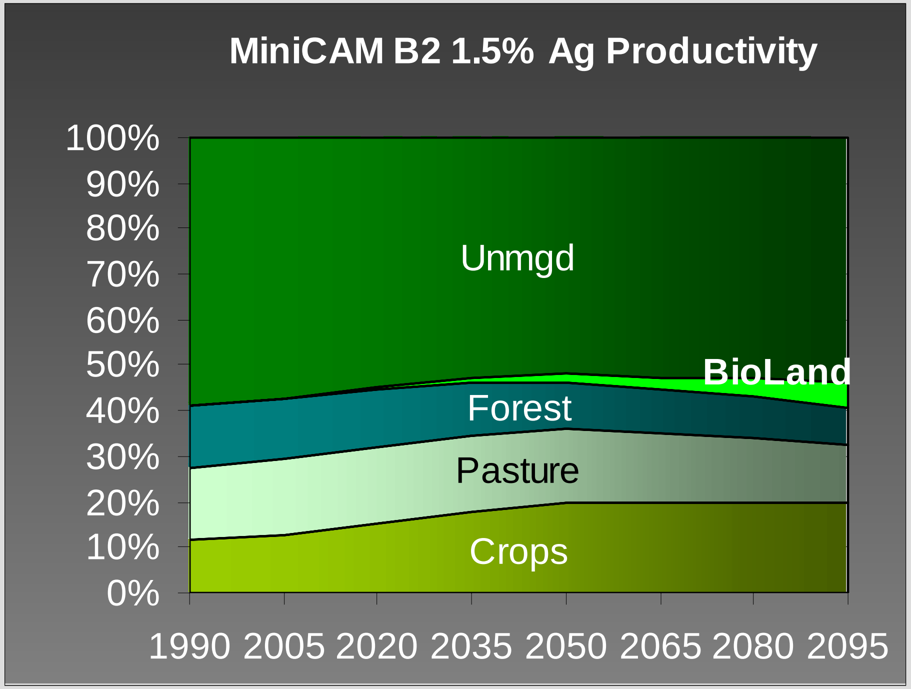
MiniCAM B2 550 Stabilization



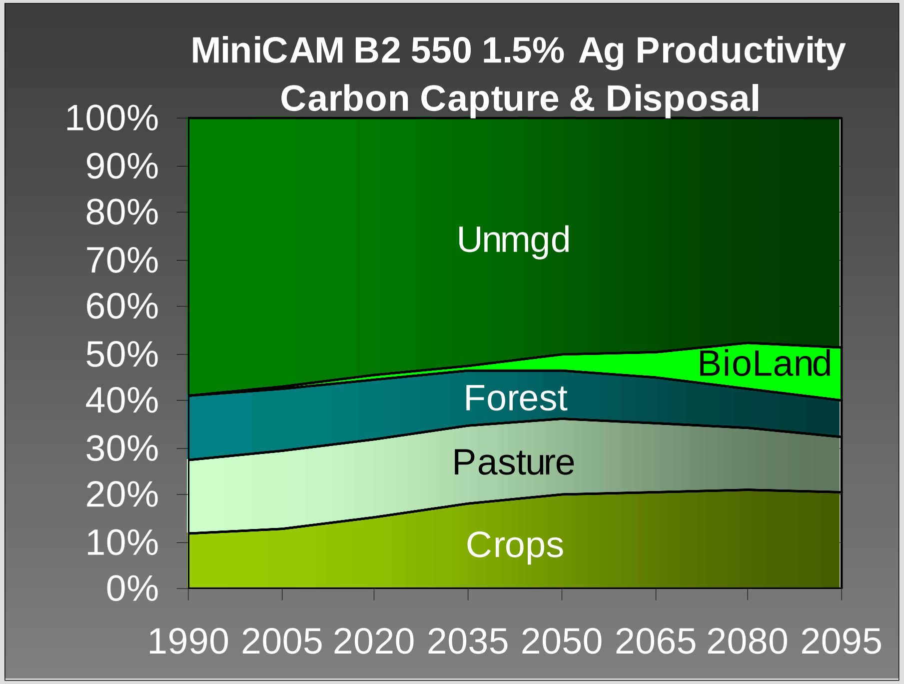
biotech

Stabilization could dramatically change land use.

MiniCAM B2 Reference

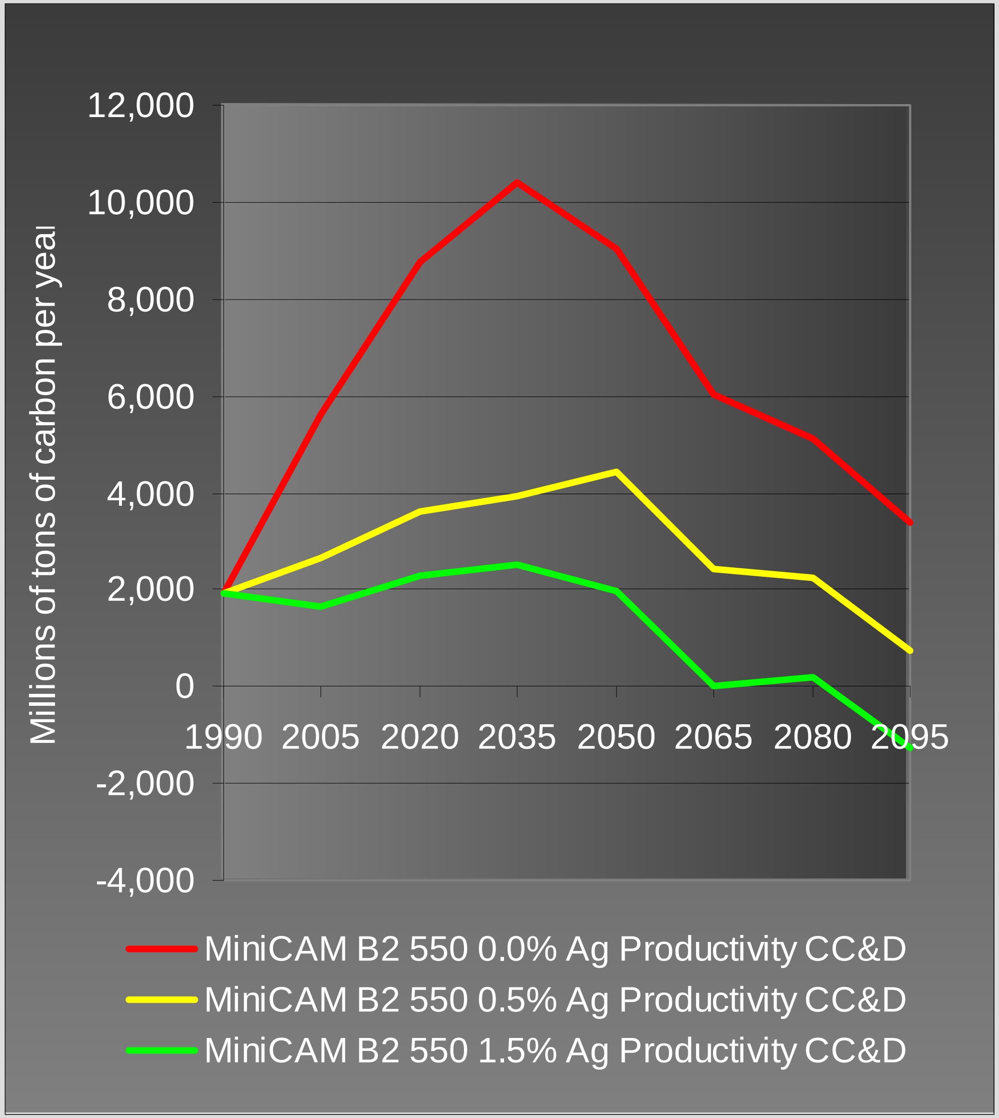


MiniCAM B2 550 Stabilization



biotech

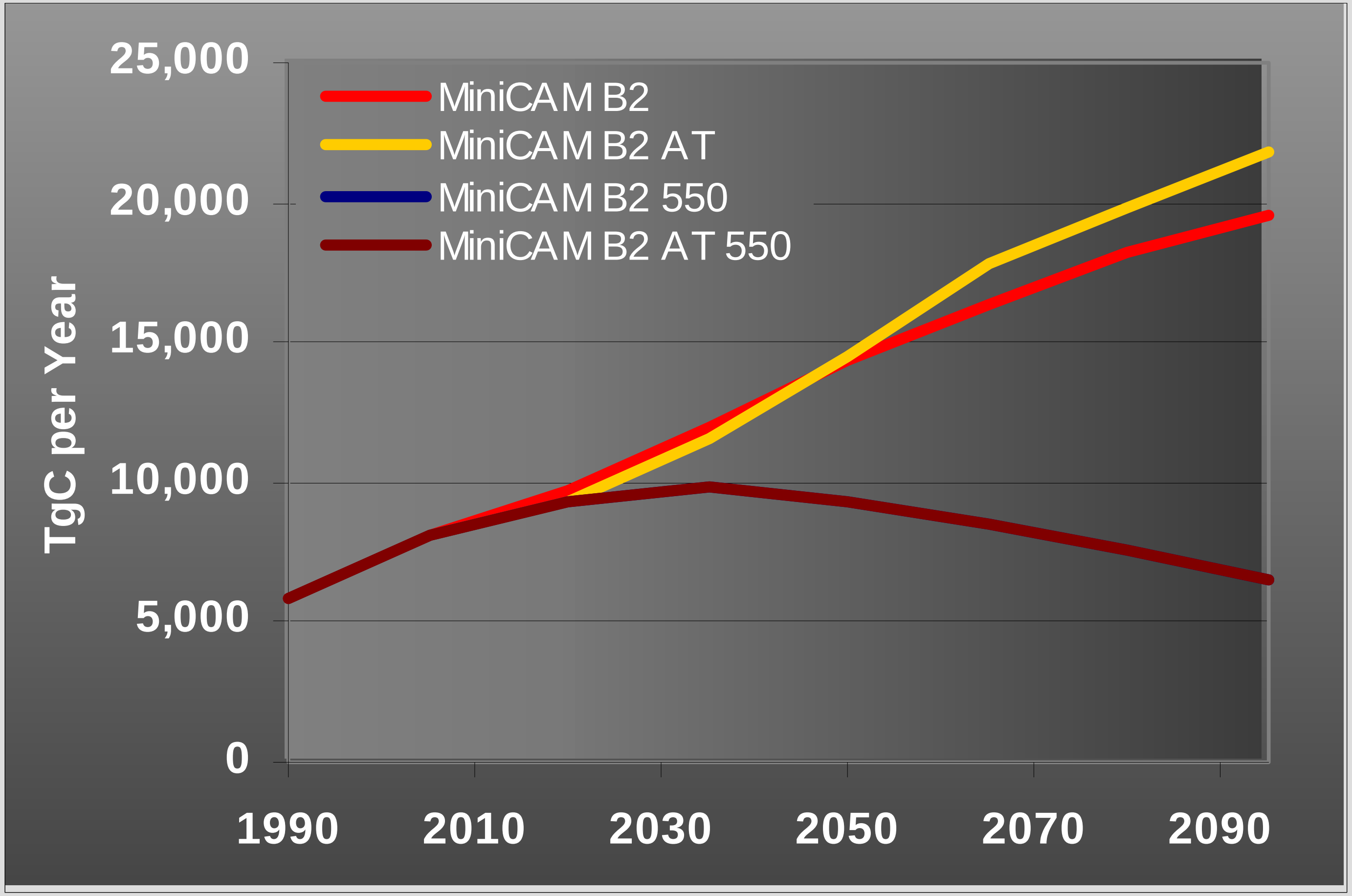
Increasing agricultural productivity dramatically reduces land-use emissions.



Technology & Policy

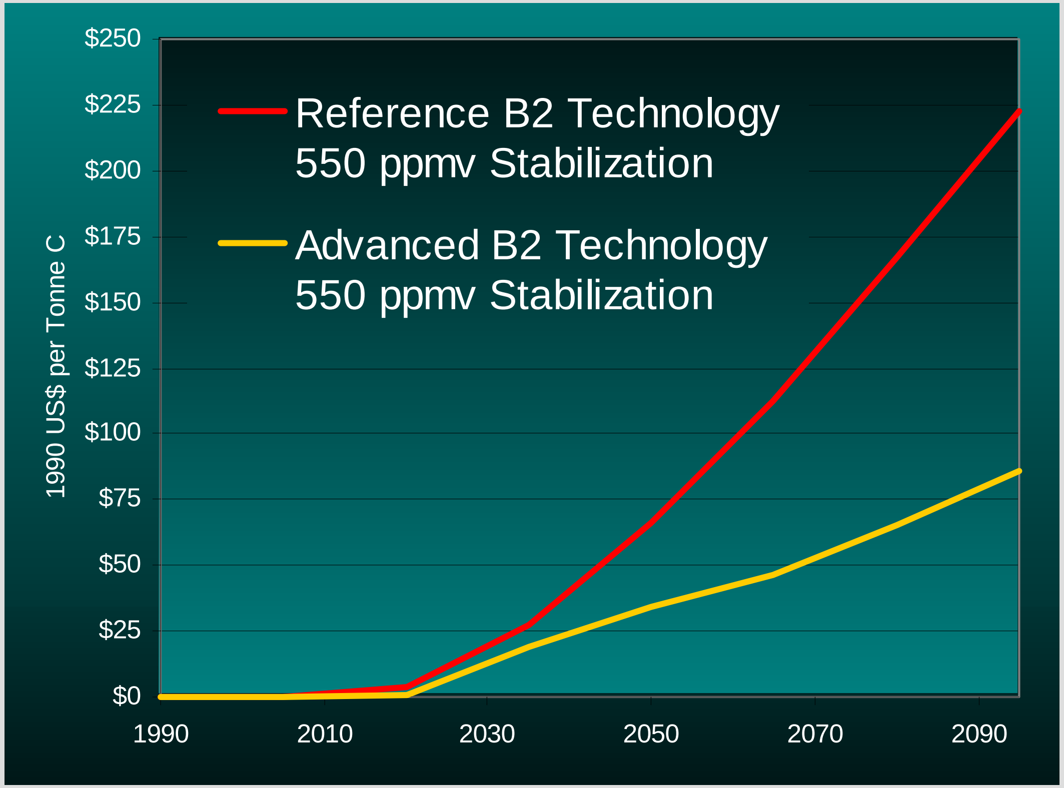
technology & policy

Technology alone may not stabilize CO_2 concentrations.



technology & policy

However, technology can dramatically lower the cost of stabilizing CO_2 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 CO_2 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 CO_2 Concentrations**

  Emissions may rise with enhanced technology. To stabilize CO_2 concentrations, cumulative emissions must be limited.