Balancing Global and Regional Energy Needs and CO2 Emissions

Gerry Stokes

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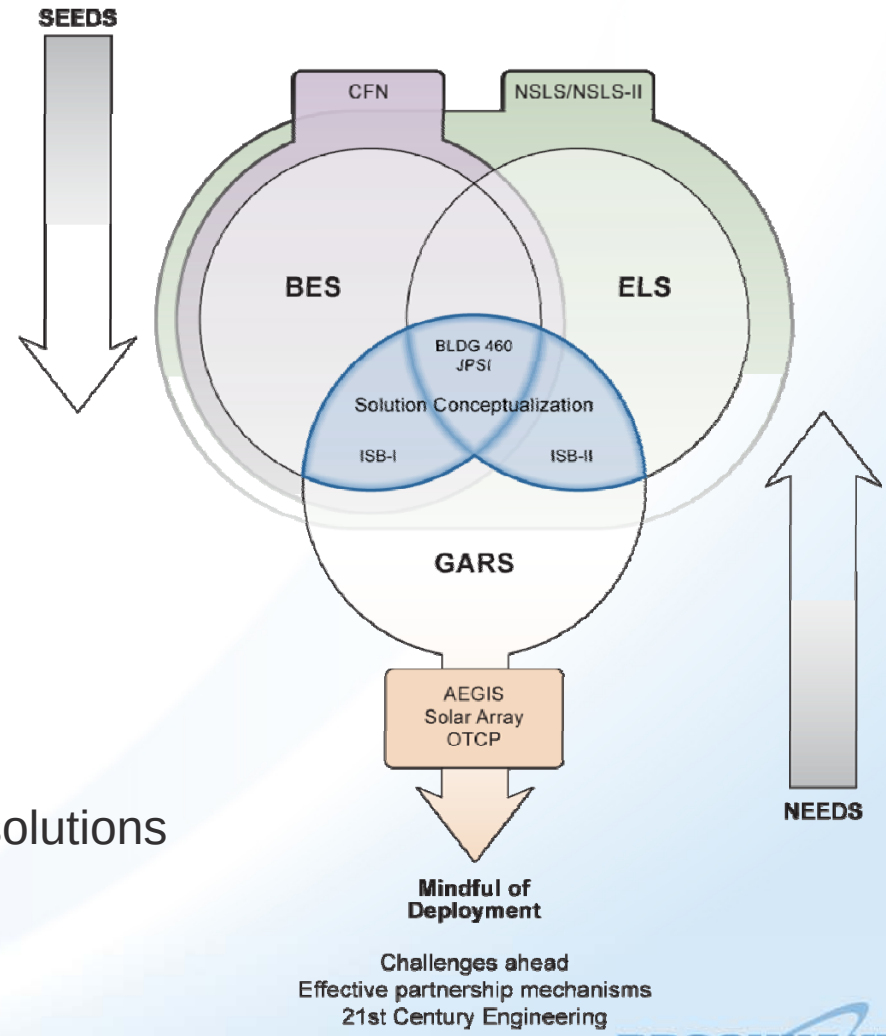
BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

Building the discovery to deployment pipeline

- Organizational focus: Create Global and Regional Solutions (GARS) Directorate
  - Applied sciences research efforts in Energy and National Security
  - Refocus Tech. Transfer functions; strengthen commercialization leadership
- Use facilities and staff to tie together seeds and needs
  - Connect BNL discoveries to deployment challenges
- Goal is the creation of impactful solutions



The UN Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change has as its ultimate objective ...

stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Article 2 (UNFCCC, 1992)

Three Key Elements:

Stabilizing concentrations not emission levels

Prevent danger at some unspecified level

Allow economic development to proceed

Our understanding of anthropogenic climate change has evolved over the last one hundred years.

Early Milestones

- Arrhenius (circa 1900) - Increasing carbon dioxide due fossil fuel combustion may change the climate system
- Keeling (1957 ->) - Carbon dioxide well-mixed yet growing in concentration in the atmosphere
- Smagorinsky and Leith (1960's) - Models of the general circulation of the atmosphere
- By 1990 we knew that the atmospheric CO2 abundance had grown from a pre-industrial value of ~280 ppm because of human activity (fossil fuels and land clearing)

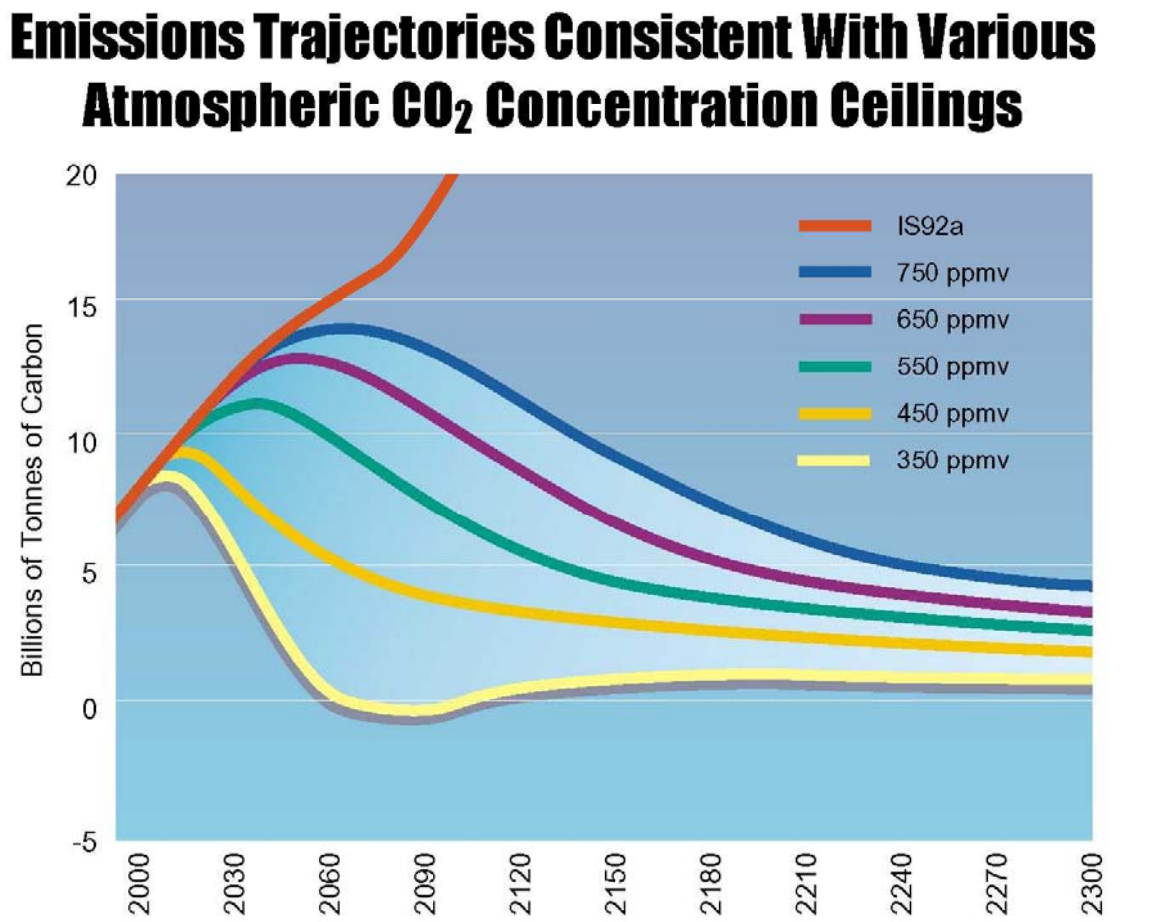
The two BIG answers of the last 20 years

- The climate is changing and humanity is in part responsible, particularly over the last 50 years.
  - “The Detection and Attribution Problem”
- If we are to mitigate the human impact, there must be a substantial change in society’s technological infrastructure, most notably in energy
  - “The Carbon Management Problem”

The current BIG questions ...

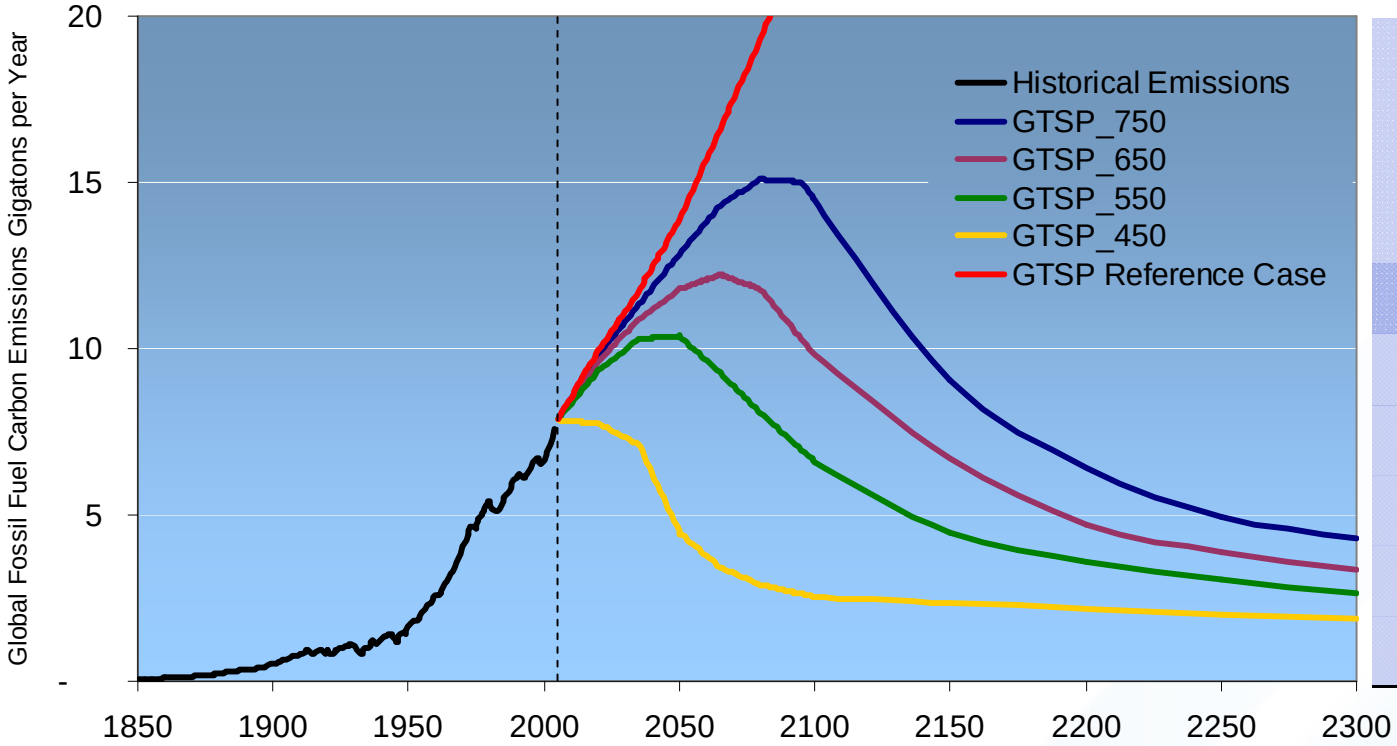
- How sensitive is the climate system to likely future anthropogenic influences?
  - “The Doubling Problem” leading to “What Constitutes Dangerous Interference?”
- How can we mitigate the influence of human activity to prevent ‘dangerous interference with the climate system’?
  - “The Mitigation Challenge” leading to “The Adaptation Challenge”

Managing the CO2 concentration implies managing emissions



Global emissions must slow, peak and tend toward zero.

This makes climate change a long-term strategic problem with implications for today

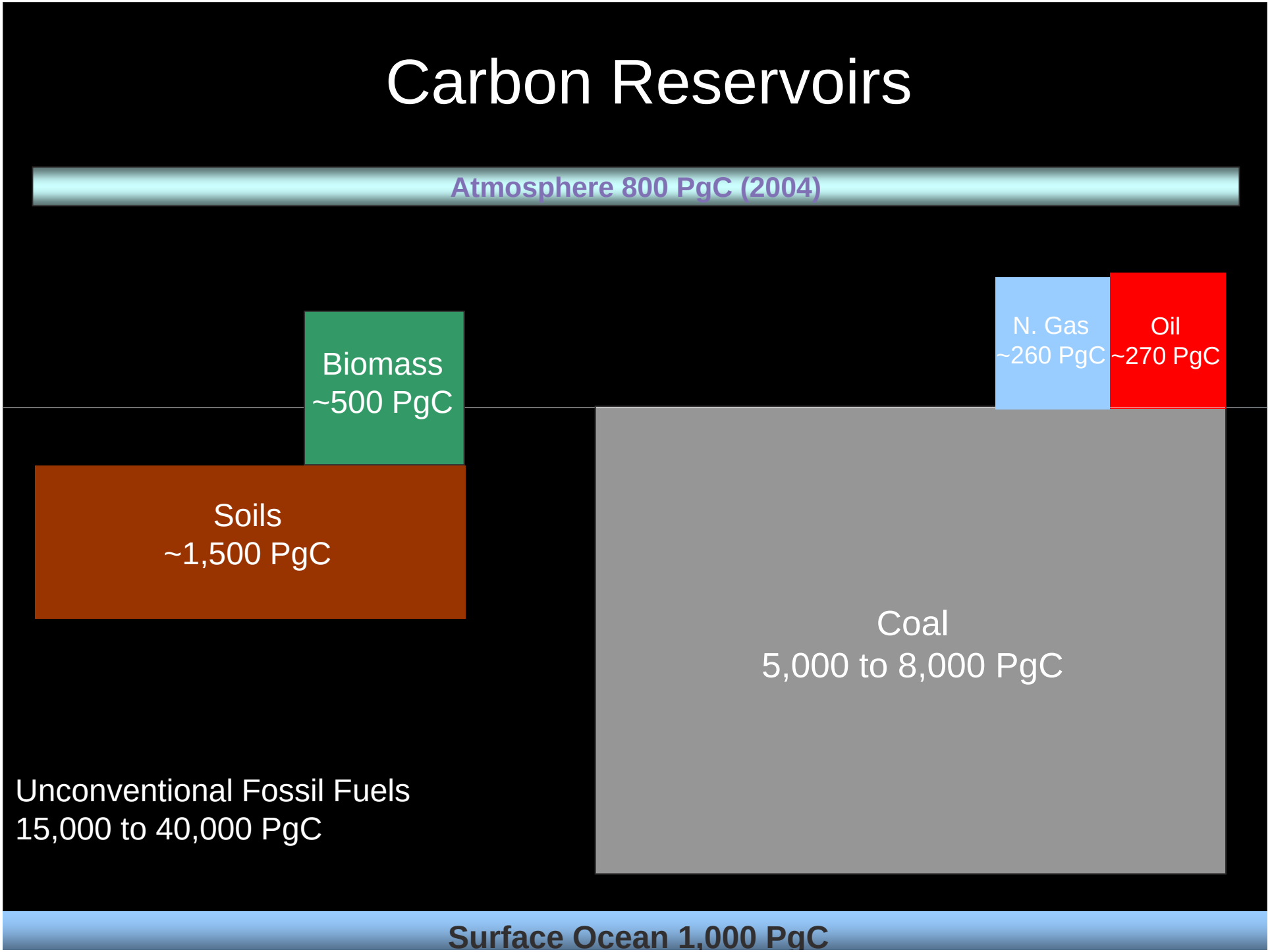


Fossil Fuel Carbon Emissions
Historic & 2005 to 2100

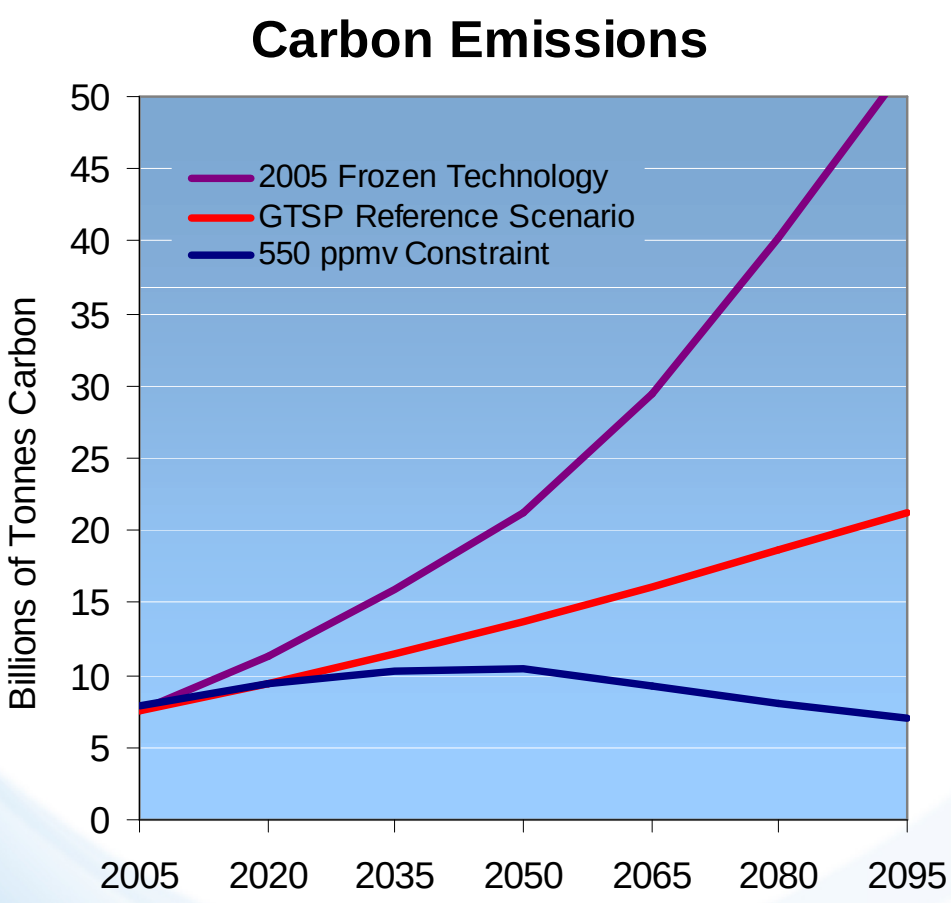
1750-2005	300 GtC
GTSP Ref	**1430 GtC**
750 ppm	**1200 GtC**
650 ppm	**1040 GtC**
550 ppm	**862 GtC**
450 ppm	**480 GtC**

- Stabilization of greenhouse gas **concentrations** is the goal of the Framework Convention on Climate Change.
- Stabilizing CO_2 **concentrations** at any level means that **global**, CO_2 emissions must peak and then decline forever.

Carbon Reservoirs



Future projections of energy use and CO_2 emissions assume tremendous technological progress in their no climate policy business as usual cases



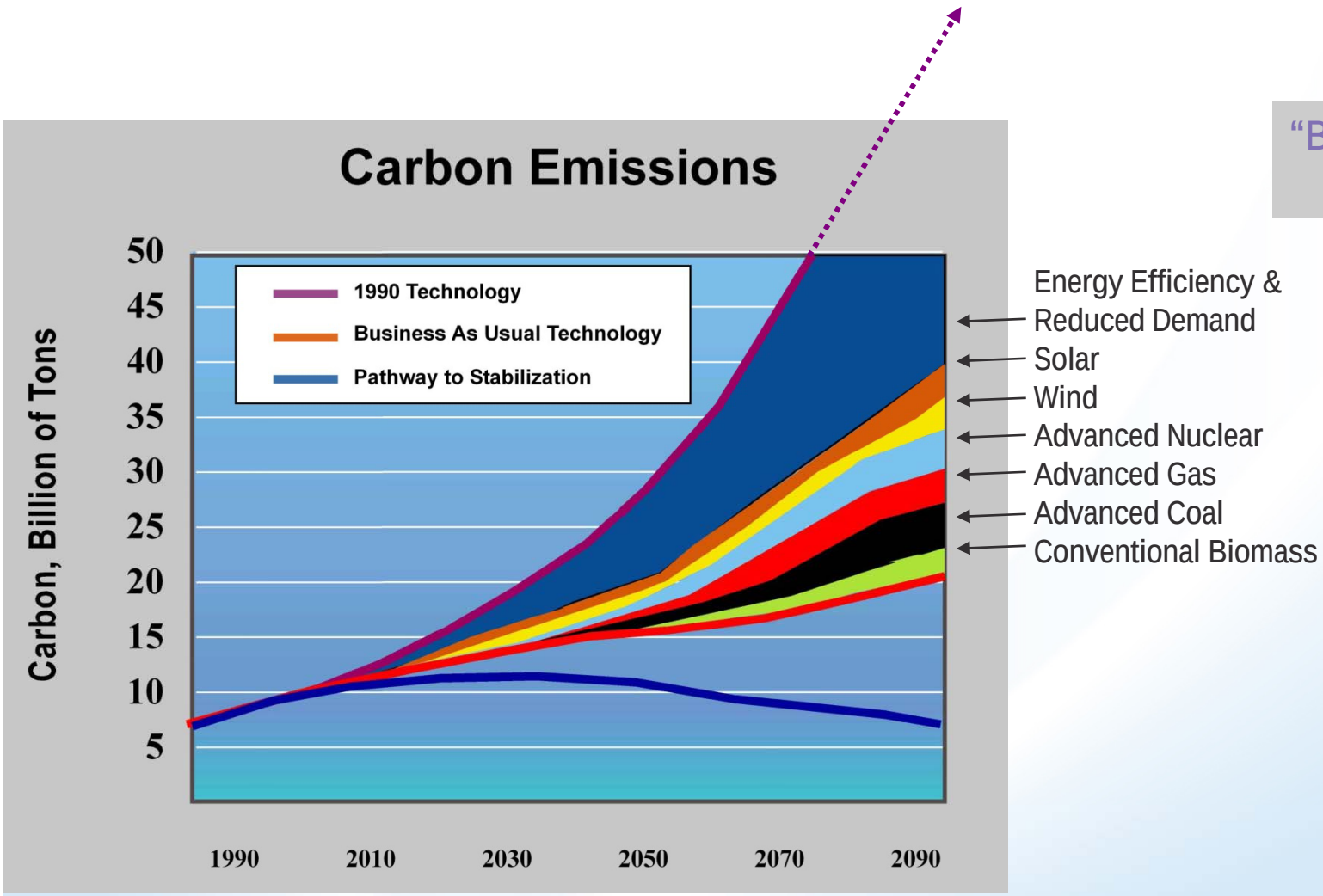
Continued deployment of today's energy technologies leads to CO_2 concentrations at the end of the century in excess of 1000 ppmv

Assumed continued progress across a broad portfolio of energy technologies yields end of century CO_2 concentrations in excess of 750 ppmv

Deployment of advanced energy technologies and a global commitment to control net greenhouse gas emissions can cost effectively stabilize CO_2 concentrations

Business-As-Usual Gap

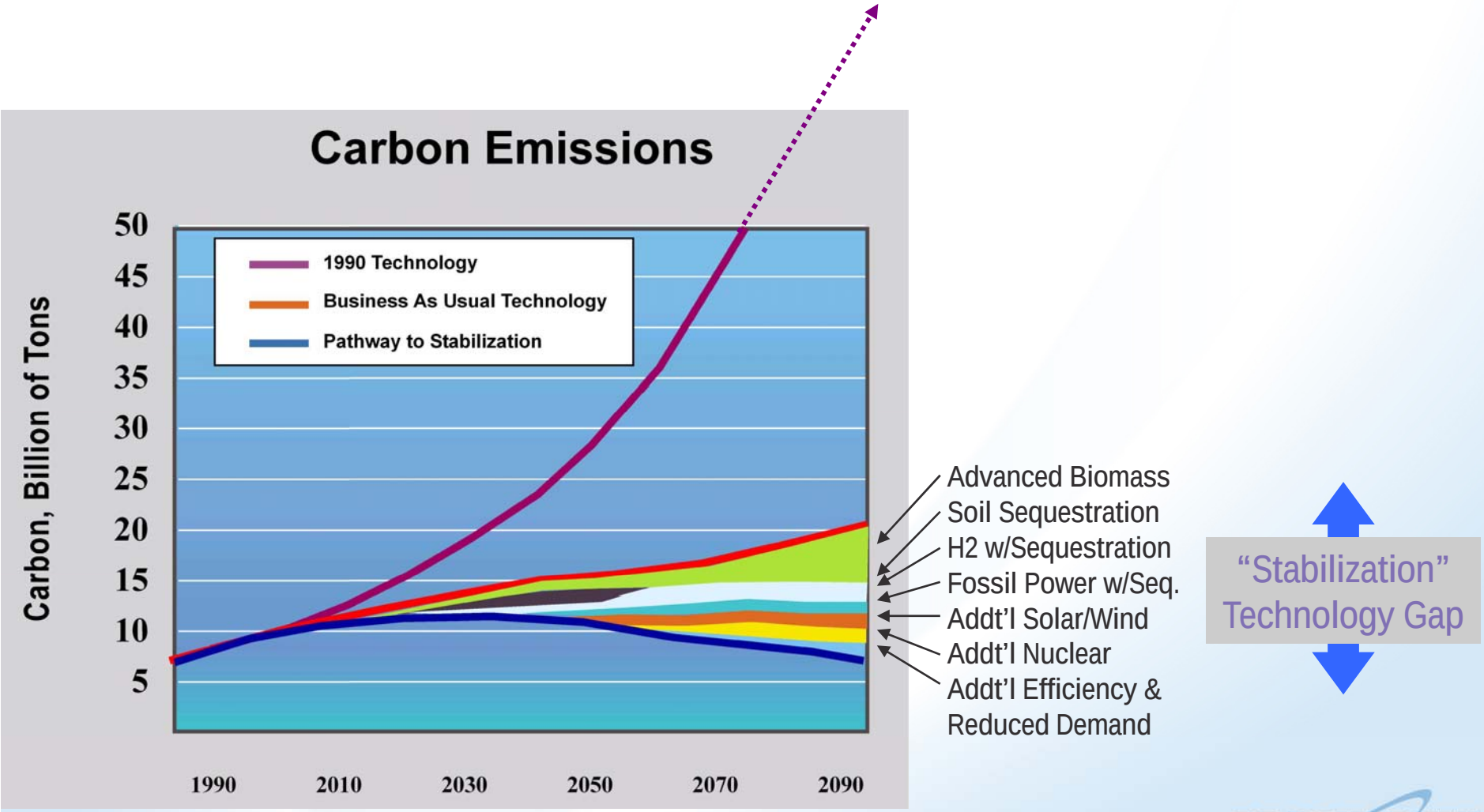
Extraordinary Improvement is Built in to BAU



"Business-As-Usual" Technology Gap

Stabilization Gap

Tremendous Additional Technological Advance Required



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Note: Conceptual Market Penetrations

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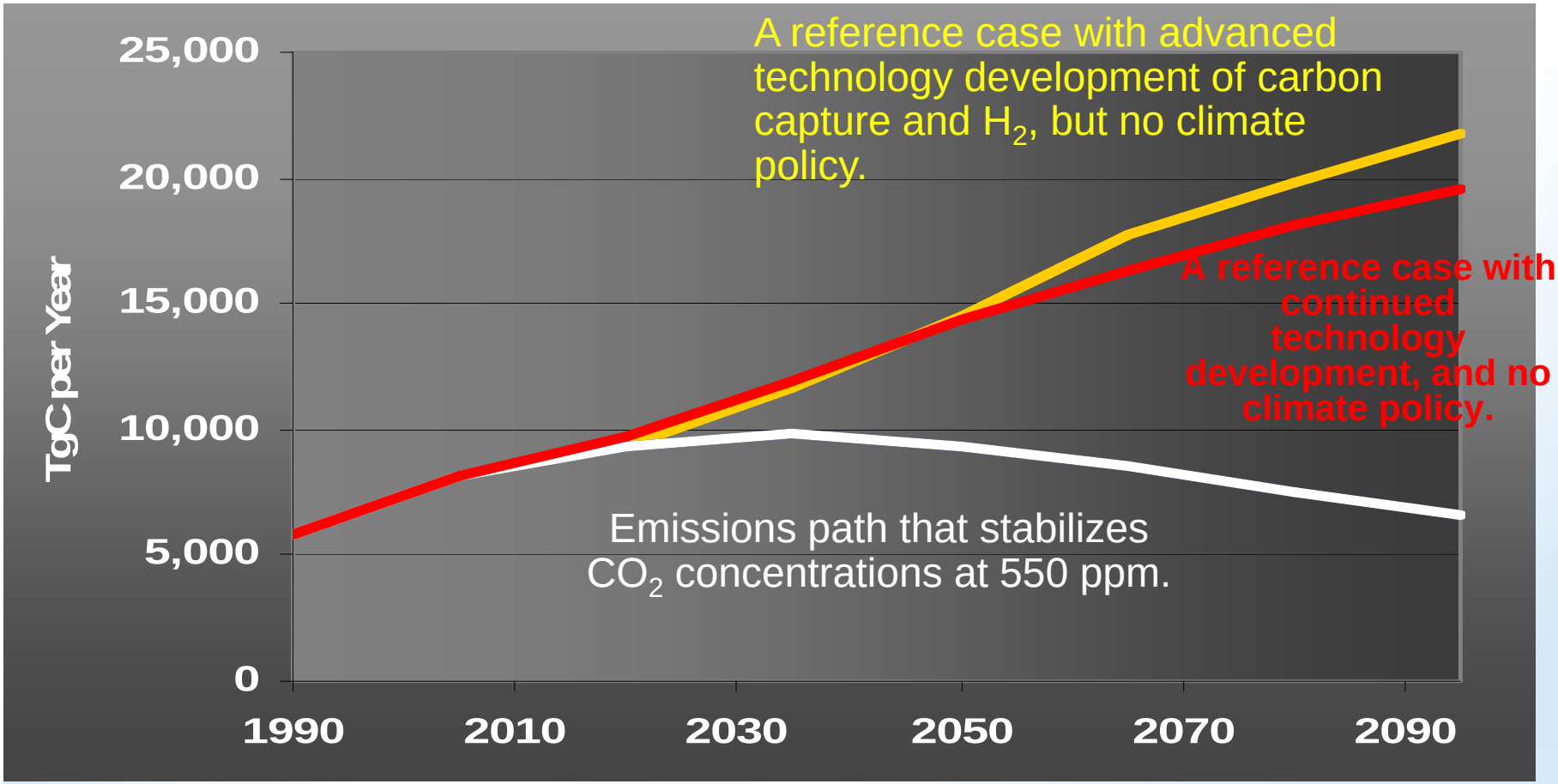
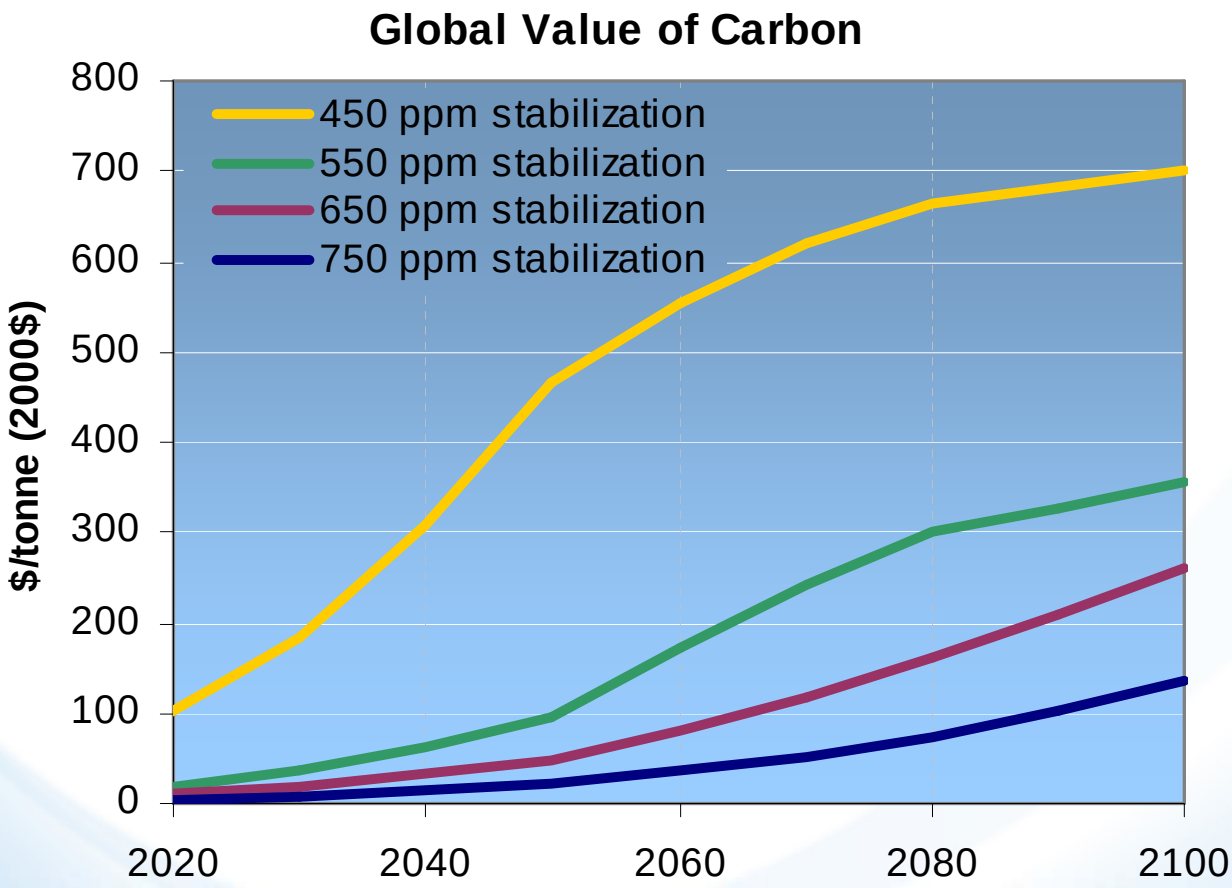
We currently know of no climate mitigation silver bullet

- The world of today is very heterogeneous - many energy technologies and many fuels - and this will continue into the future.
- Which technologies deploy, at what rate, and to what extent will unfold over time.
- Stabilization technologies are unlikely to penetrate absent a specific signal that GHG emissions must be reduced - e.g. a ‘price’ for carbon.

Technology Alone Won't NECESSARILY Stabilize CO_2 Concentrations

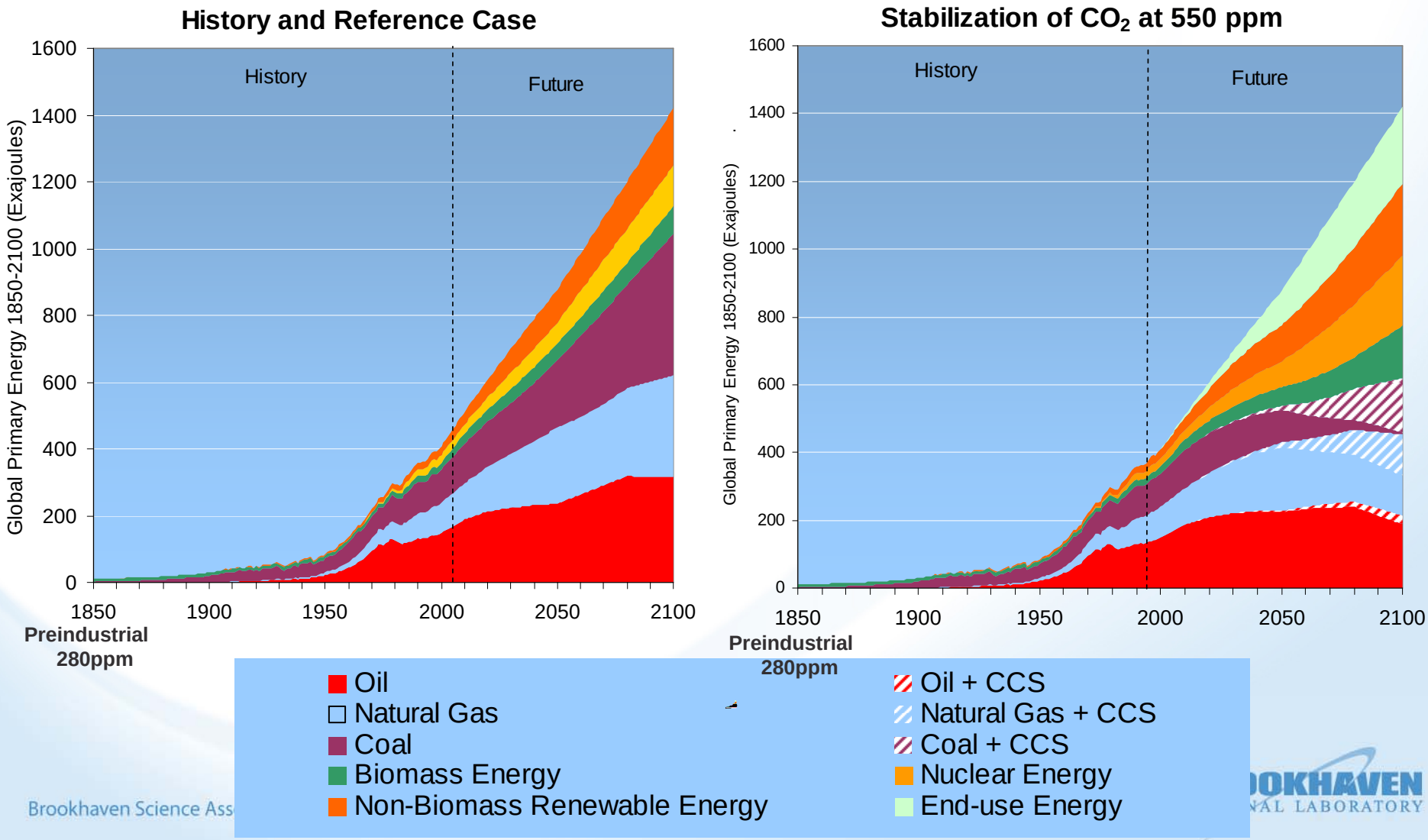


A global commitment to stabilizing CO_2 concentrations requires a carbon price that escalates over time



- Price of carbon should start low and rise steadily to minimize society's costs.
- Eventually all nations and economic sectors need to be covered as the atmosphere is indifferent as to the source of CO_2 emissions.
- The response to this escalating price of carbon will vary across economic sectors and regions.

Stabilization of CO_2 concentrations means fundamental change to the global energy system



The scale of the climate change mitigation is hard to grasp - the combustion of fossil fuels is one of the largest industries on the planet.

Many times we lose sight of the scale of the problem

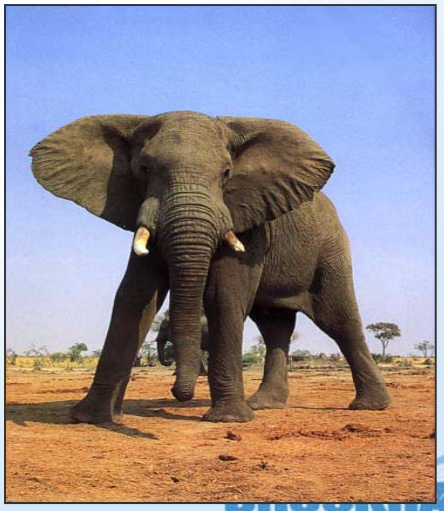
- Annual current global emissions (without deforestation) ~7 gigatons of carbon -
  - ~25 gigatons of carbon dioxide
- Global reservoirs
  - Atmosphere is 750 gigatons (carbon)
  - Standing biomass is 650 gigatons (carbon)
  - Terrestrial soils have 1500 gigatons (carbon)
- Increase in Atmosphere since pre-industrial period - 200 gigatons carbon
- Just 1 gigaton is a lot …

One gigaton is…

- Greater than the mass of all the humans on the planet
- Greater than the annual global production of iron and steel

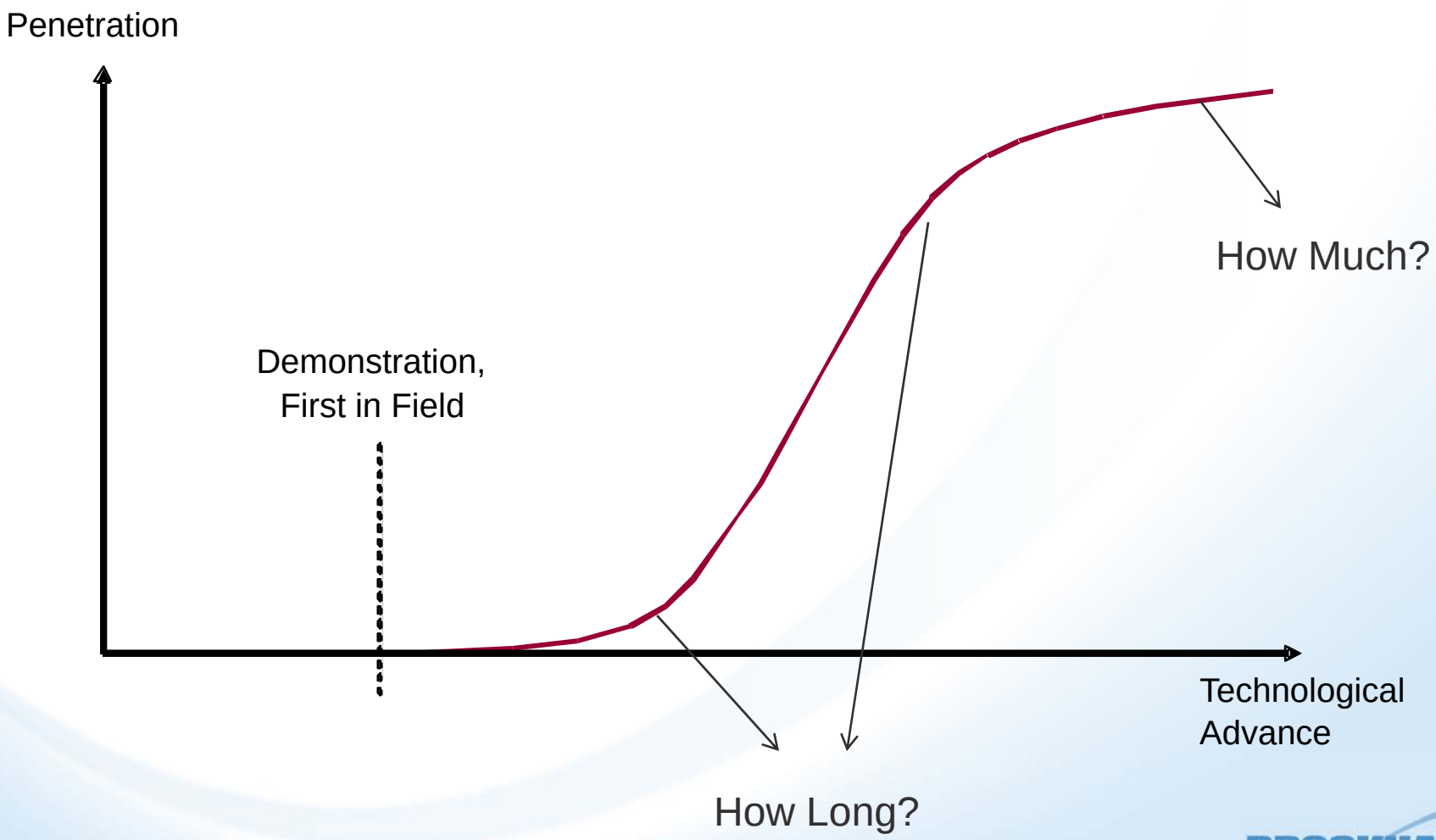
2740 Empire State Buildings
or 77 Empire State Buildings
made out of solid lead

142,857,142 African elephants
That's enough elephants stacked on
top of each other to reach from
Earth to the moon and halfway back

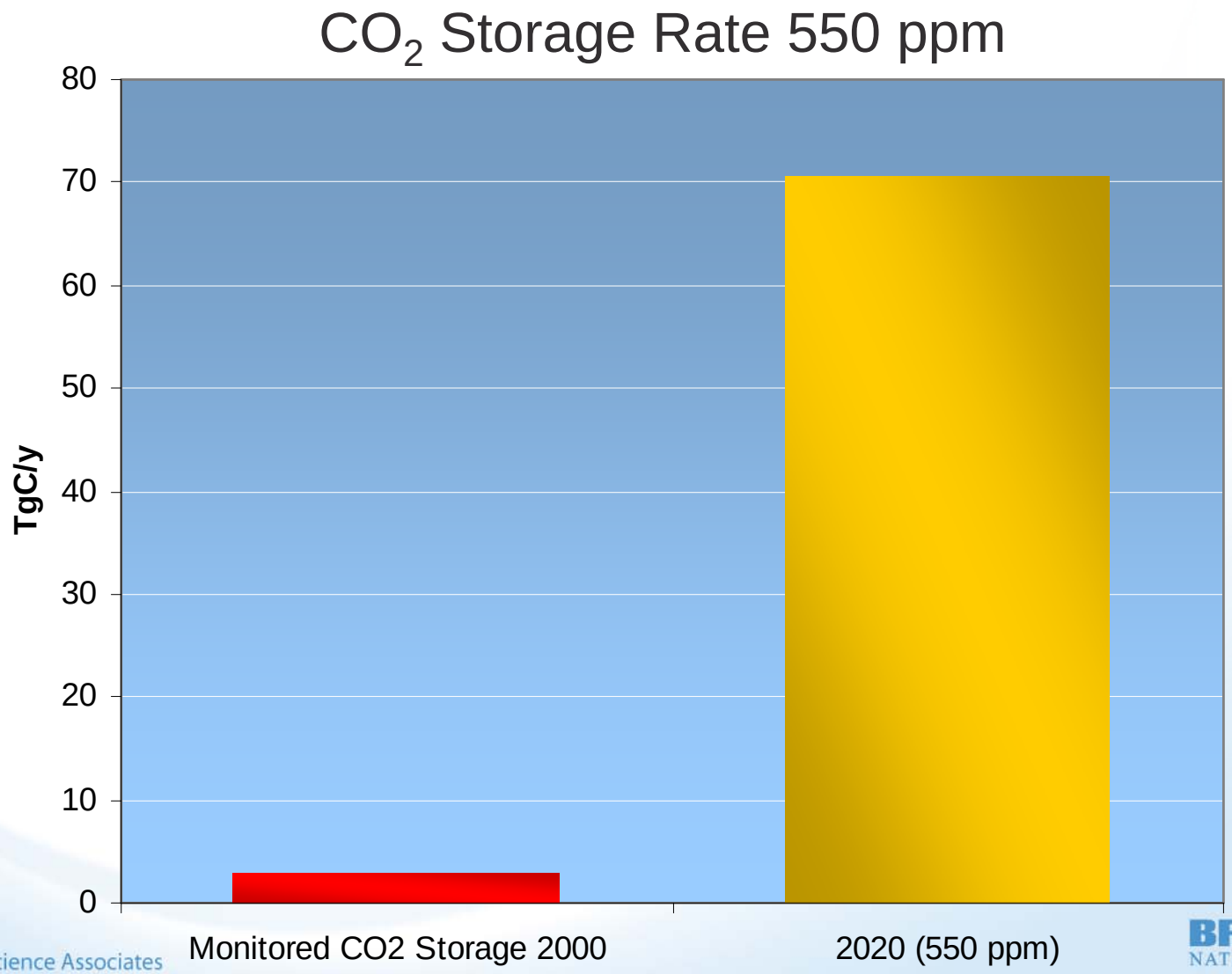


There is a long way from the ‘bench’ to large scale deployment

The likely pattern of large scale deployment of technology is known …



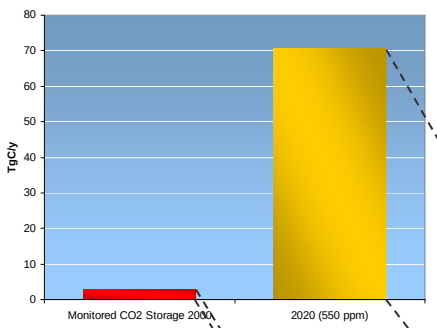
For sequestration the penetration might look like this …



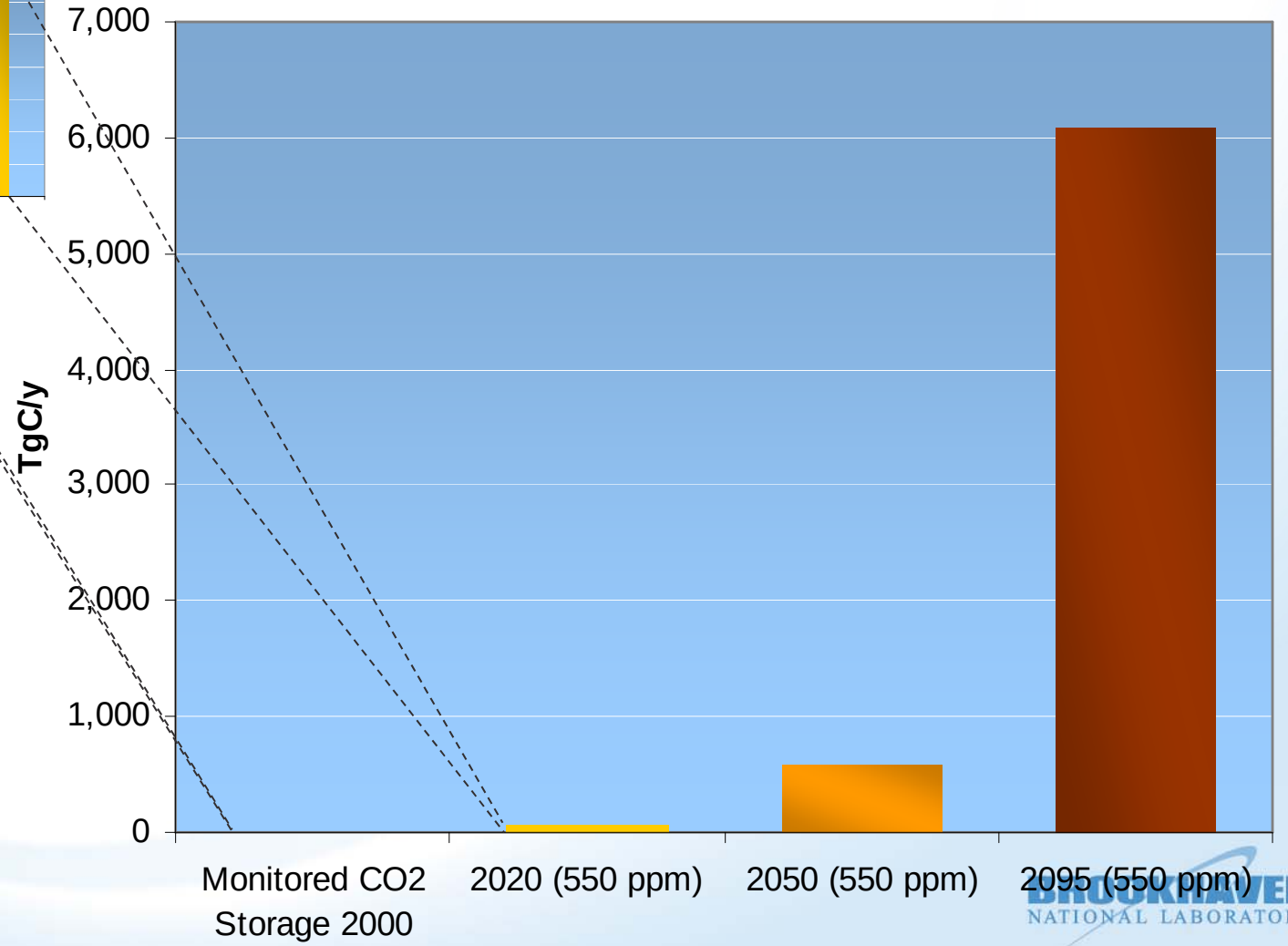
Stokes' Law of Mitigation

- To be considered a climate "solution" –
  - a technology must lead to 1 gigaton (gt) of avoided carbon emissions per decade [3.7 gt of CO2]
  - It becomes a "significant contributor" at 1gt per year reduction over the "technology as usual" case.

In the long-term the challenge grows – as the process industrializes

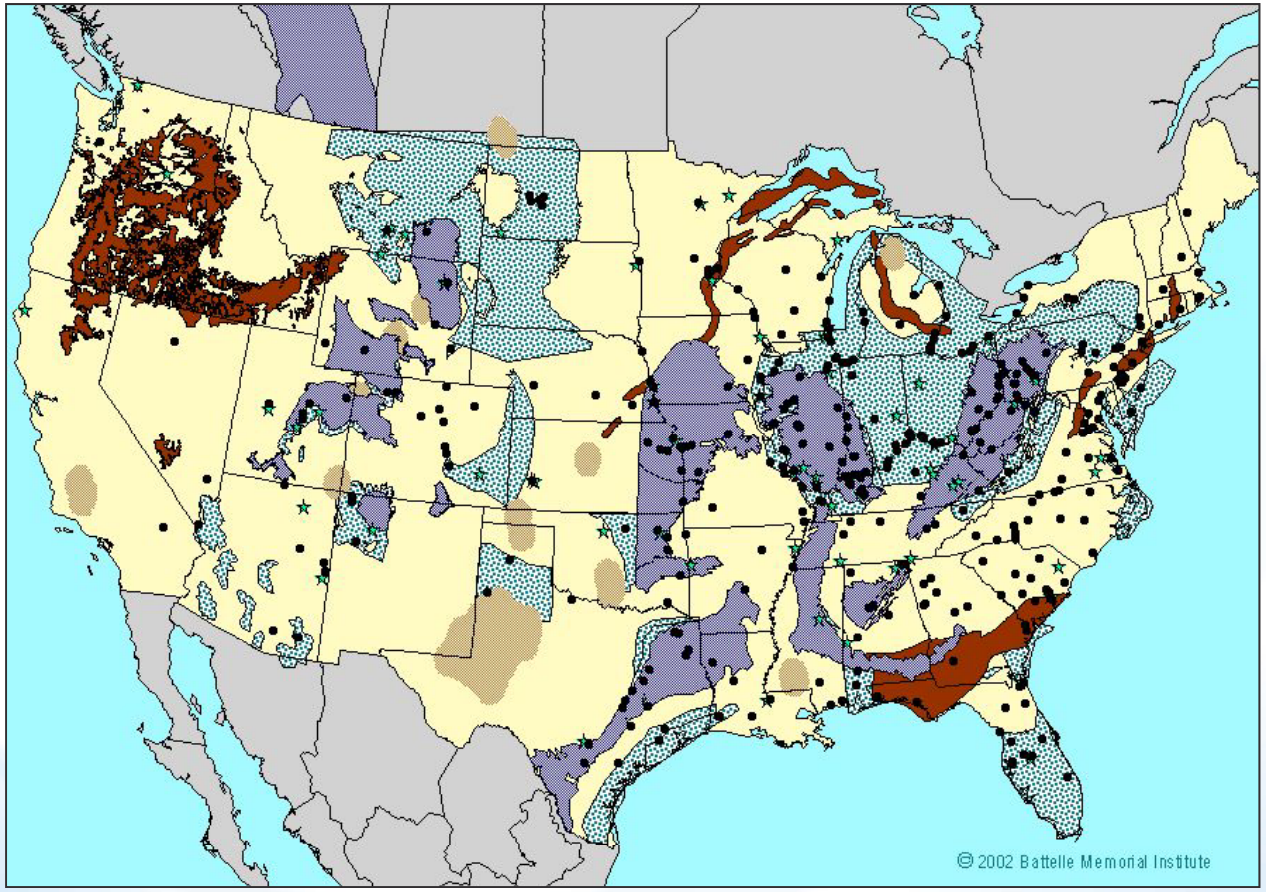


CO_2 Storage Rate Level 2 (~550 ppm)



Not all climate solutions work everywhere. Some have advantages over others in different parts of the world even within countries.

The U.S. will likely be heavily tied to sequestration … where will we put the carbon?



- There is some mismatch between capture and storage and existing power plants
- Even more so for motor vehicles.

Not only *where* will we put the carbon – but will it stay there?

Or

Will the leakage from sequestration become the dominant CO2 source at the end of the century?