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WHY CCS?

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with thanks to
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AGENDA

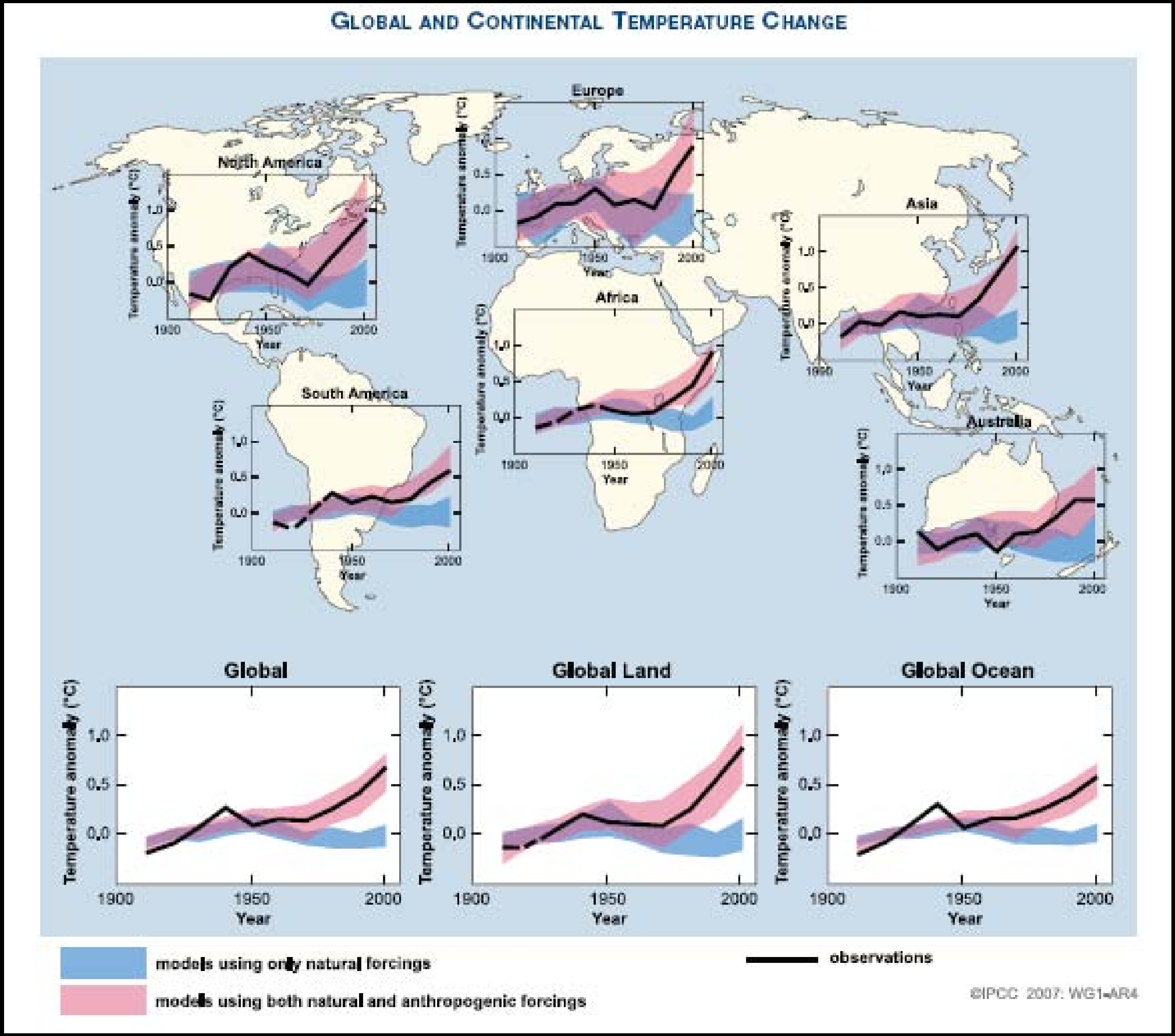
INTRODUCTION
Climate change, What is CCS?, CCS options, Analogs, Monitoring

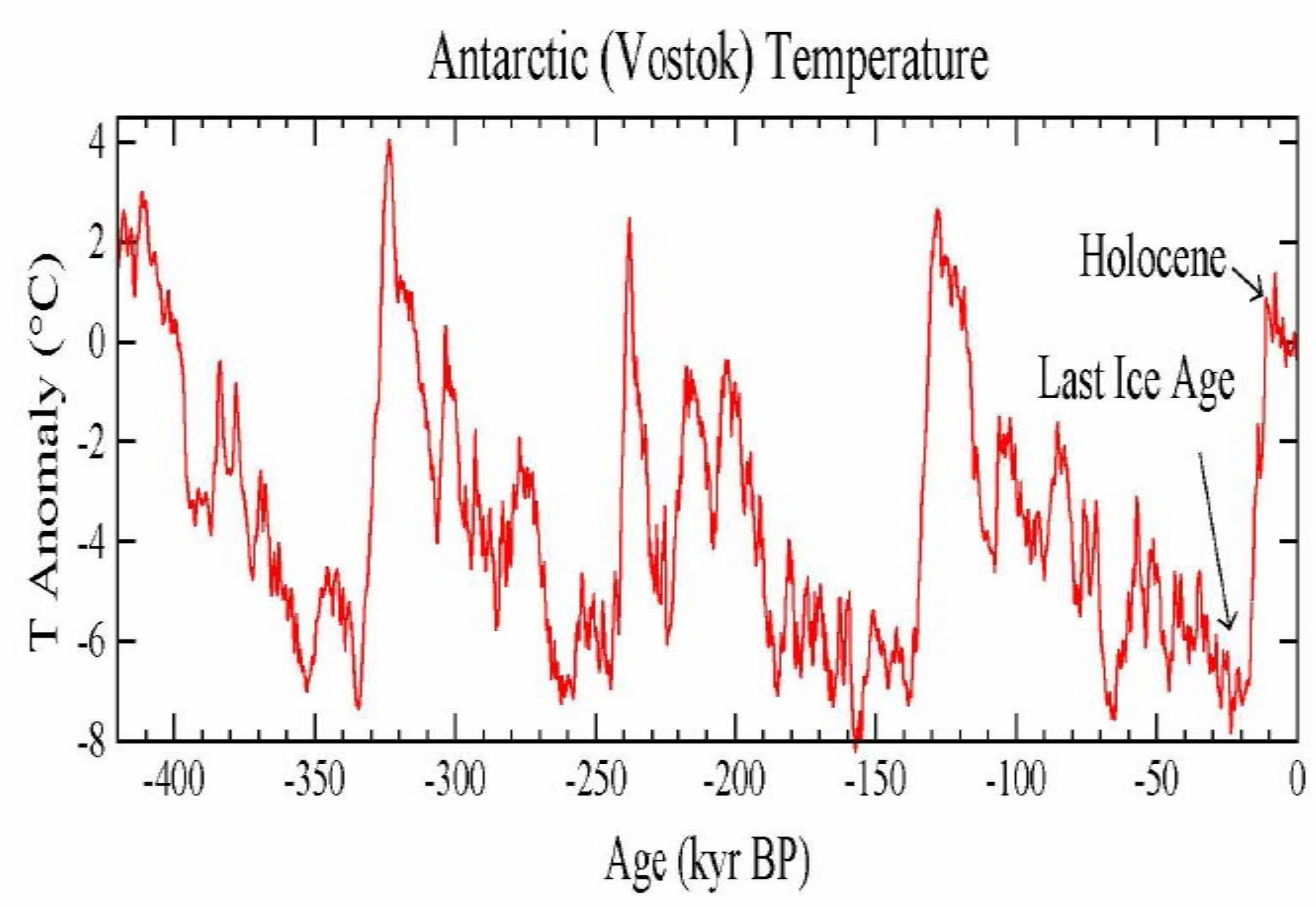
WHY CCS?
Scale of the problem, Scale of the solutions, The role of CCS

WHY NOT CCS?
Can we safely do CCS? How to deploy CCS?

FINAL REMARKS

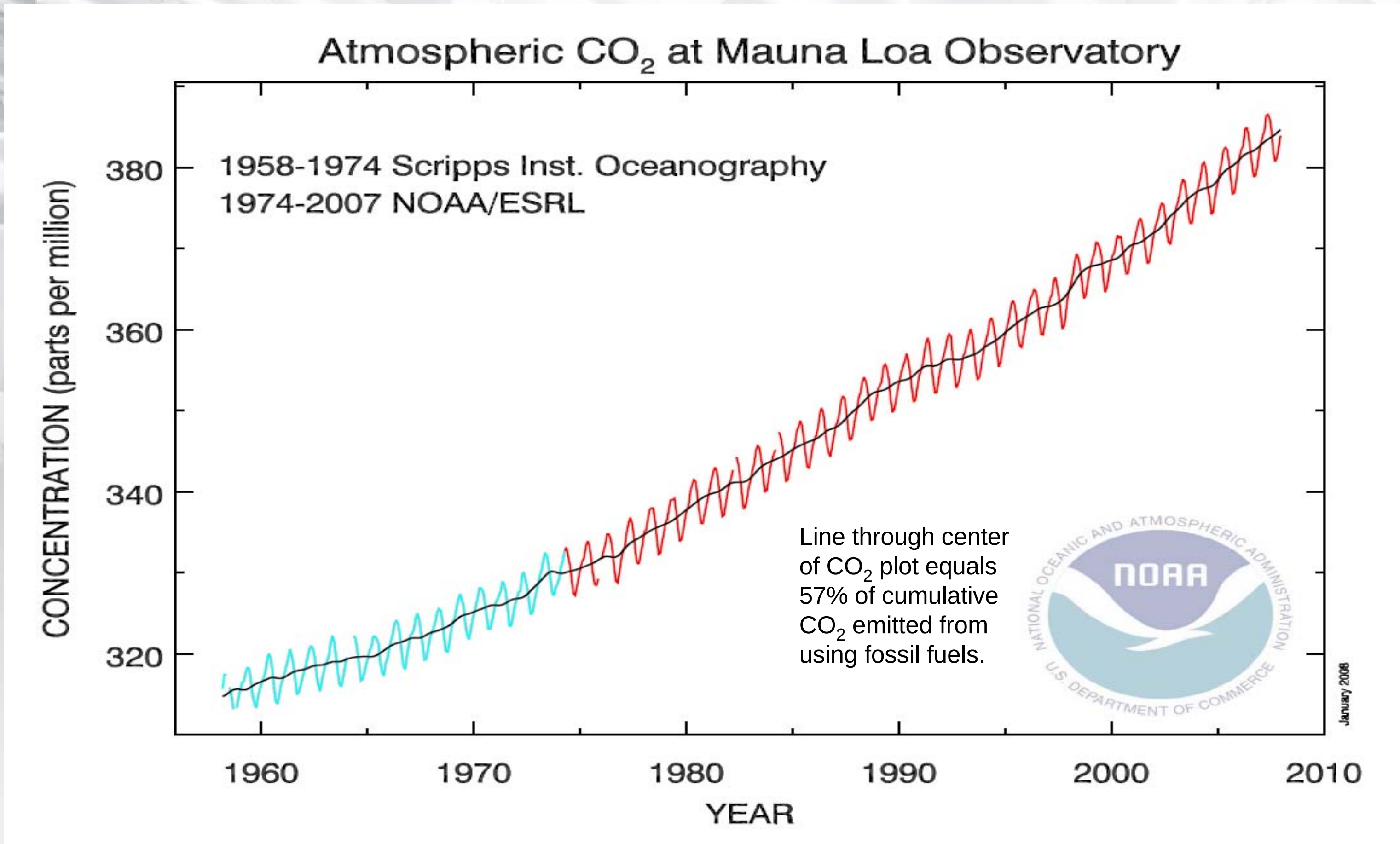
The question of "Why CCS" only makes sense if climate change is induced by human kind…





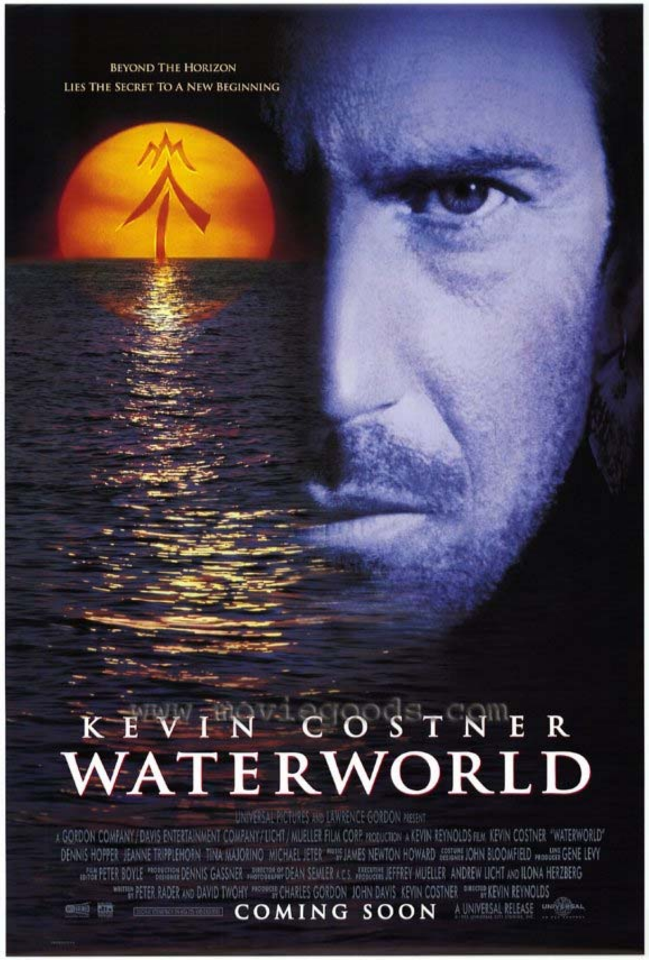
- Earth's history provides most important information on global warming.
- Recorded human history occurs within the Holocene warm period.

Mauna Loa CO_2 Record



Scripps data courtesy of Dr. Ralph Keeling, Scripps Institution of Oceanography, University of California, San Diego.

Will We Soon be Treading Water?

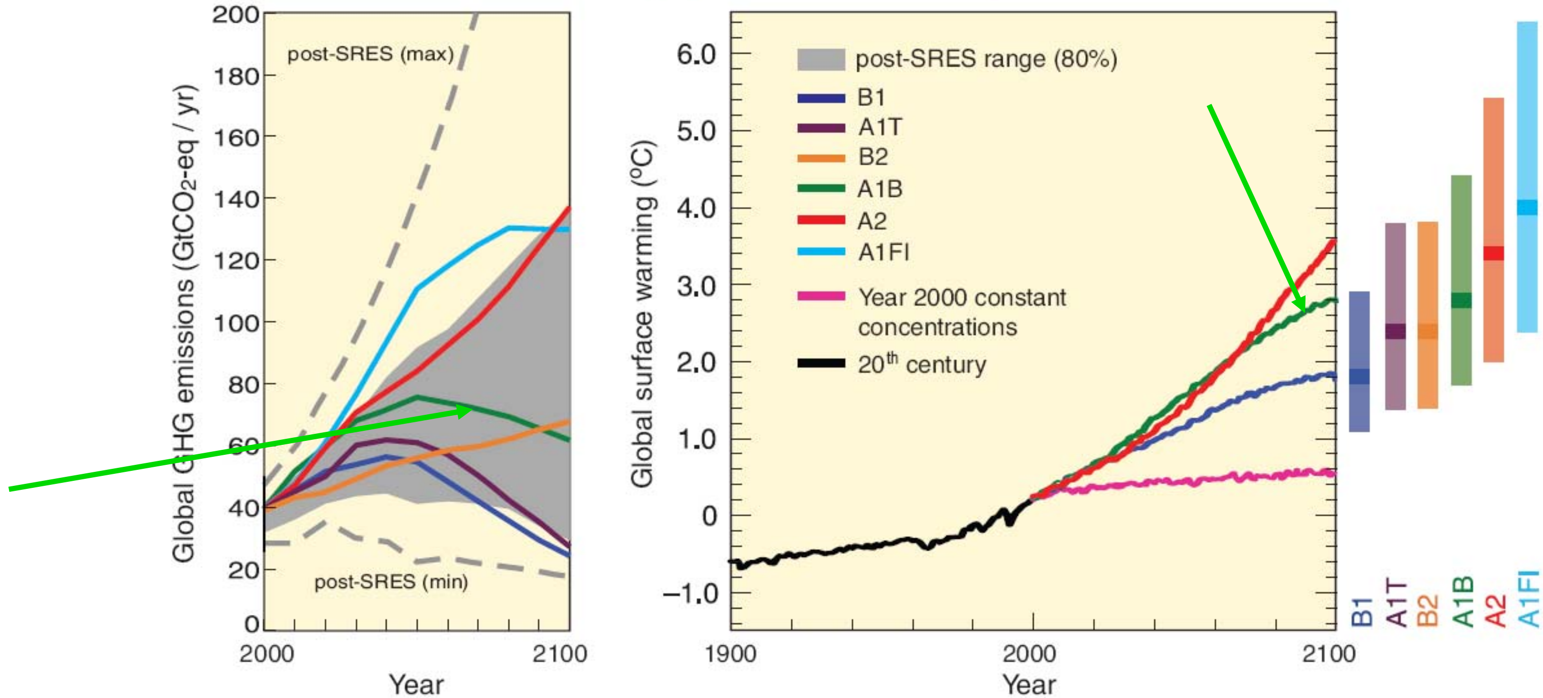


The Day After Tomorrow

Or Will It Be

More Like This?

Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures



Case	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]		Sea level rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations[b]	0.6	0.3 – 0.9	Not available
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Greenland Melt descending into a moulin, a vertical shaft carrying water to ice sheet base.

Source: Roger Braithwaite, University of Manchester (UK)

How much Could Ice Sheets Affect Sea Level Rise?

If small glaciers and polar ice caps on the margins of Greenland and the Antarctic Peninsula melt, the projected rise in sea level will be around 0.5 m.

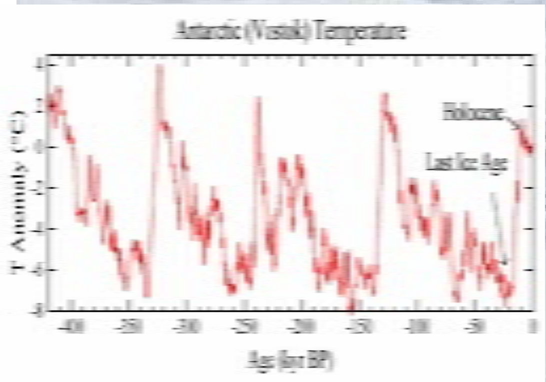
- Melting of the Greenland ice Sheet would produce 7.2 m of sea-level rise

- The collapse of the grounded interior reservoir of the West Antarctic Ice Sheet would raise sea level by 5-6 m.

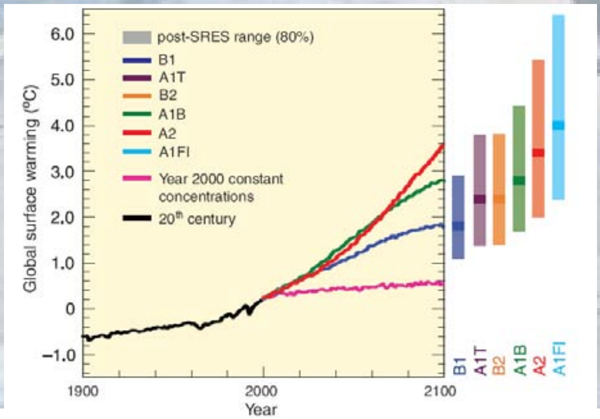
- Melting of the Antactic ice sheet would produce 61.1 m of sea level rise. Most of the Greenland and Antarctic ice sheets lie above the snowline and/or base of the permafrost zone -- they cannot melt in a timeframe much less than several millennia. It is unlikely that they will contribute significantly to sea level rise in the coming century. They can, however, do so through acceleration in flow and enhanced iceberg calving.

- Interesting but irrelevant factoid: Since the peak of the last ice age, over 20,000 years ago, sea levels have risen about 120 meters.

And Then There Are All Those Other Annoying Questions, Such As Species Extinction, Ocean Acidification, Droughts, Storms, etc.



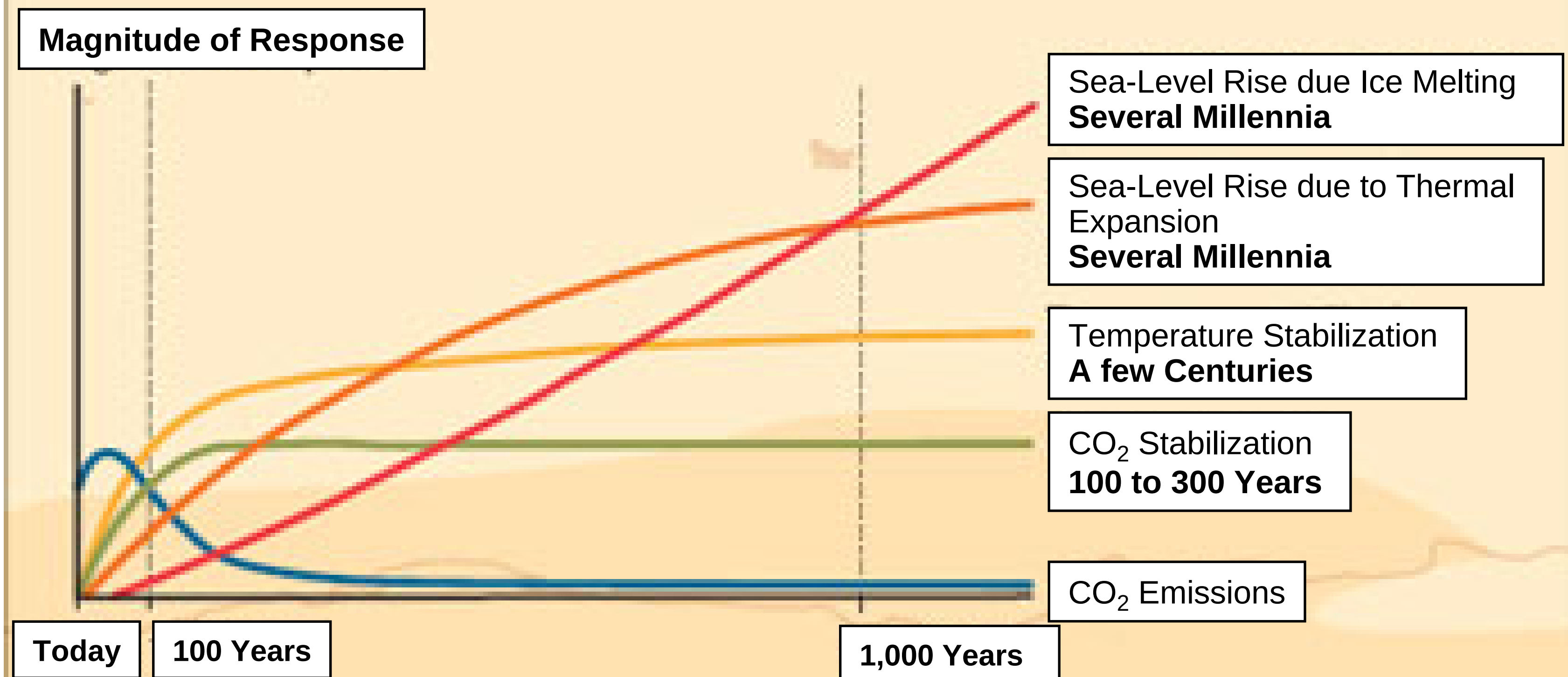
Instead of 1000(s) of years per degree C of climate change, we are heading toward decades per degree C change.



There is *medium confidence* that approximately 20 to 30% of species assessed so far are *likely* to be at increased risk of extinction if increases in global average warming exceed 1.5 to 2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40 to 70% of species assessed) around the globe. (IPCC Fourth Assessment)

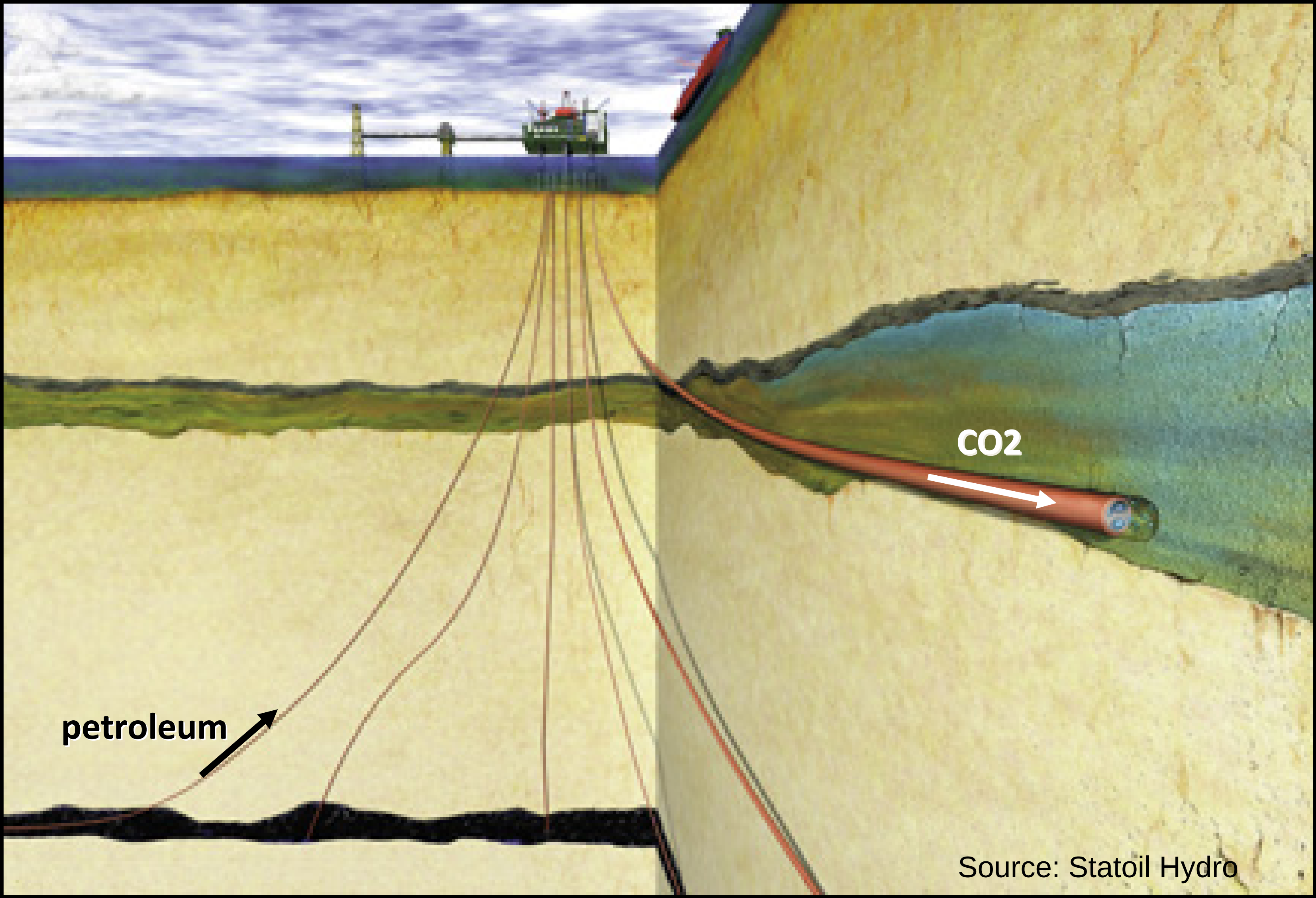
Time to Equilibrium

Climate-change experts predict that even when GHG emissions are curtailed, their effects on the environment will continue to be felt for hundreds, if not thousands, of years.

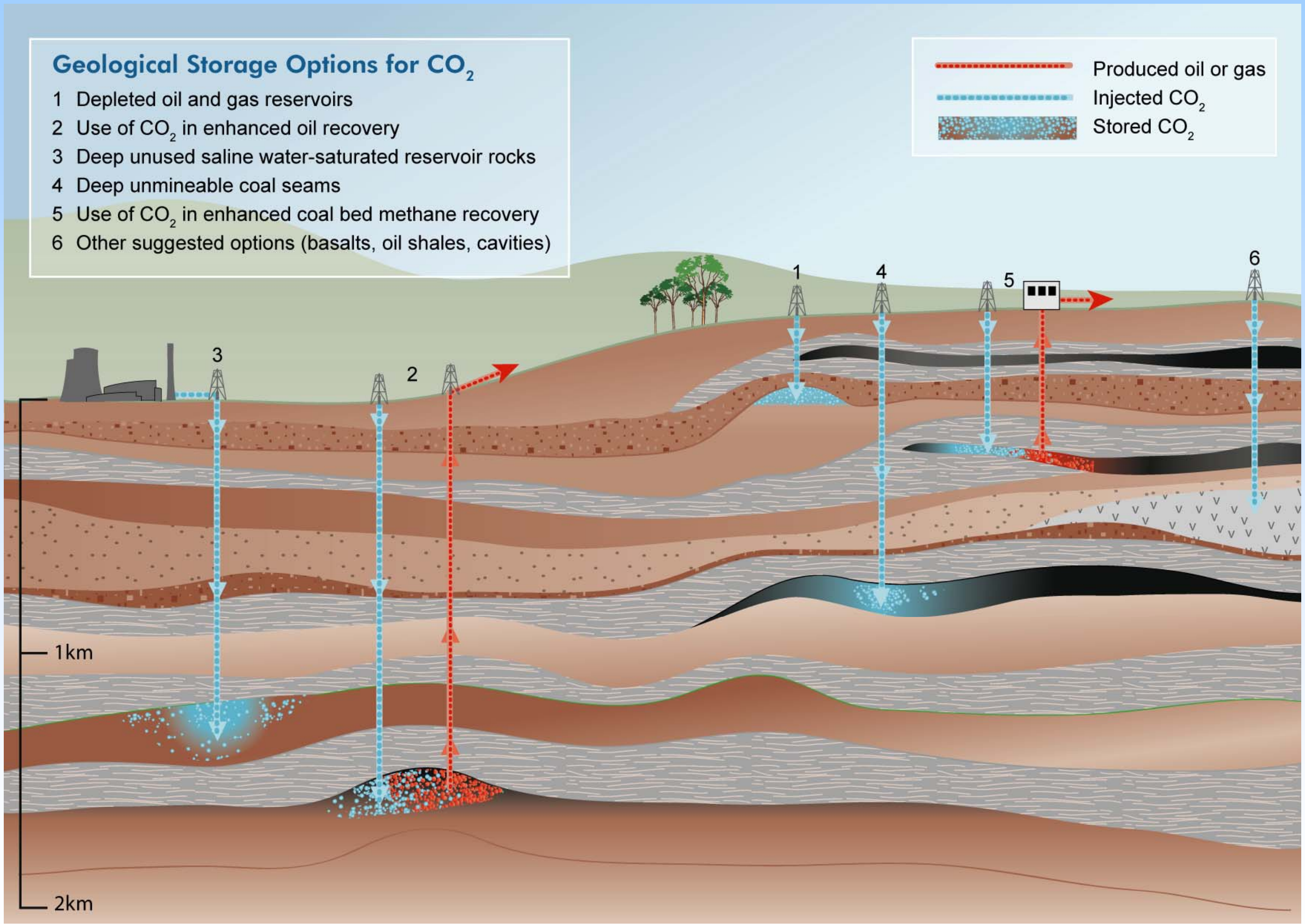


Jones-Thompson, Maryanne, “Engineering Climate”, *Technology Review*, MIT, March 2005

CCS to the Rescue!
"Putting carbon back to the ground".

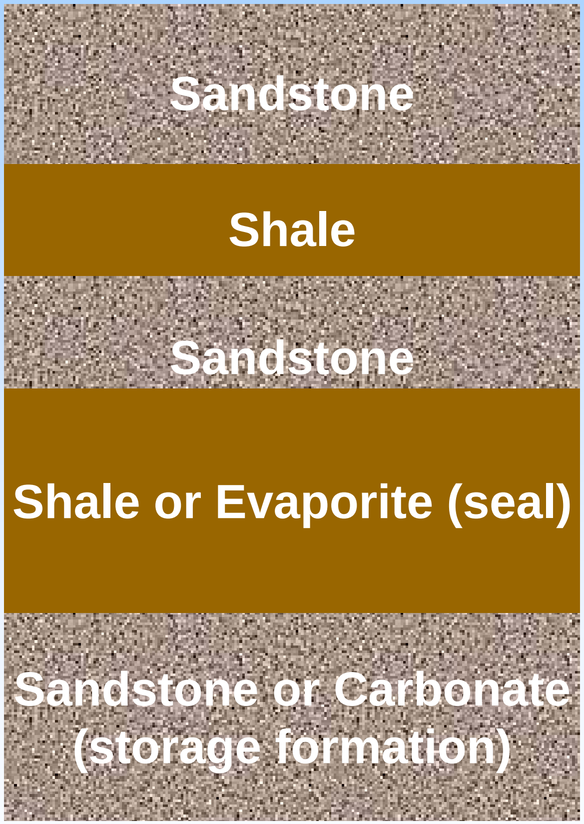


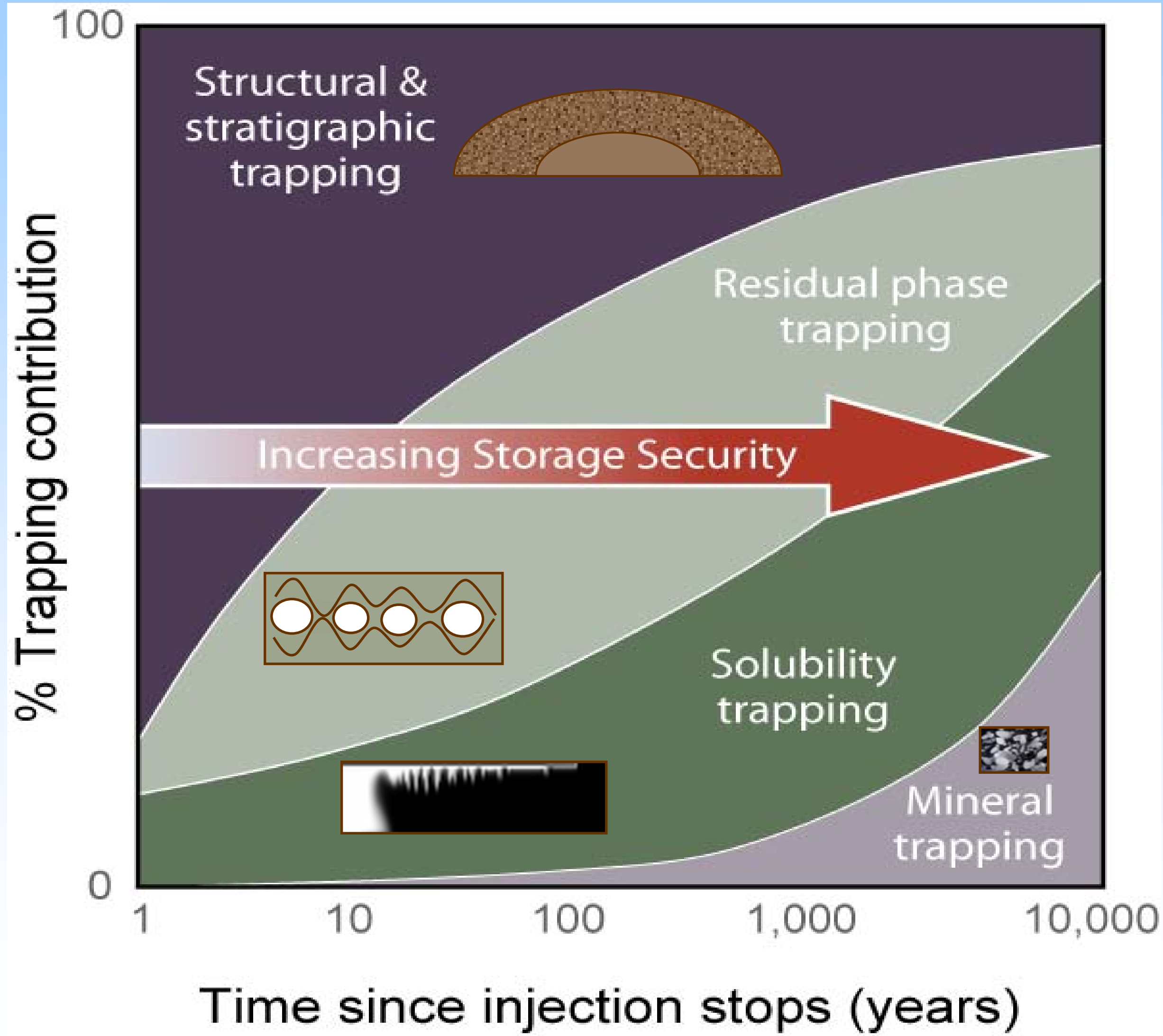
Options for Geological Storage



http://www.ipcc.ch/activity/csspm.pdf

Primary and Secondary Trapping Mechanisms





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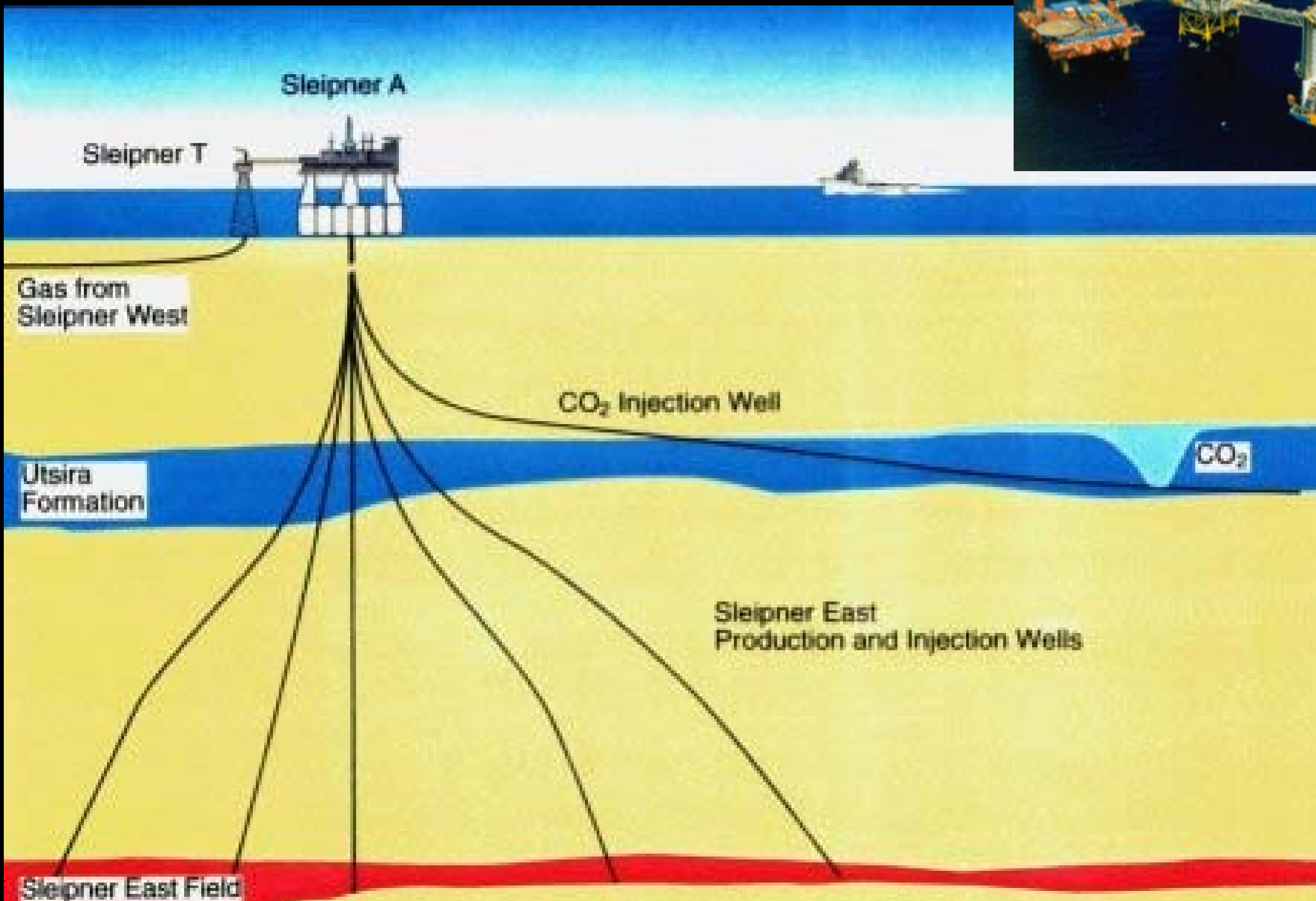
In Salah Project, Algeria (BP)

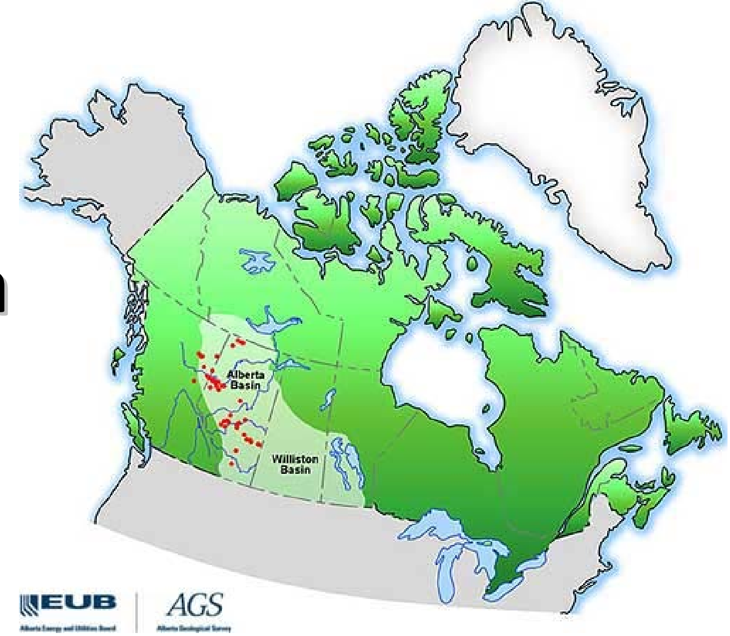
Source: BP

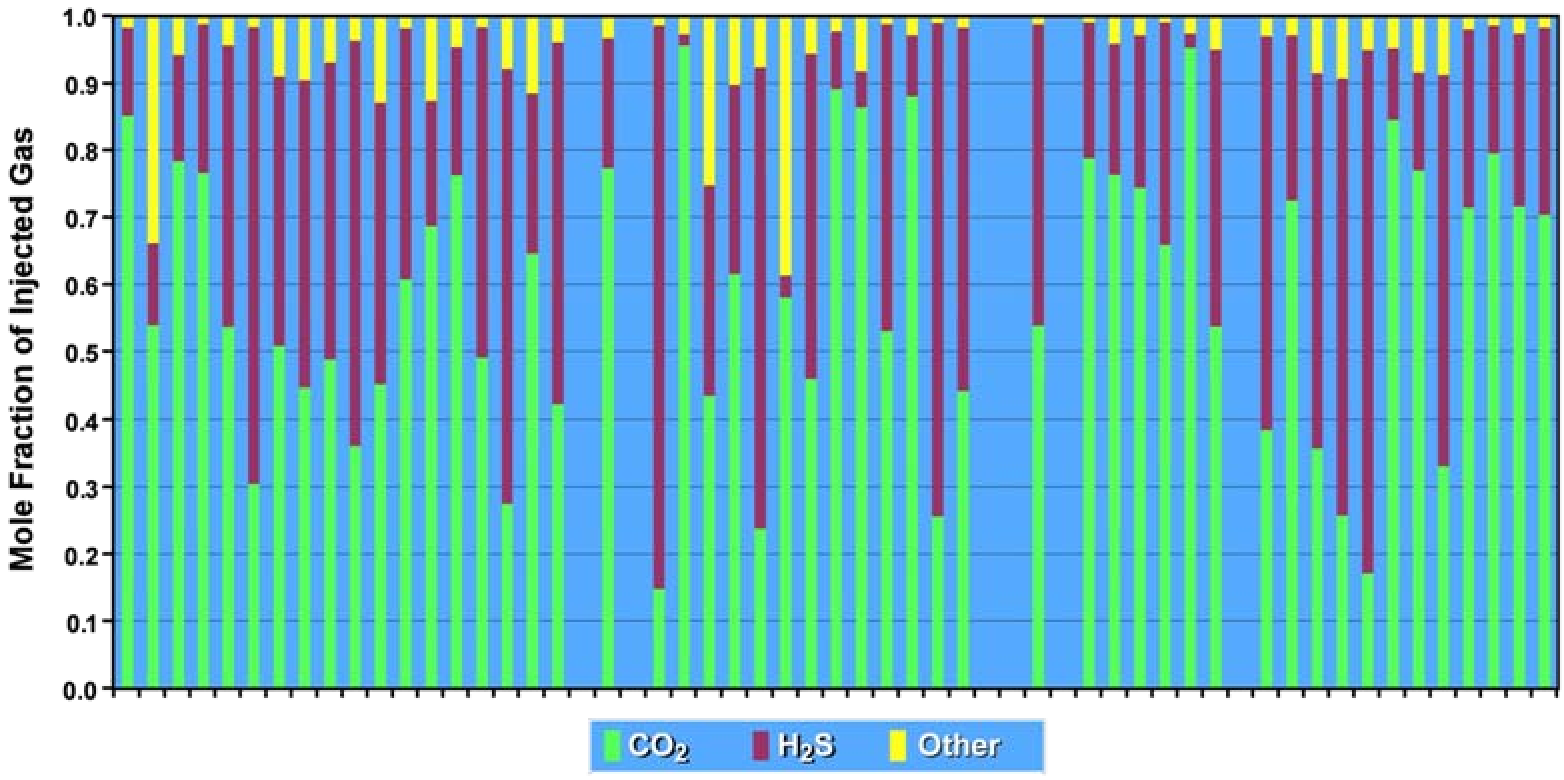
SACS (Saline Aquifer CO2 Storage) Offshore Norway, Statoil Hydro



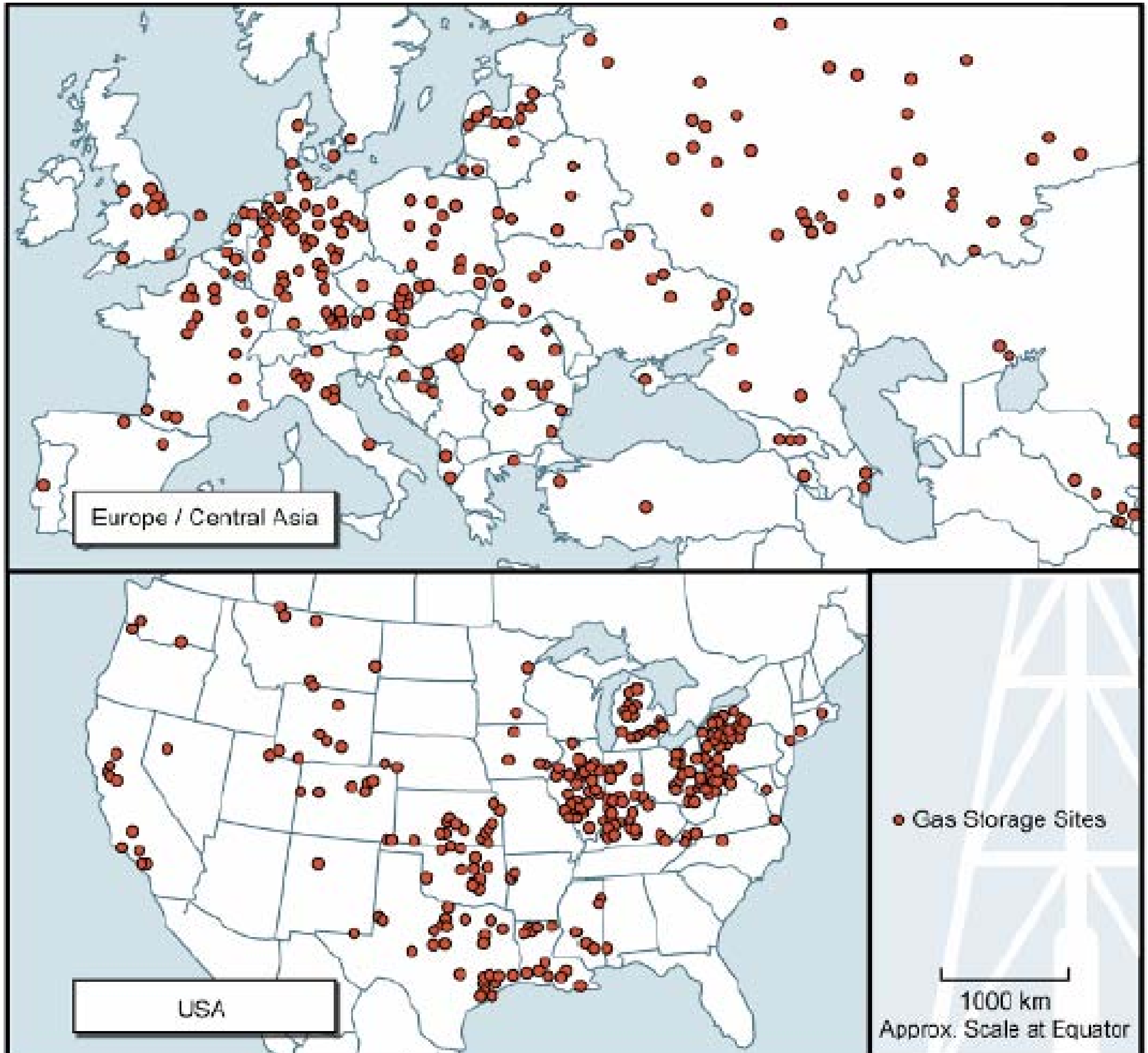
Analogs for CO_2 storage

Acid gas storage in Canada

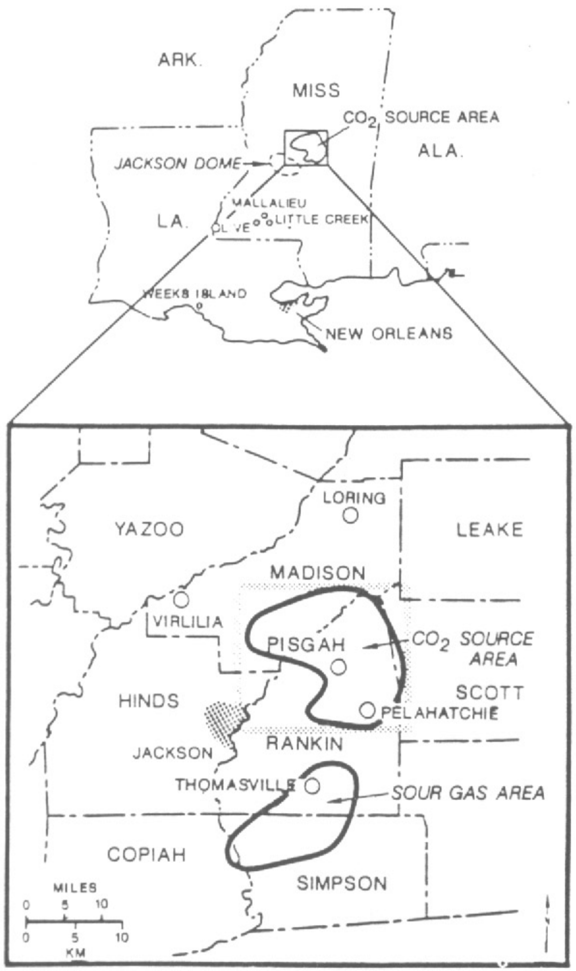




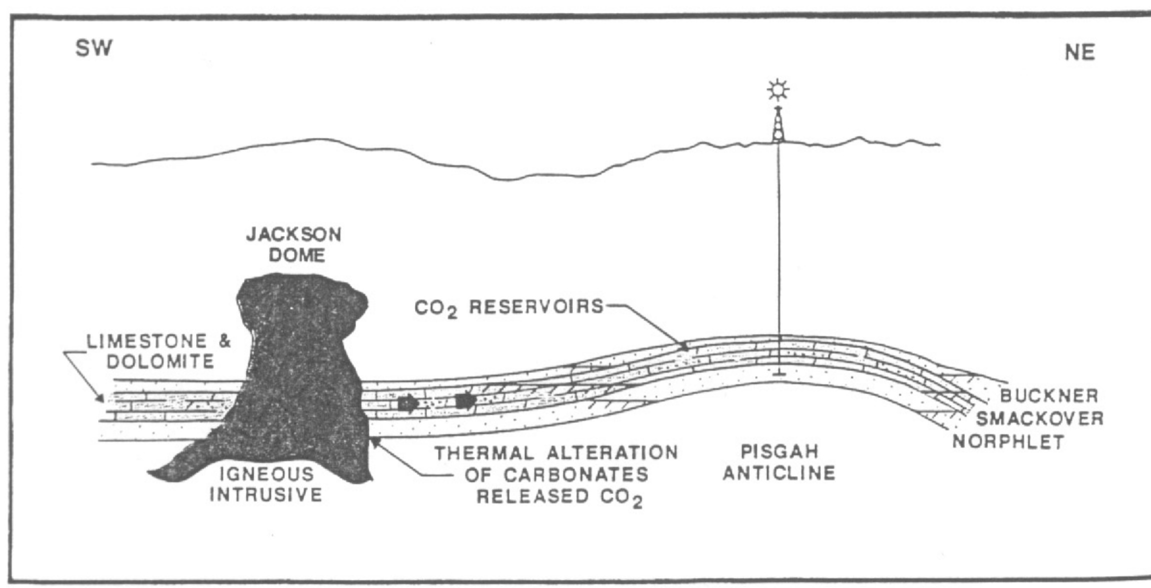
Natural gas storage sites in Europe and USA (caverns and reservoirs)



Natural CO_2 field, Norphlet Formation, Mississippi

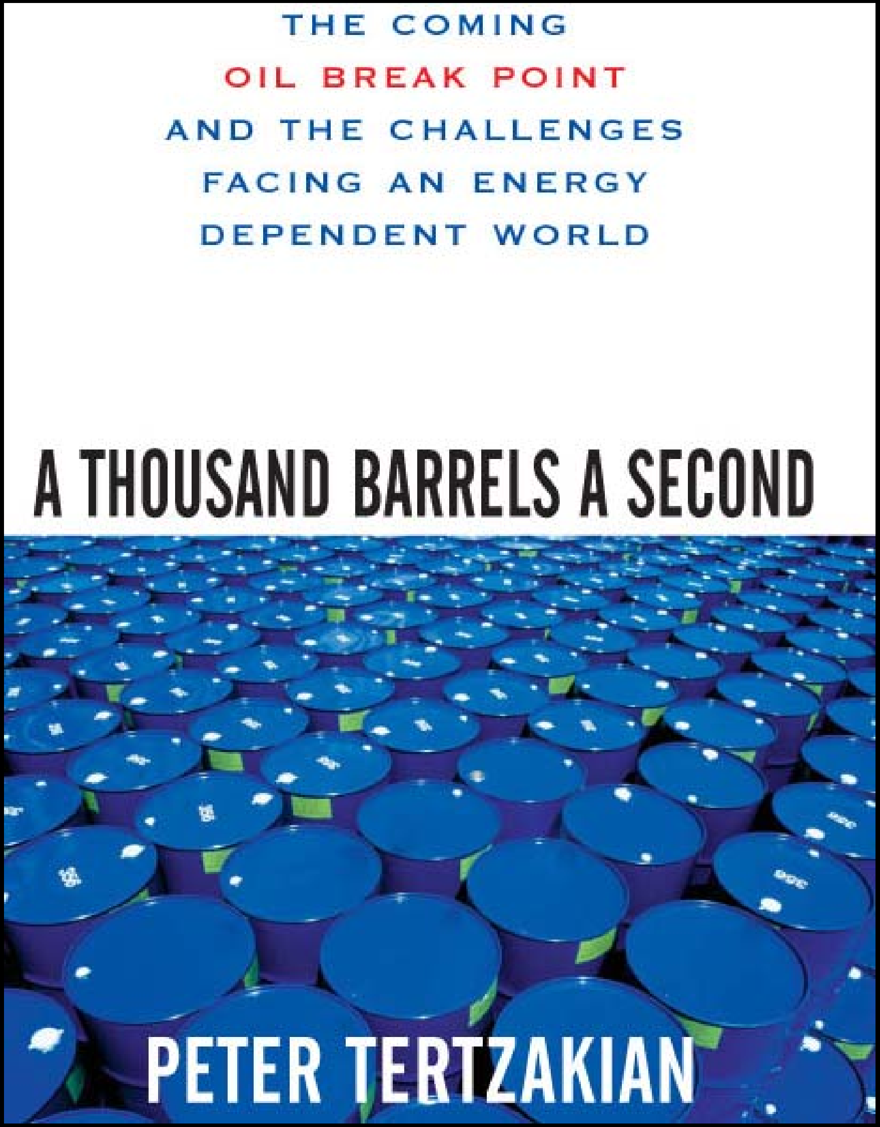


- Jurassic aeolian sandstones
- Original CO_2 column: 154 m
- CO_2-water contact: 4.827 m
- Purity: > 98% CO_2 (3-120 ppm H_2S)
- Original volume in-place: 2,0 TCF ($5,7 \times 10^{10}$ m^3)
- Recovery 65%
- Operators: Shell, Chevron
- Discovered in 1967
- CO_2 piped to Mississippi and Louisiana oil fields for EOR



Scale of the problem

Any viable option must consider the present-day and future great dependency of fossil fuels



Scale of the Problem – USA

U.S. emits roughly 6 billion tons per year, currently

Under a reference case scenario, cumulative CO_2 emissions 2004-2100 are expected to be 1 trillion tons

Enough to fill Lake Erie with liquid CO_2 almost twice or cover the entire state of Utah with a blanket of liquid CO_2 14 foot thick.

Lake Erie volume, 113 cubic miles

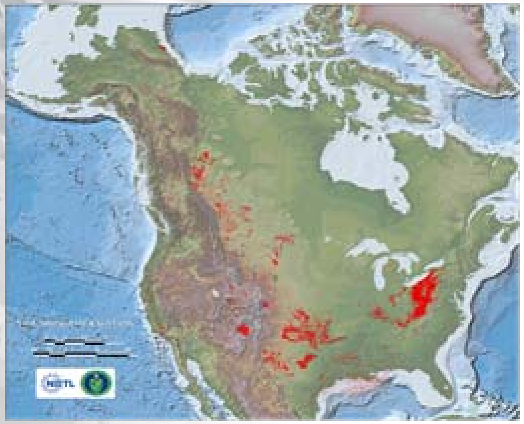
1 x 10^{12} tons CO_2 * 2000 lb/ton*ft^3/68 lb *(1 mile / 5,380 ft)^3/1 mile = 200 cubic miles

U.S. CO_2 emissions increase 60% between 2004 and 2050, 30% between 2051 and 2100

National Atlas Highlights

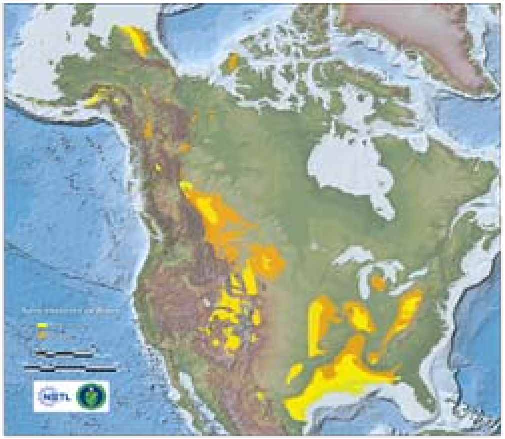
Adequate storage projected

U.S. Emissions ~ 6 GT CO_2/yr all sources



Oil and Gas Fields

Saline Formations



Unmineable Coal Seams

North American CO_2 Storage Potential (Giga Tons)

Conservative Resource Assessment

Sink Type	Low	High
Saline Formations	969	3,223
Unmineable Coal Seams	70	97
Oil and Gas Fields	82	83

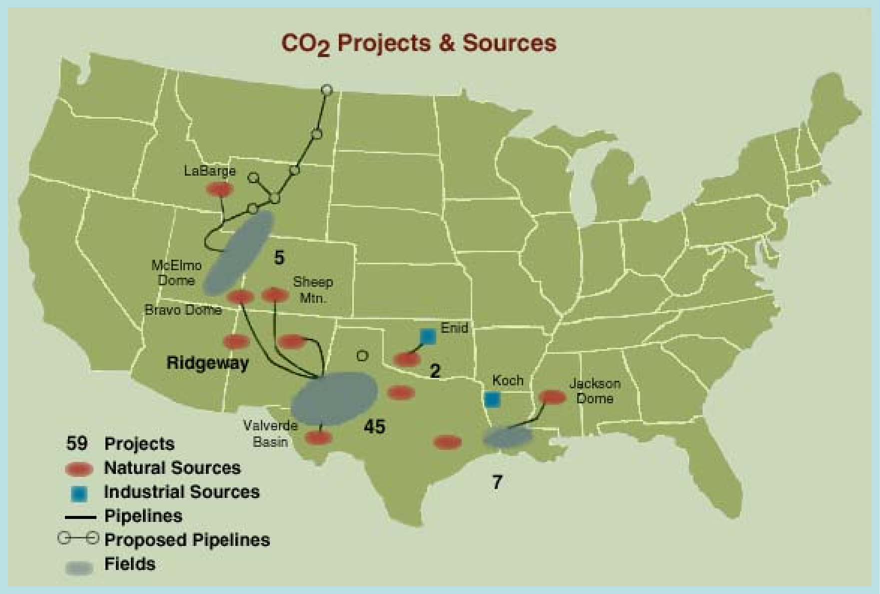
Hundreds of Years of Storage Potential

Available for download at http://www.netl.doe.gov/publications/carbon_seq/refshelf.html

Ensuring the Safety and Permanence of CCS

Multiple Lines of Evidence Indicate Storage Can Be Secure and Effective

1. Natural analogues
   - Oil and gas reservoirs
   - CO_2 formations
2. Industrial analogues
   - CO_2 EOR
   - Natural gas storage
   - Liquid waste disposal
3. Existing projects
   - Sleipner, Off-shore Norway
   - Weyburn, Canada
   - In Salah, Algeria
4. Fundamental physical and chemical processes
5. Numerical simulation of long term performance



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Storage security and trapping mechanisms in a time framework

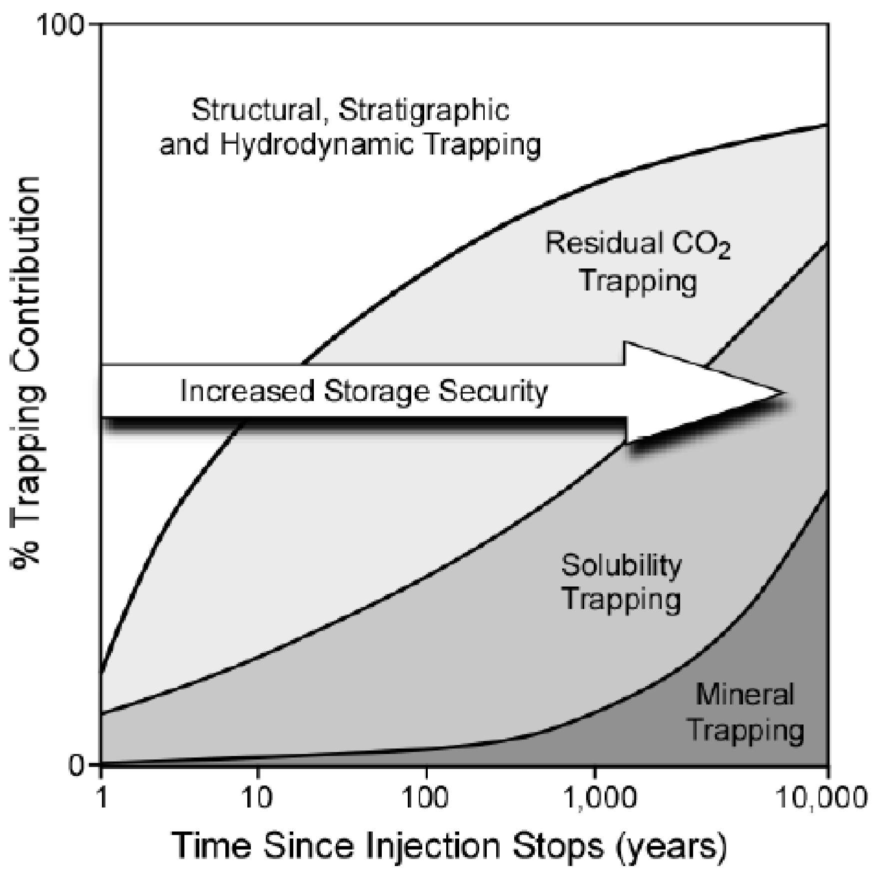

Figure 2. Contribution and storage security of various CO_2 geological-storage mechanisms (from IPCC, 2005).

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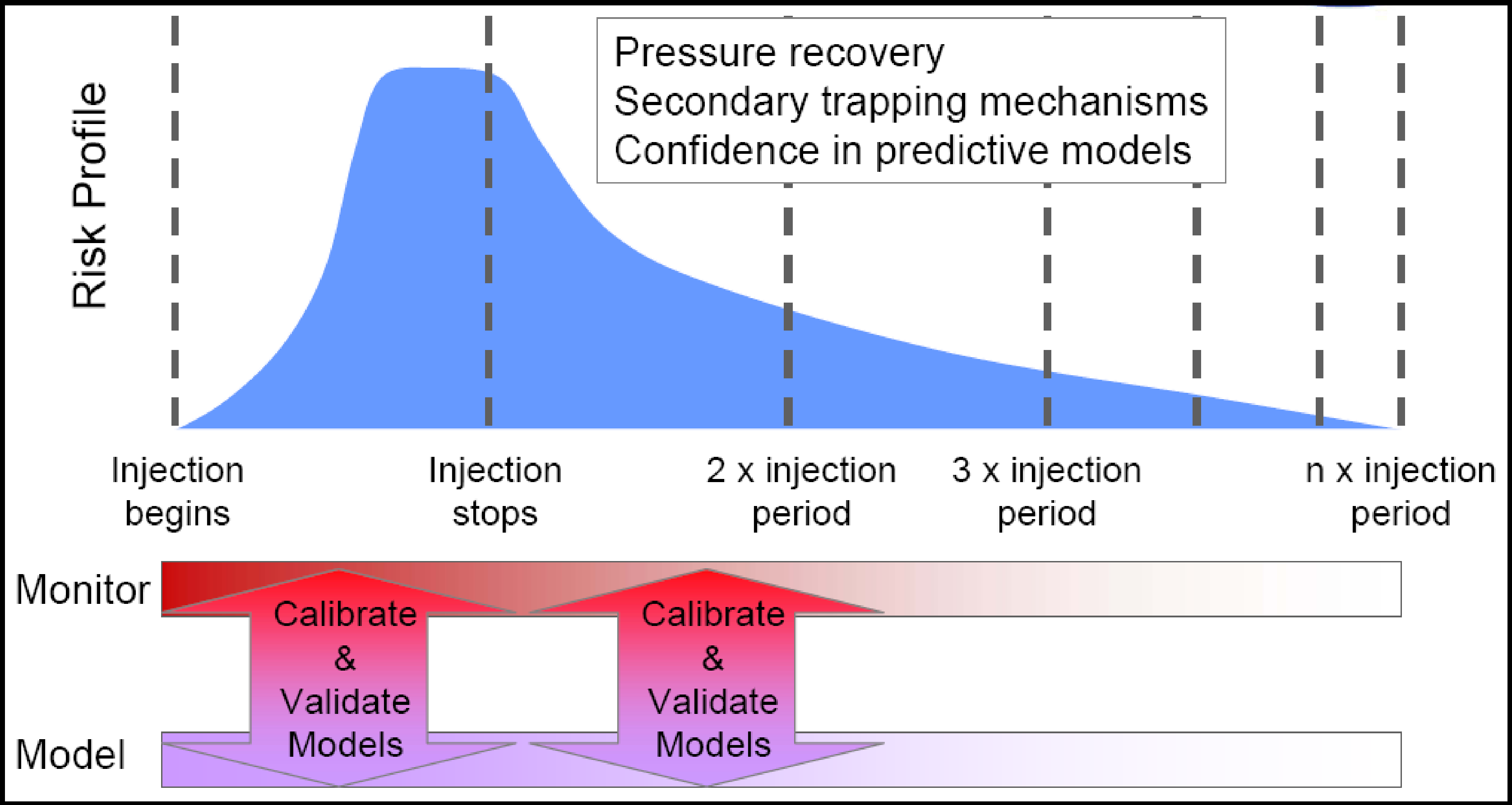
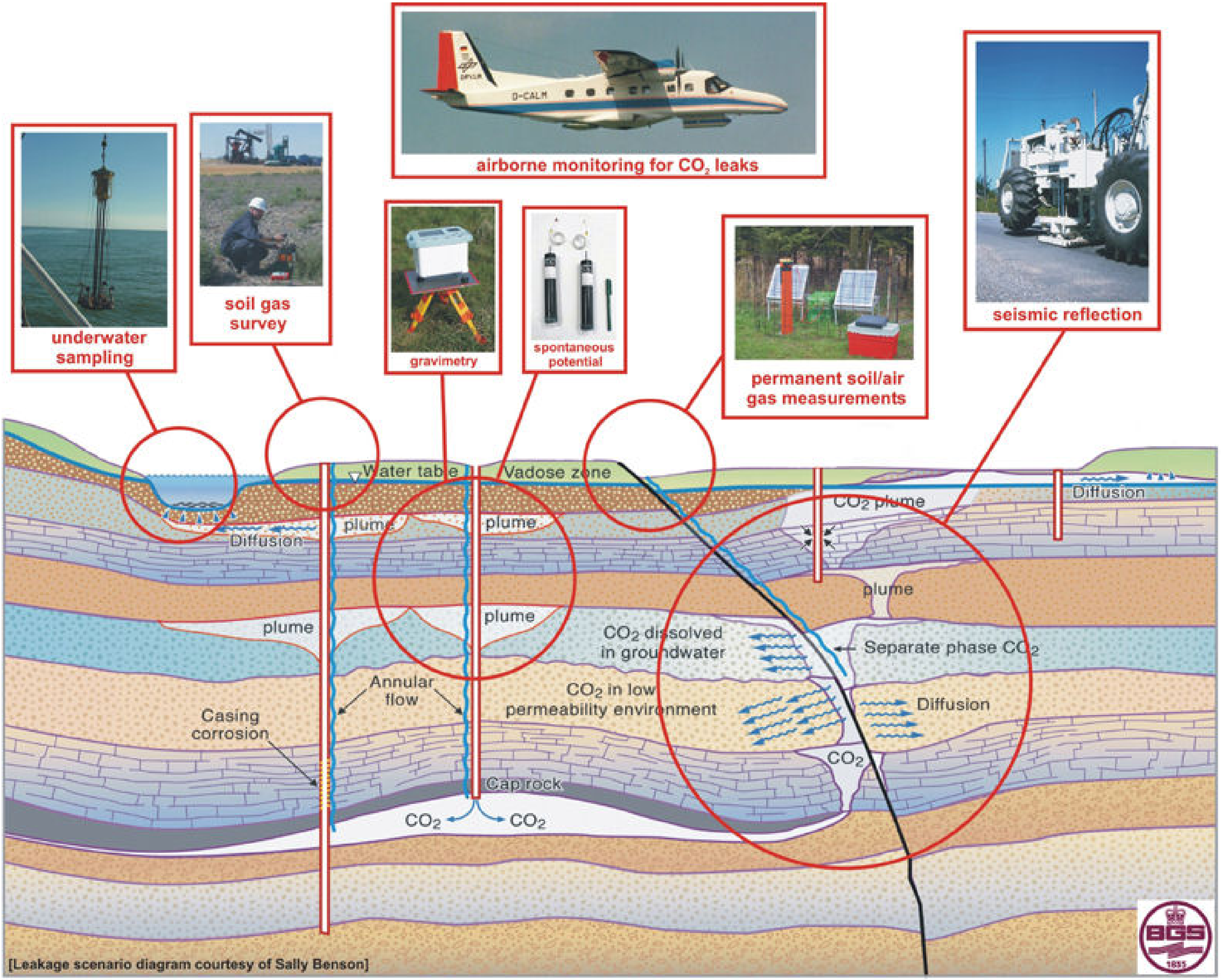
Risk (leakage) profile in time



(from Myer, CSFL workshop Brazil)

Monitoring, Accounting and Verification of Stored CO_2



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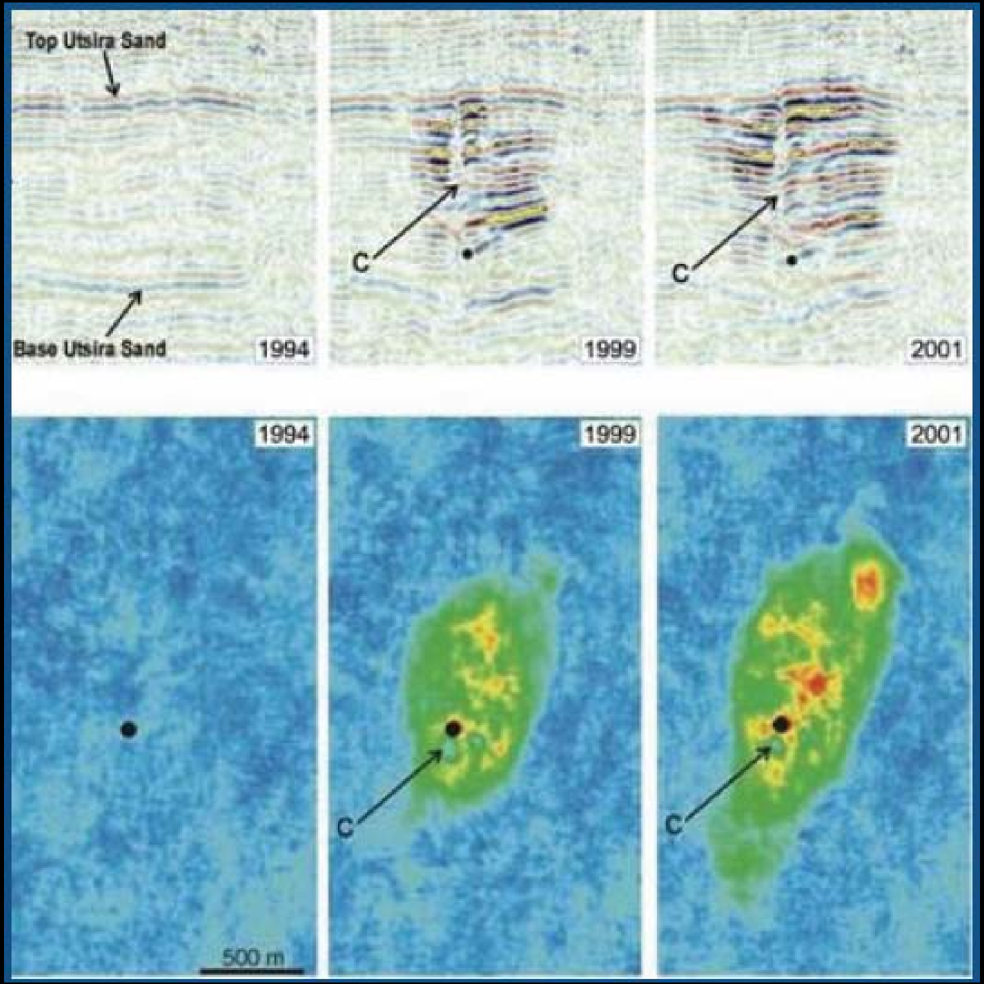
4D Seismic survey in the Utsira Formation (offshore Norway)



BUT……

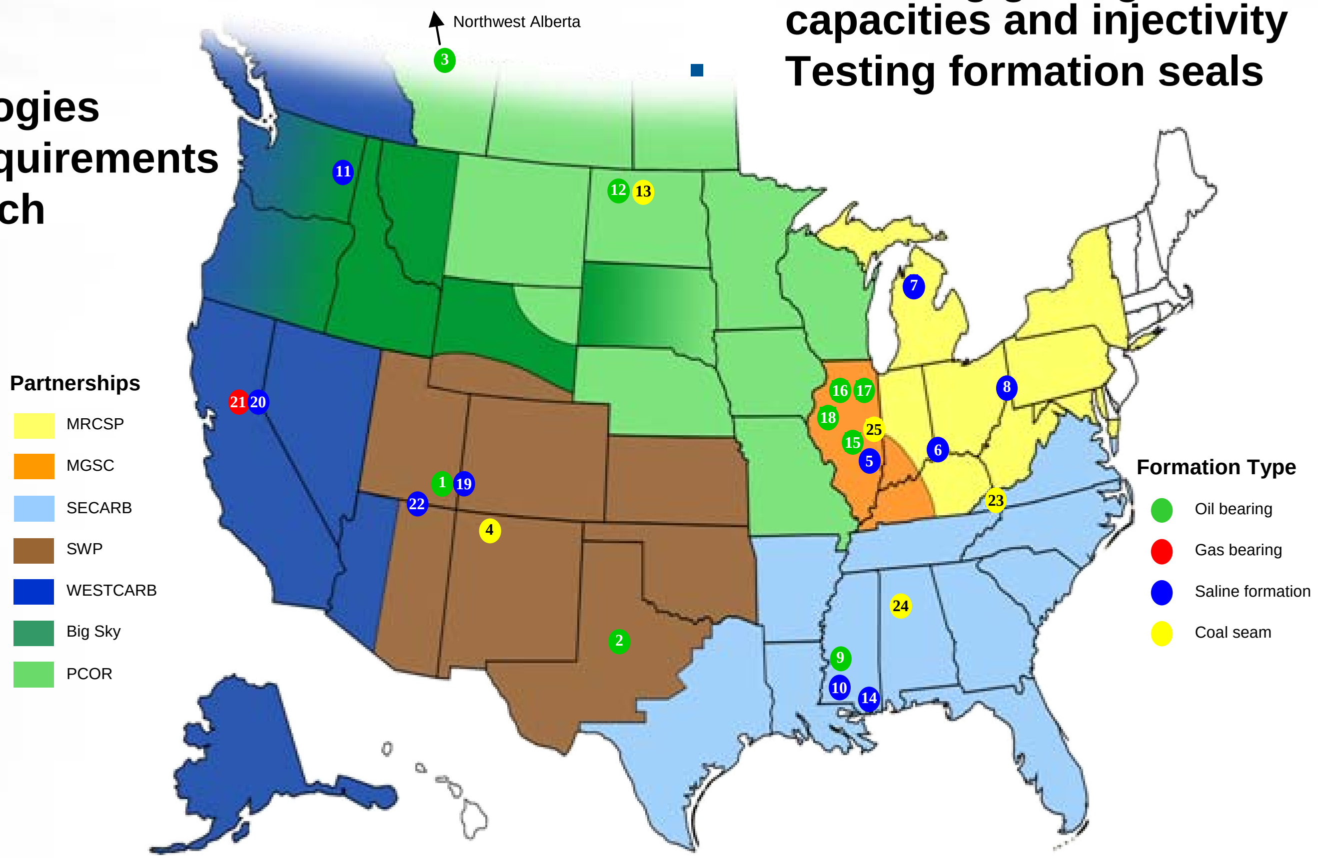
CCS is expensive, still needs to be demonstrated in large scale (several Mt/year/site), and requires more fossils fuels to operate (ca. 25% more in a coal fired power plant).

Phase II Field Validation

25 Geologic Tests

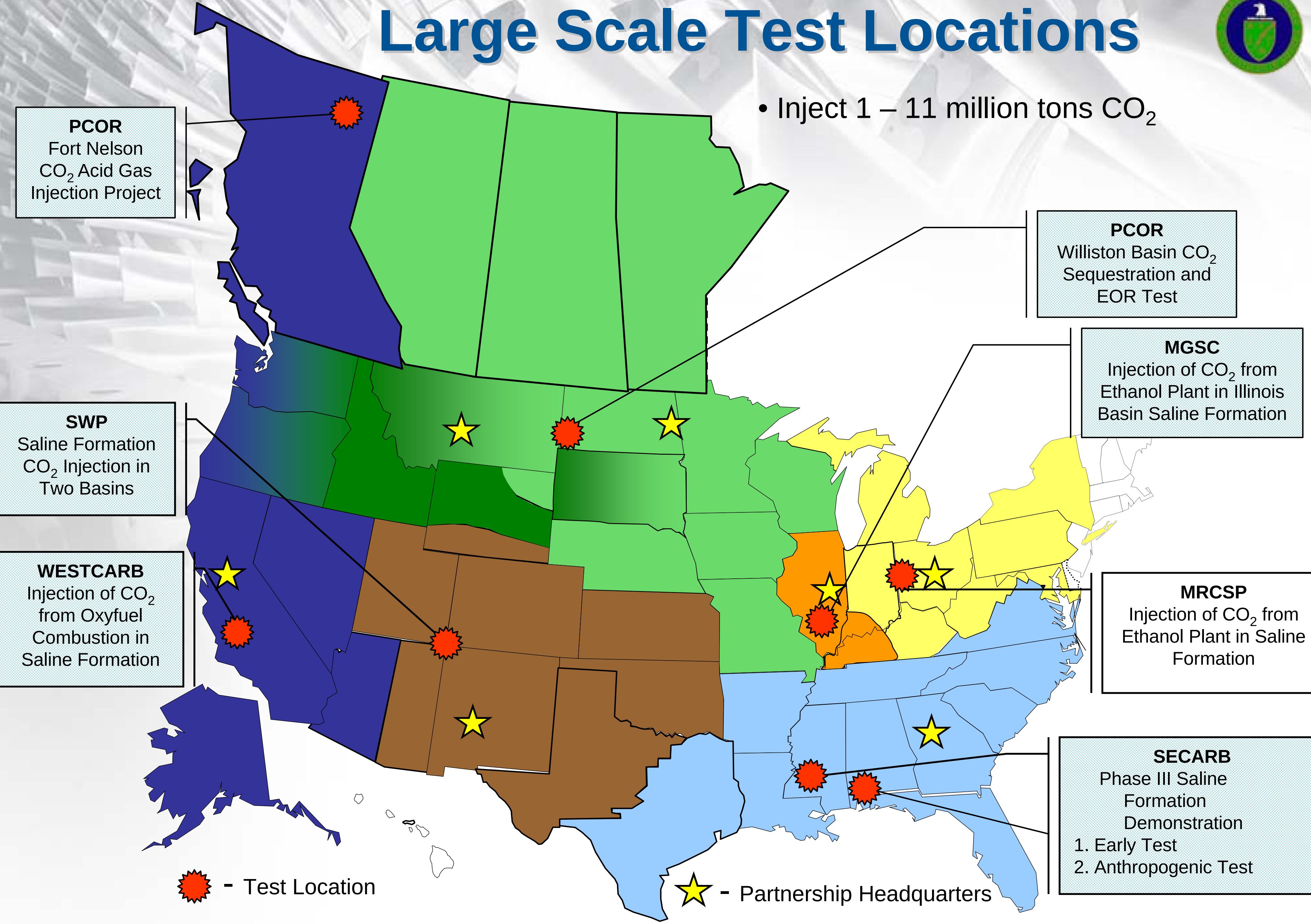
- **Injection 750-525,000 Tons CO_2**
  - Larger in conjunction with EOR
- **Validating geologic formation capacities and injectivity**
- **Testing formation seals**

- **MMV technologies**
- **Permitting requirements**
- **Public outreach**

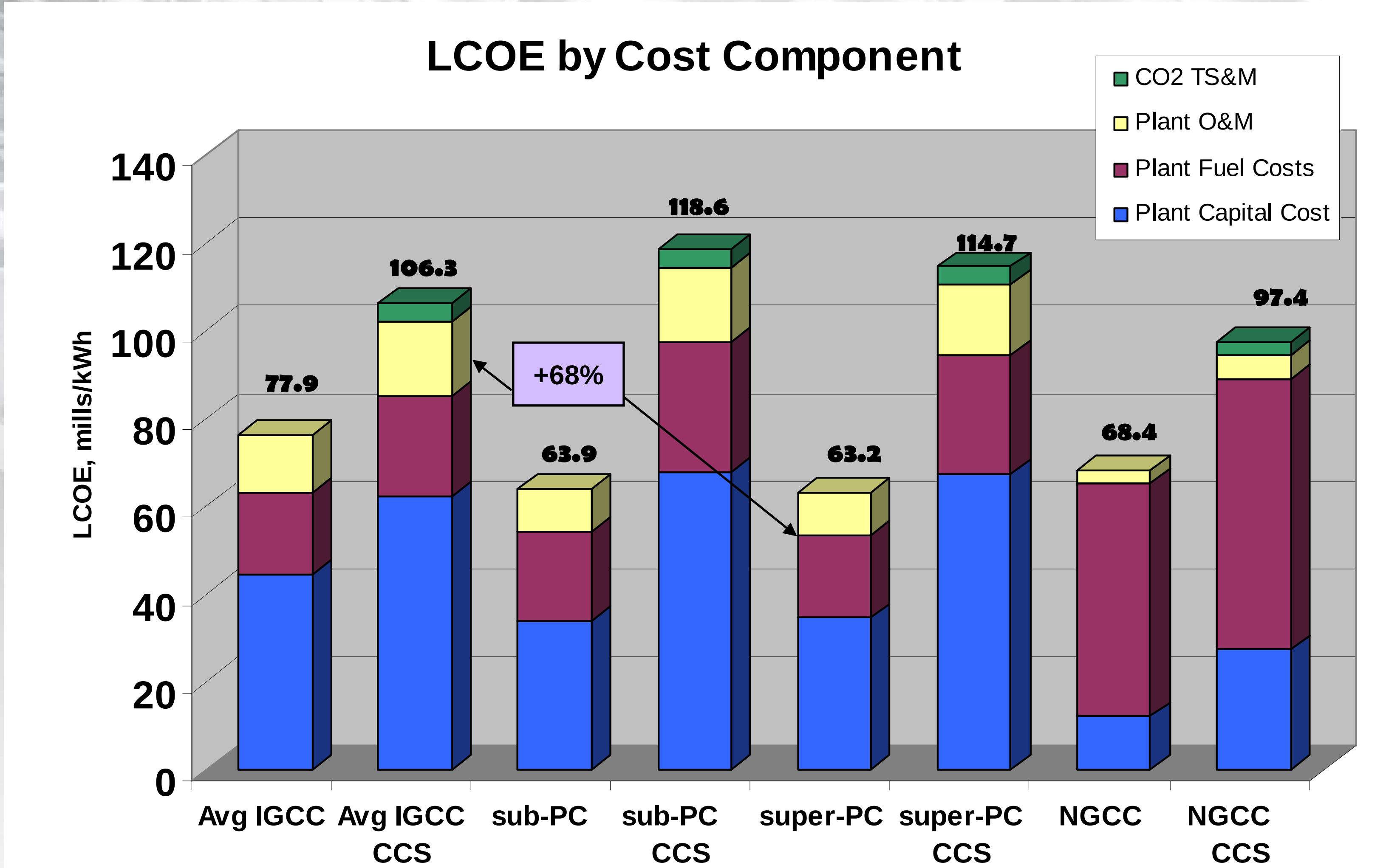


Large Scale Test Locations

- Inject 1 – 11 million tons CO_2



Busbar Cost of Electricity

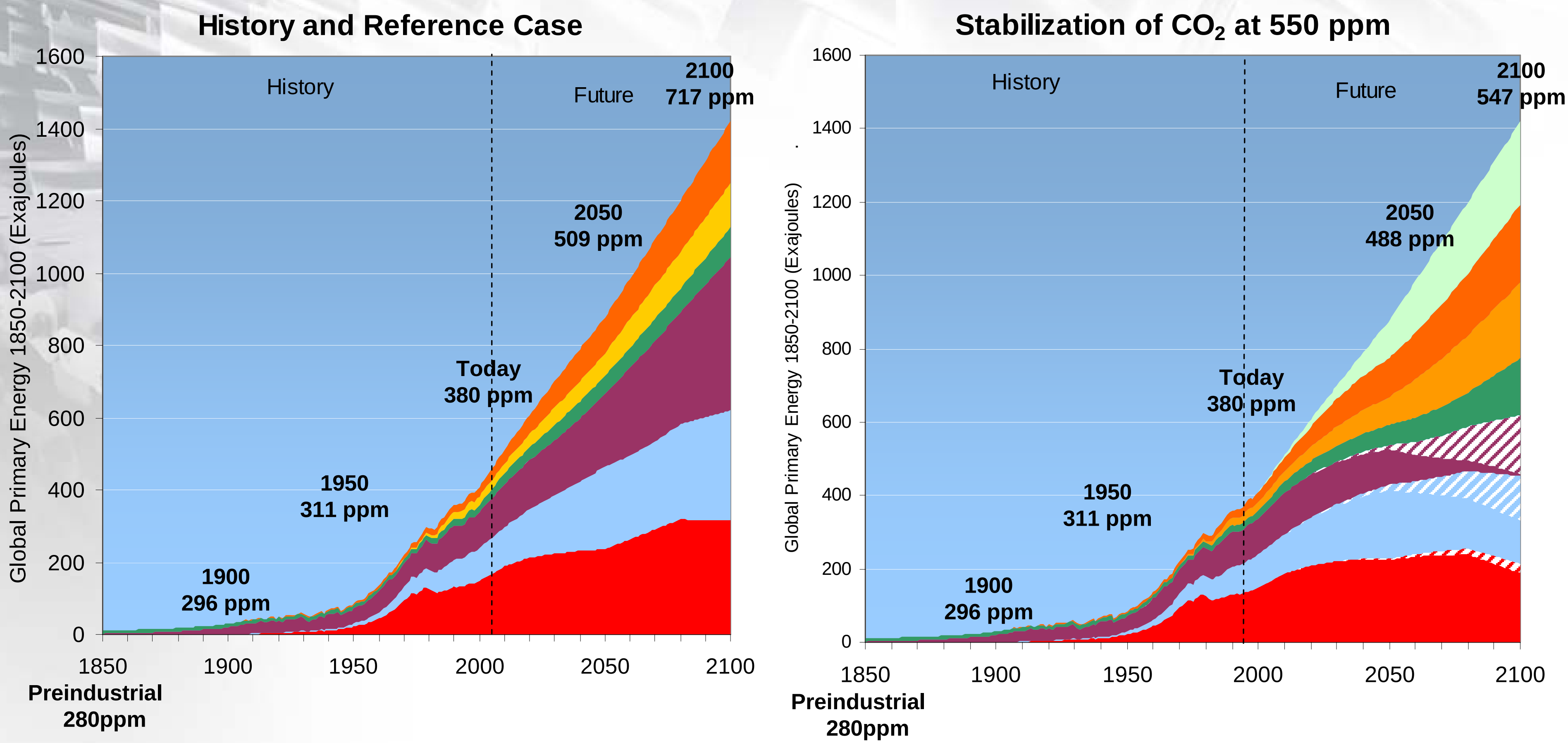


January 2007 Dollars, Coal cost $1.80/10^6Btu, Gas cost $6.75/10^6Btu
CCS = Carbon capture and sequestration
TS&M = transport, storage, and monitoring

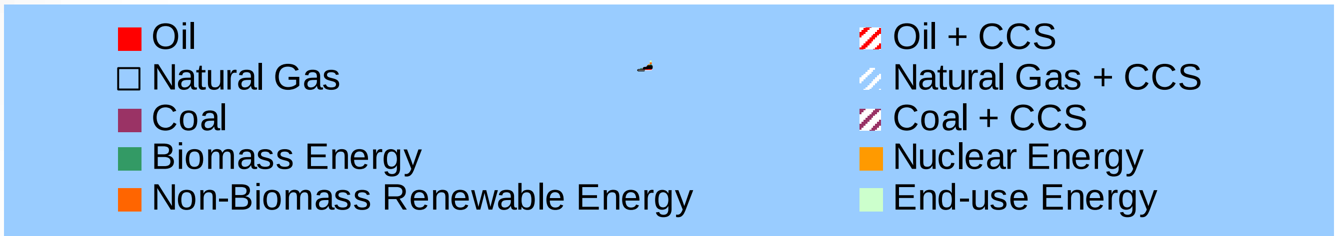
Are there other things we can do instead of CCS?

Stabilization of CO_2 Concentrations

Requires a fundamental change to the global energy system

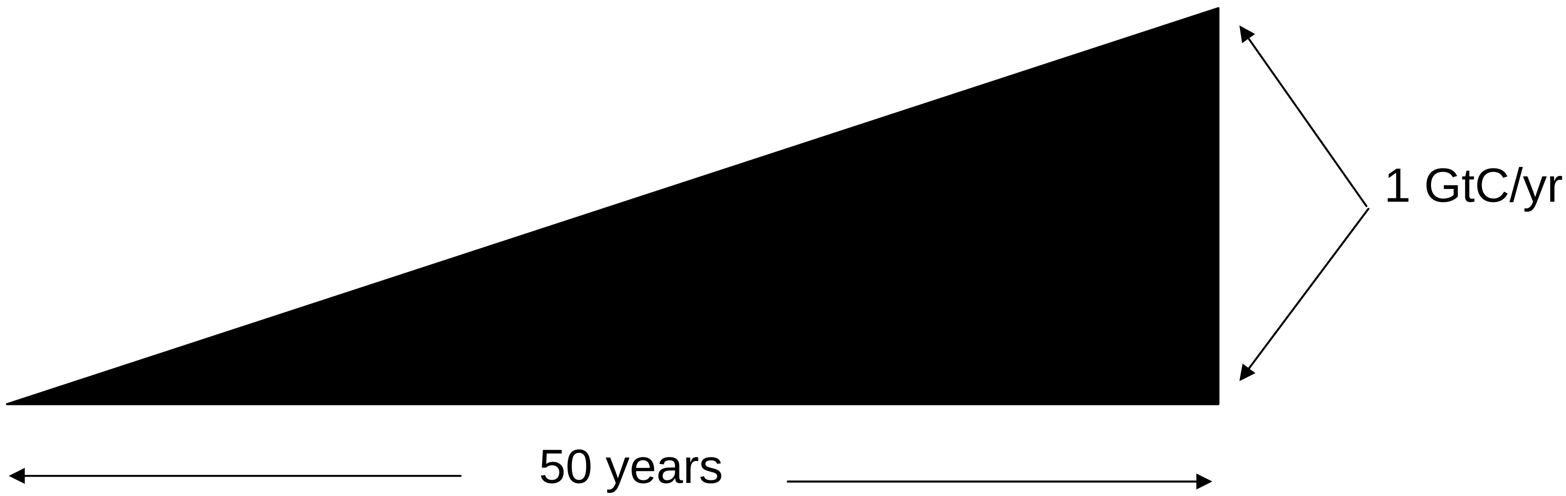


Source: Dooley , et. all, 2006



What is a “Wedge”?

A “wedge” is a strategy to reduce carbon emissions that grows in 50 years from zero to 1.0 GtC/yr. The strategy has already been commercialized at scale somewhere.



Cumulatively, a wedge redirects the flow of 25 GtC in its first 50 years. This is 2.5 trillion dollars at $100/tC.

A “solution” to the CO_2 problem should provide at least one wedge.

Photos courtesy of Ford Motor Co., DOE, EPA

Efficiency

Double the fuel efficiency of the world's cars or halve miles traveled

There are about 600 million cars today, with 2 billion projected for 2055

Produce today's electric capacity with double today's efficiency

Average coal plant efficiency is 32% today

Use best efficiency practices in all residential and commercial buildings

Replacing all the world's incandescent bulbs with CFL's would provide 1/4 of one wedge

E, T, H / $

Sector s affected:

E = Electricity, T =Transport, H = Heat

Cost based on scale of $ to $$$

Nuclear Electricity

Triple the world's nuclear electricity capacity by 2055

Graphic courtesy of NRC

The rate of installation required for a wedge from electricity is equal to the global rate of nuclear expansion from 1975-1990.

E/ $$

Wind Electricity

Photo courtesy of DOE

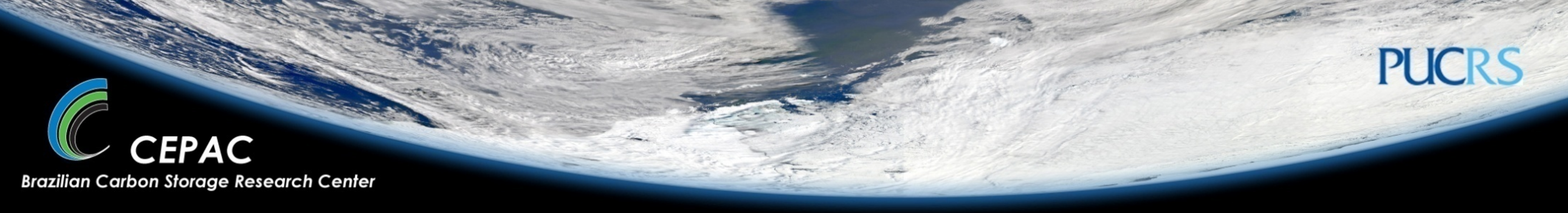
Install 1 million 2 MW windmills to replace coal-based electricity,

OR

Use 2 million windmills to produce hydrogen fuel

E, T, H / $-$$

A wedge worth of wind electricity will require increasing current capacity by a factor of 30



How to deploy CCS?

The G8/IEA/CSLF plan of action

THE G8/IEA/CSLF CARBON PLAN: The near-term first phase 200 Mt/yr (by 2025)

- Low-cost forms of CCS (processes that already capture CO2 or have “little” additional capture cost such as NG processing, ammonia and hydrogen plants).

- Forms of CCS with costs are offset by EOR or avoided emissions taxes.


Statoil


www.princeton.edu

THE G8/IEA/CSLF CARBON PLAN: The longer-term second phase 6000 Mt/yr (by 2050)

• Widespread deployment of CCS for power generation, facilitated by reduction of capture costs.

• Forms of CCS with heavy industries, such as steel and cement.

• As opportunities for EOR decline, CCS will likely be in saline formations.

ZEROGEN - ARTISTS IMPRESSION - PROPOSED ZEROGEN POWER STATION SITE
VIEW SOUTH FROM FALLS CREEK HILL

gc3.cqu.edu.au

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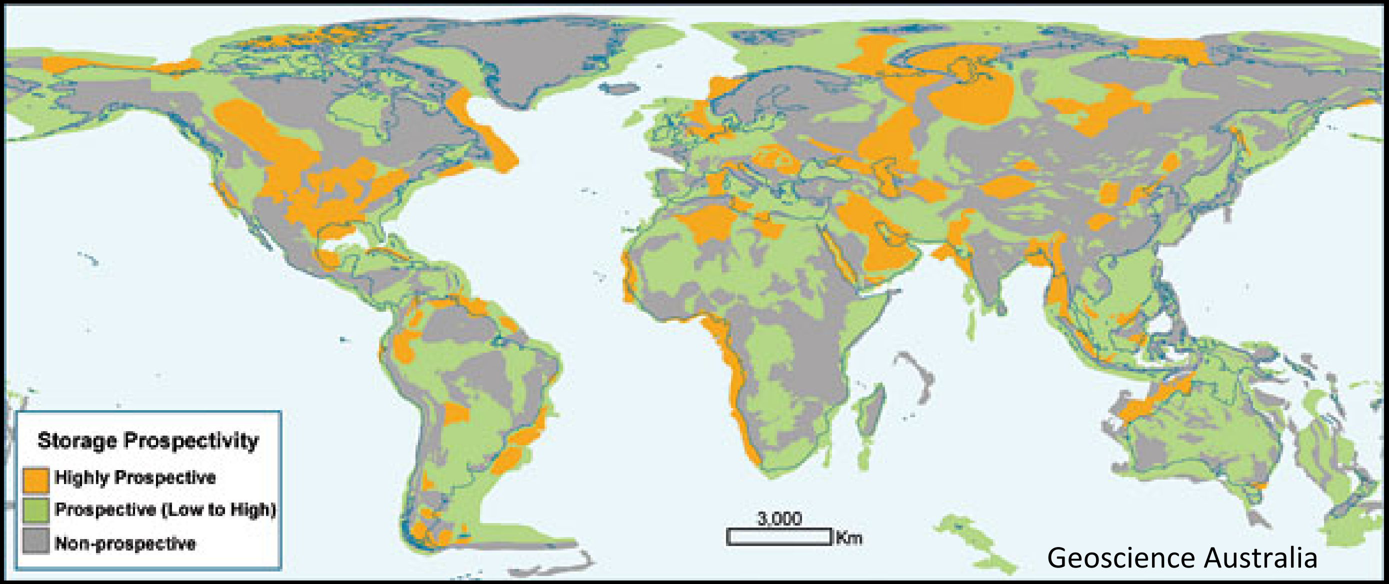
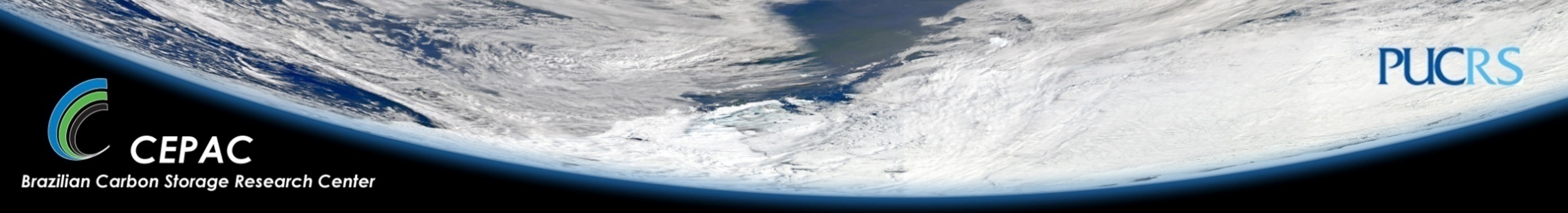
THE G8/IEA/CSLF CARBON PLAN: Key issues governing the deployment of CCS to be resolved already in the FIRST phase:

1. Identification and characterization of storage resources
2. The development and implementation of regulatory and incentive regimes
3. Deployment on a sufficient scale to gain community confidence and support
4. The development of low-cost capture technologies.





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Final remarks:

•*Most of CCS technology is available, but further development is needed to reduce cost.*

•*CCS is one of the most promising solutions to meet GHG emission reductions needs.*

•*CCS can assure the sustainable and safe use of affordable, secure fossil based energy.*

•*CCS does not compete with renewable energy but contributes to a friendly transition from a fossil based to renewable based economy.*

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Thank you for your attention!