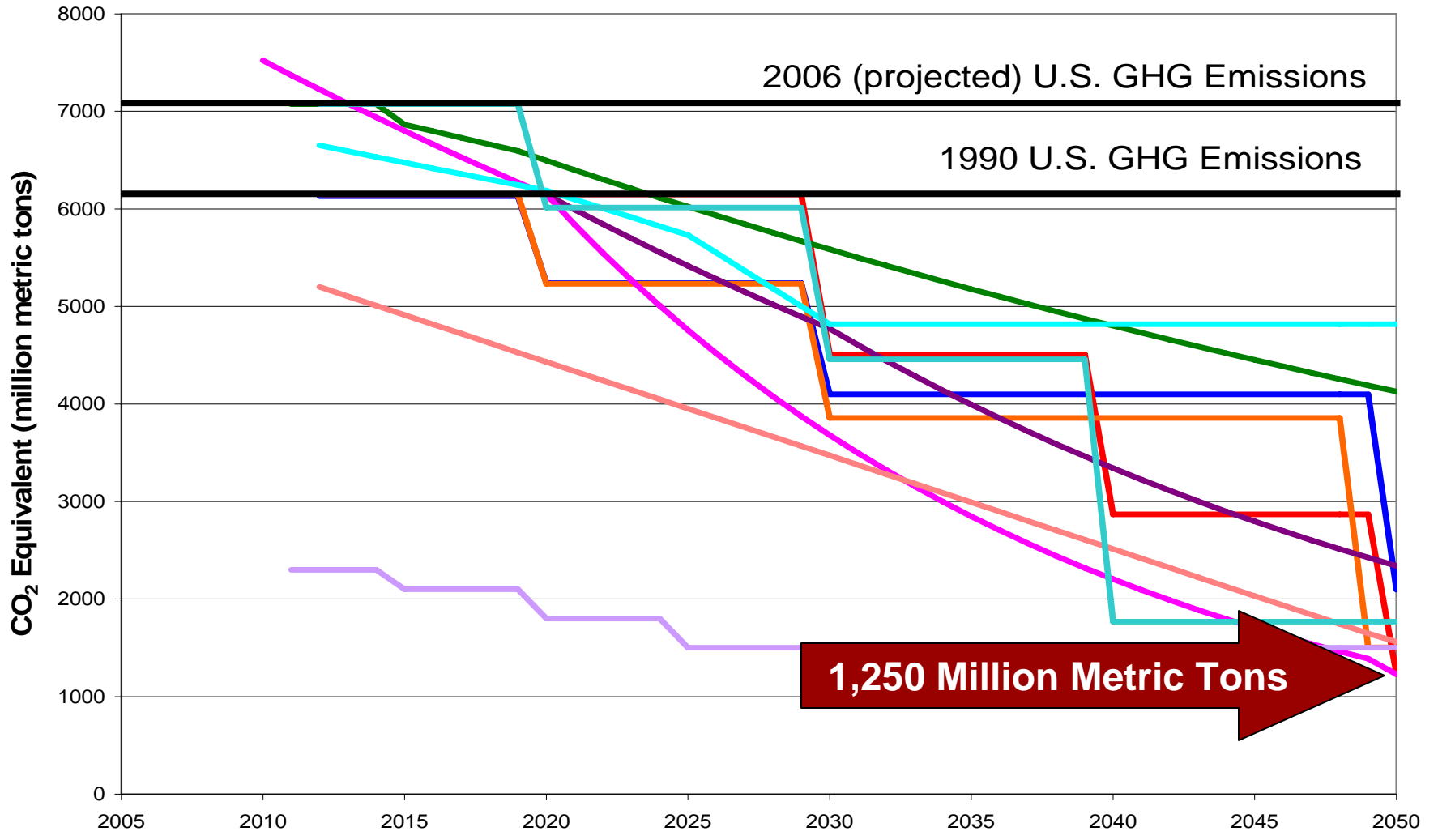




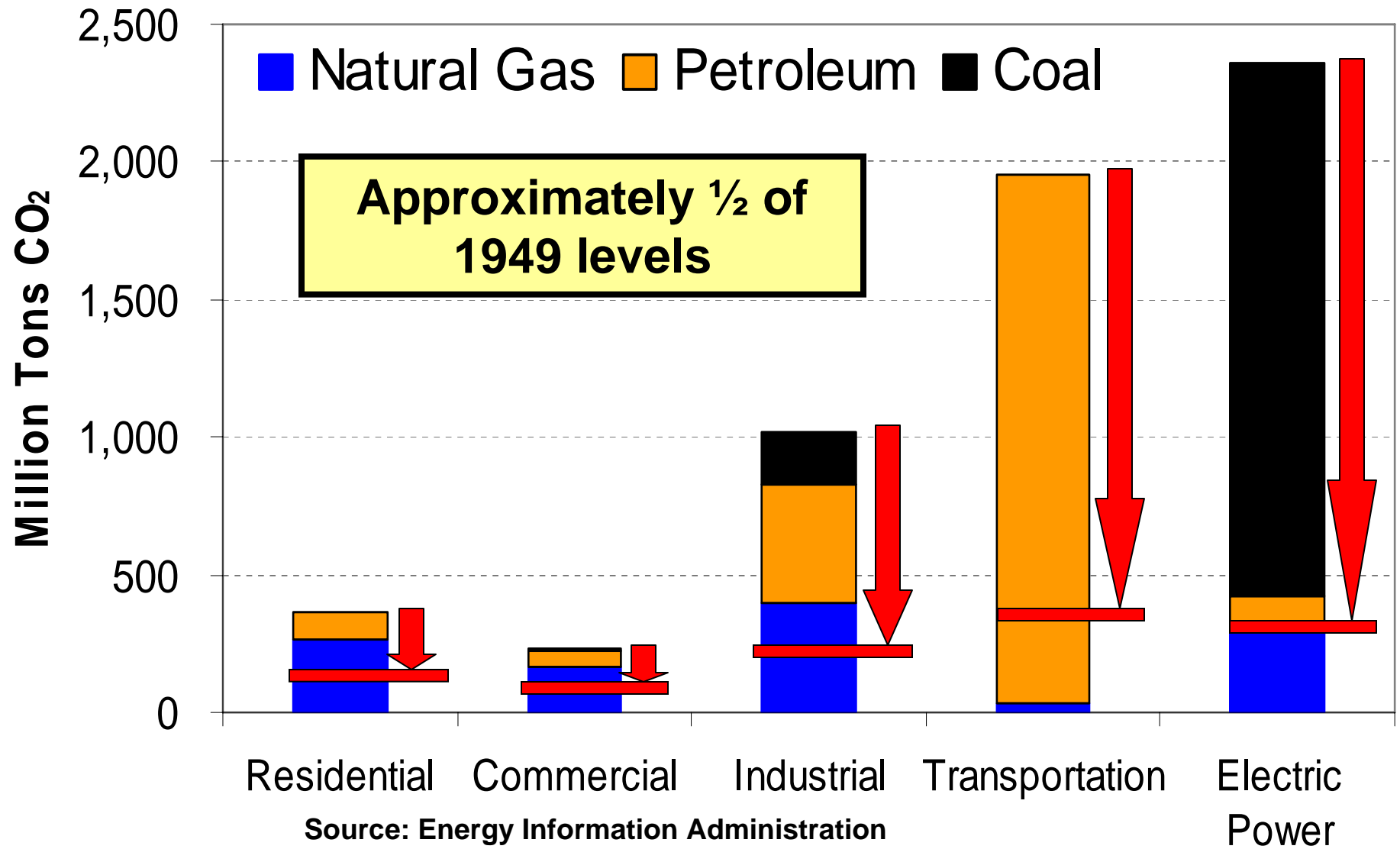
The Sequestration Challenge

Grant E. Grothen, P.E., GHG Programs Director
Burns & McDonnell Engineering

“Aggressive” Carbon Reduction Legislation



EXTREMELY Aggressive Targets



Capture & Sequester – The Magic Bullet?

- Technical feasibility looks good
- Low statistical risk
- Growing R&D funding support
- Support from politicians



Capture Timeline

Pre-Combustion (Convert Syngas to H₂ – IGCC)



Post-Combustion (Flue Gas Cleanup)



Oxy-Fuel Combustion (Pure Oxygen Combustion)



SERIOUS Volume Issues

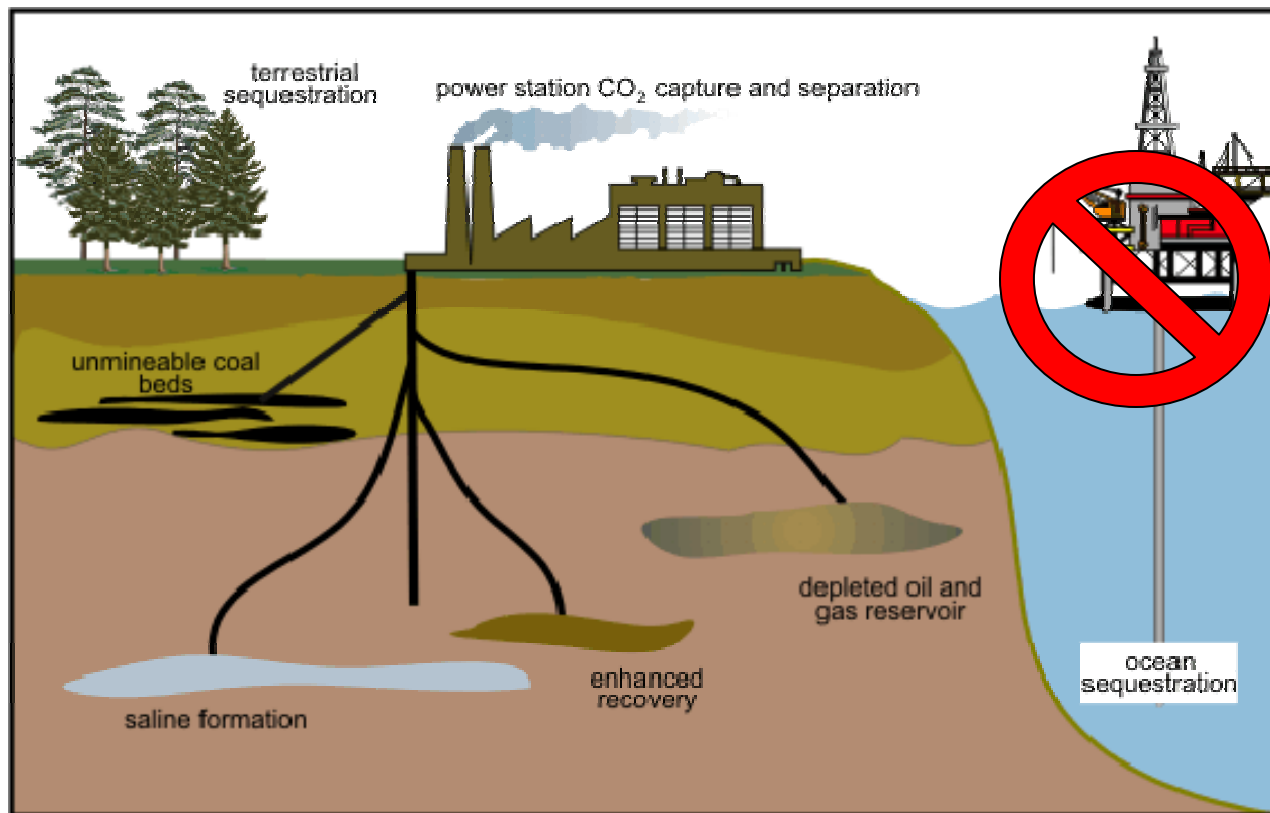


Total U.S. Yearly Emissions Blanket Entire Country with Over 13.5 inches of CO₂

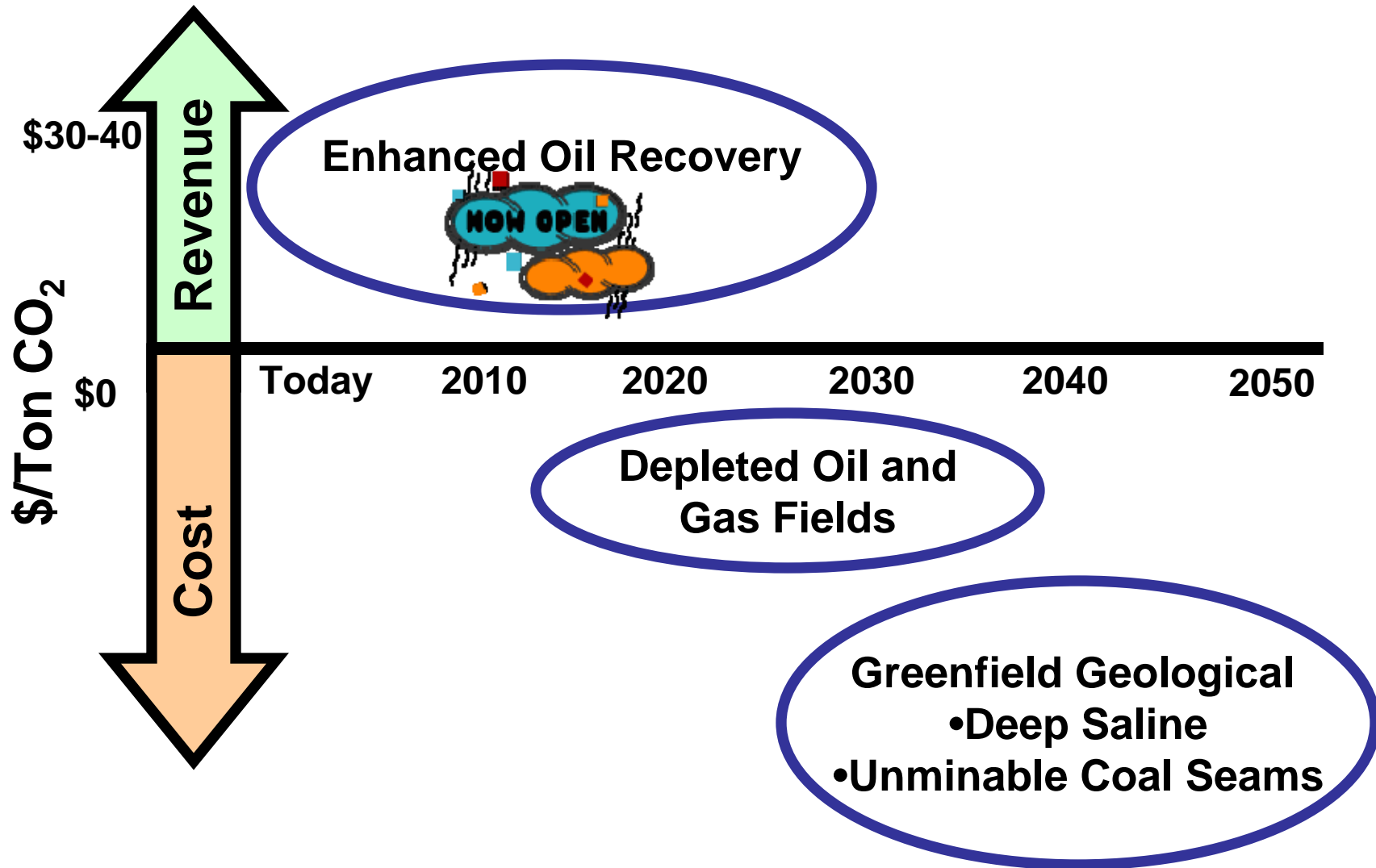
Source: International Carbon Bank & Exchange

Sequestration Options

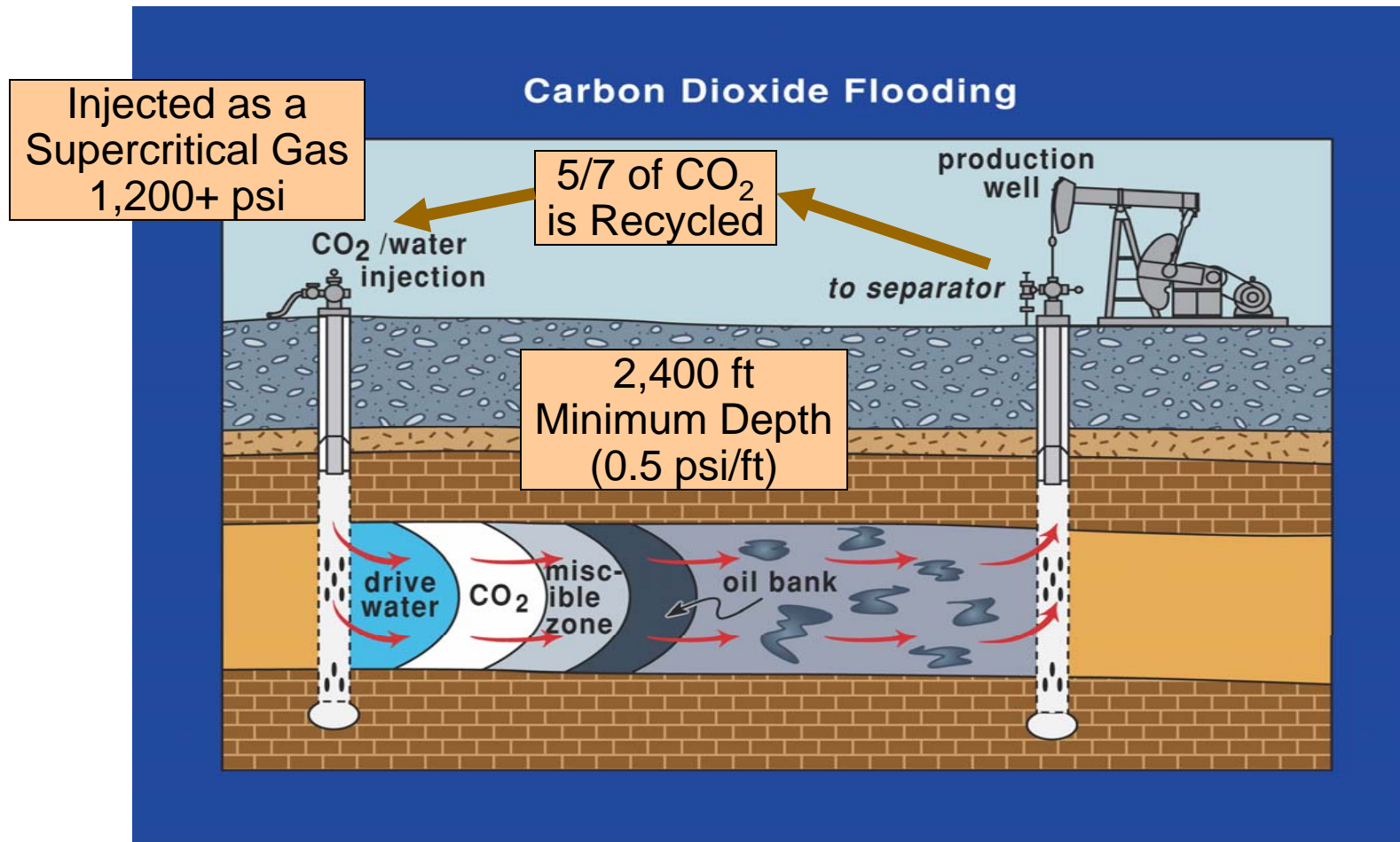
- Geological Reservoirs
- ~~Deep Ocean Injection~~



Sequestration Timeline

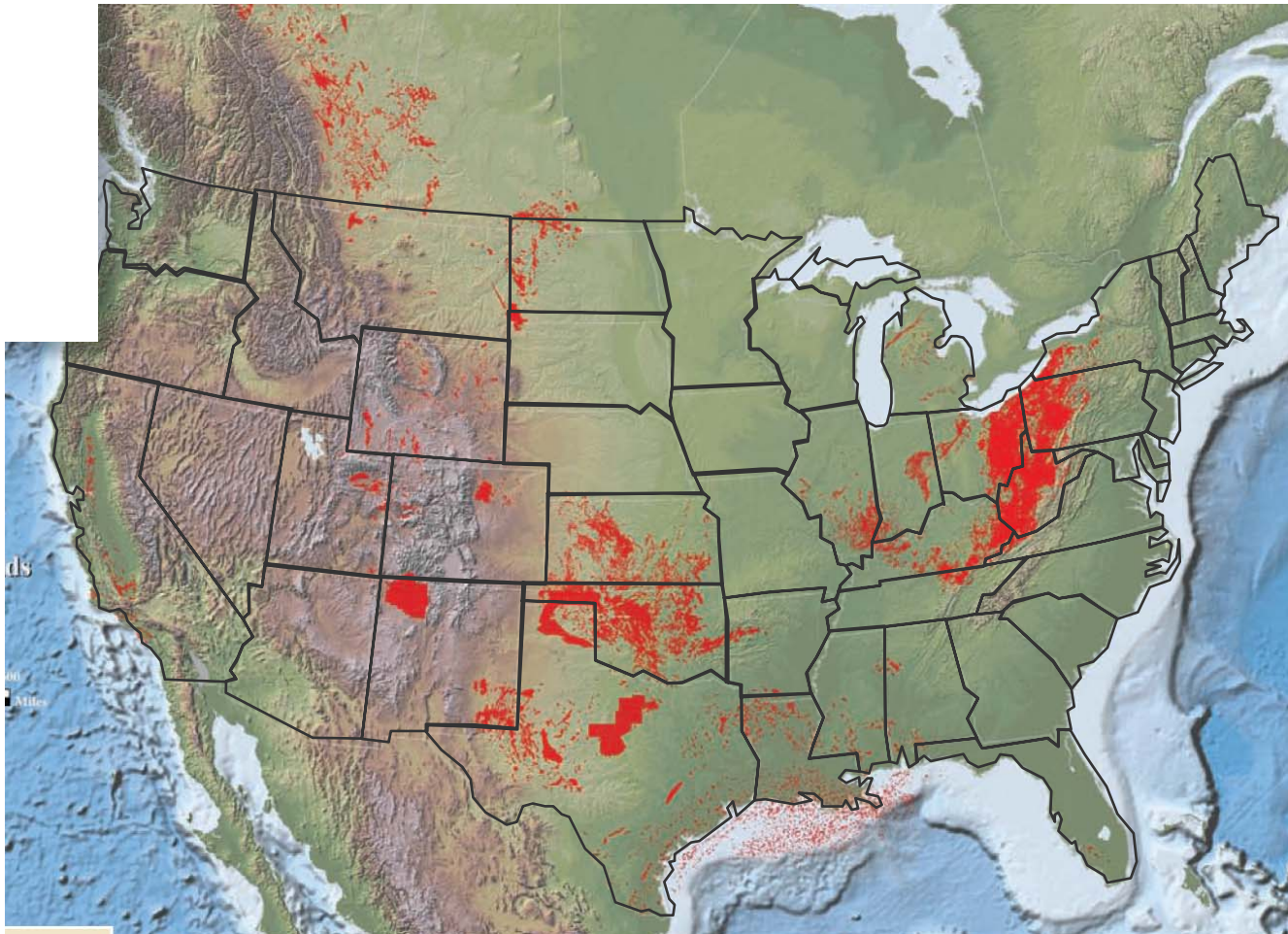


Enhanced Oil Recovery (EOR)



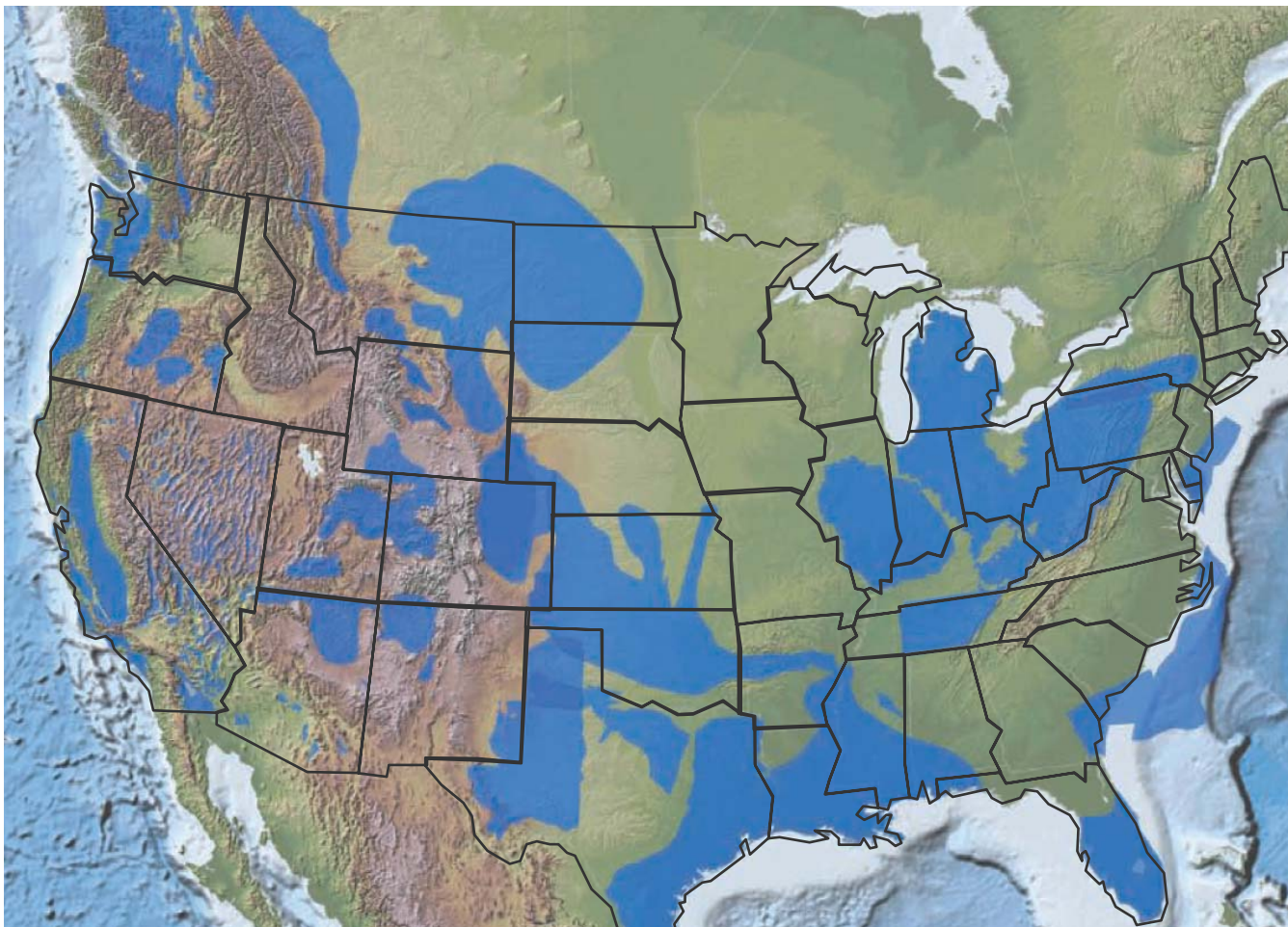
Fully Implemented – 10-20% of CO₂ Worldwide Potential

Oil/Gas Reserves – (EOR Potential)



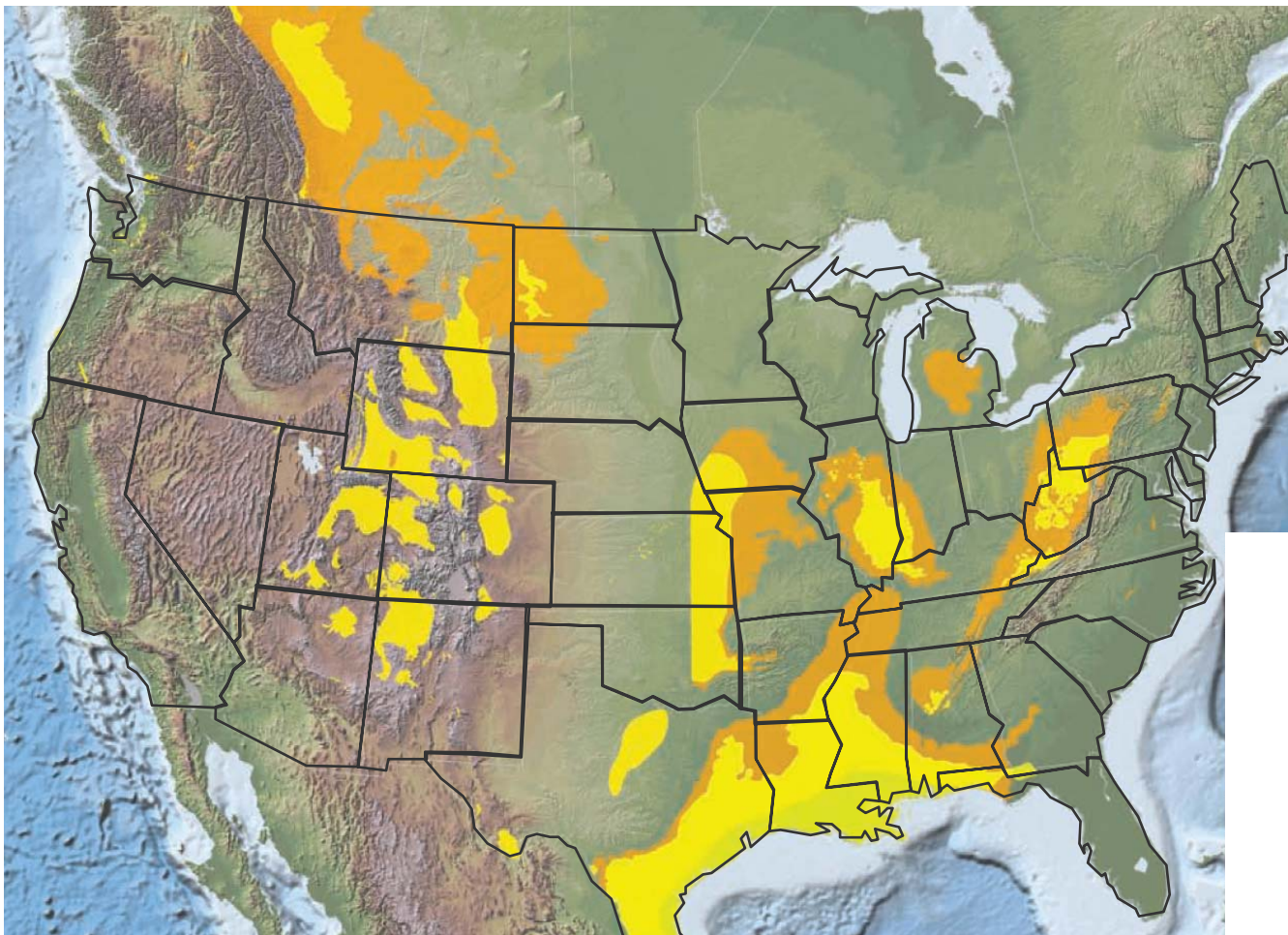
Source: DOE/NETL Carbon Sequestration Atlas

Deep Saline Formations



Source: DOE/NETL Carbon Sequestration Atlas

Unmineable Coal Seams



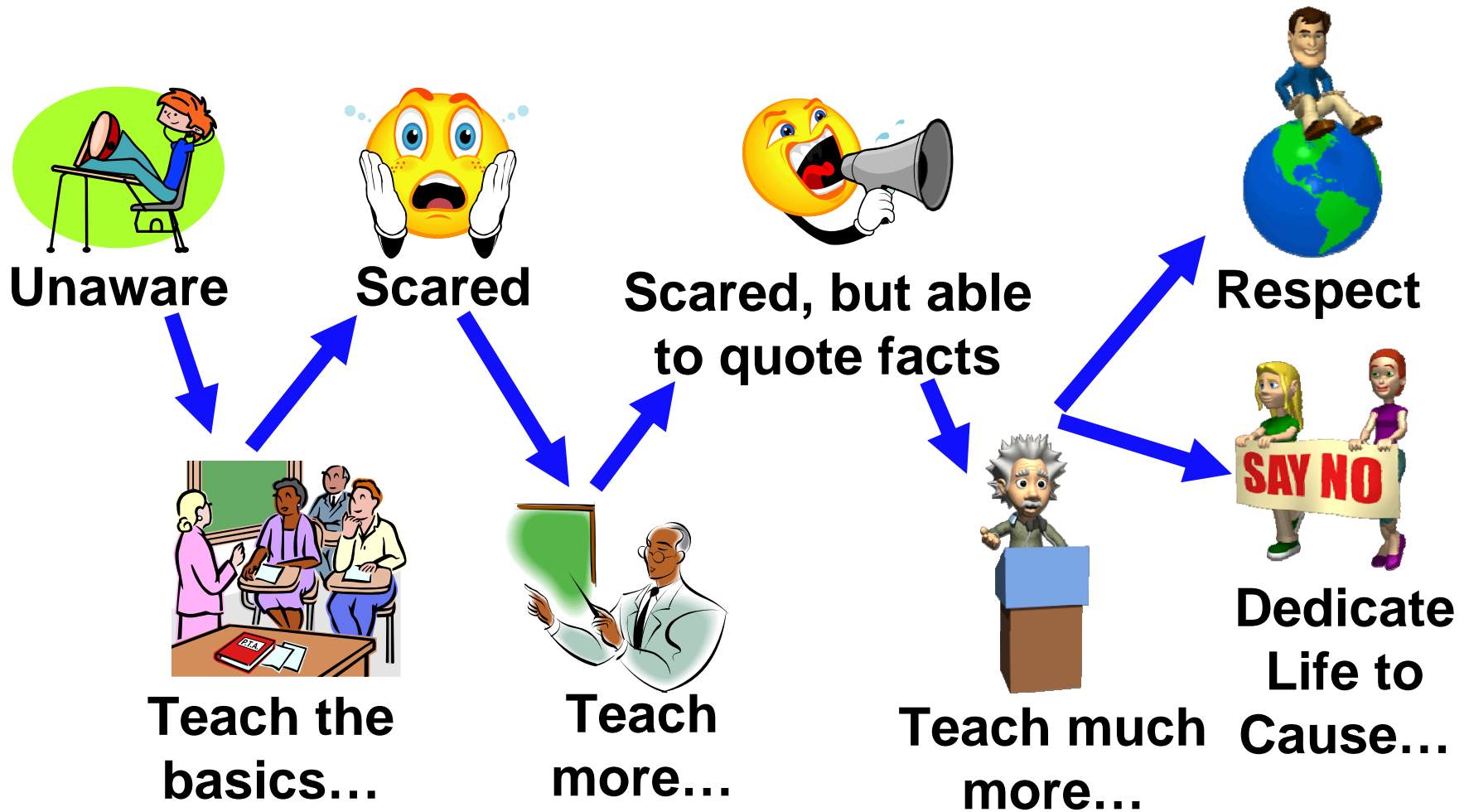
Source: DOE/NETL Carbon Sequestration Atlas

Geological Regulatory Structure Slowly Developing

- State Standards for CO₂ Ownership
 - EOR in Texas
- Federal Catastrophic Insurance Program
 - Similar to federal nuclear insurance program
- State Permitting Programs Developing
- Pipelines – FERC or others



Public In Initial Educational Process...



“Educational” Material – Horseshoe Lake

**Tree Kill – 1990
Horseshoe
Lake, Mammoth
Mountain, CA**

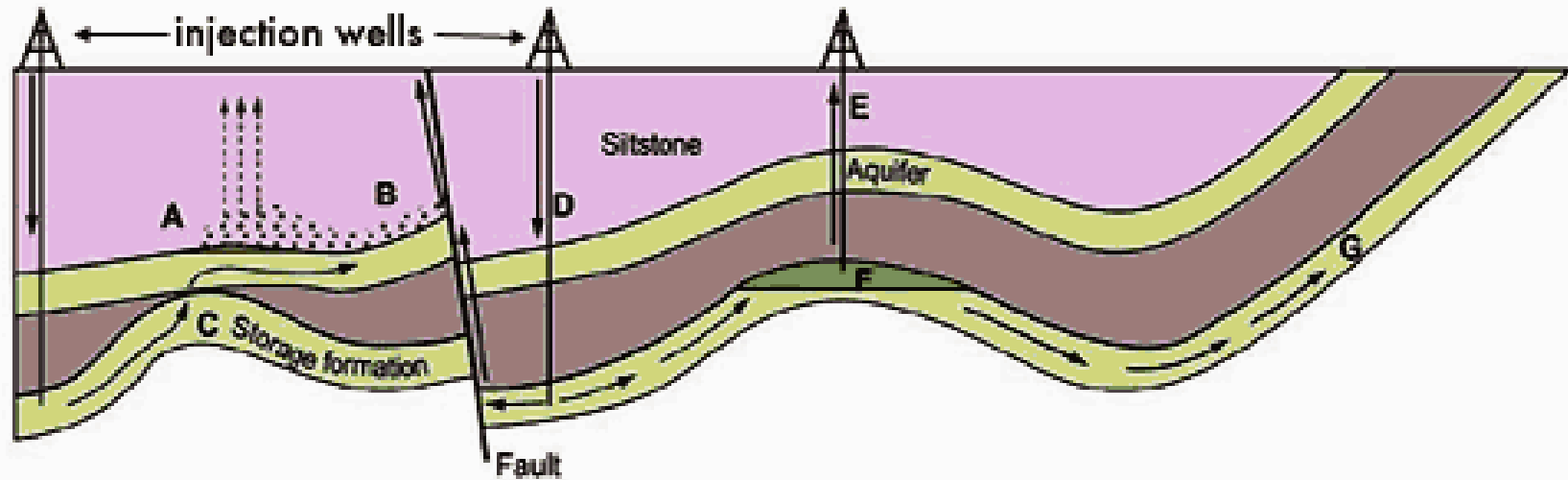


“Educational” Material – Lake Nyos

**1.6 million ton CO₂
Release from
Lake Nyos
August 21, 1986
1,700 dead + 3,500
livestock,
Cameroon, West
Africa**



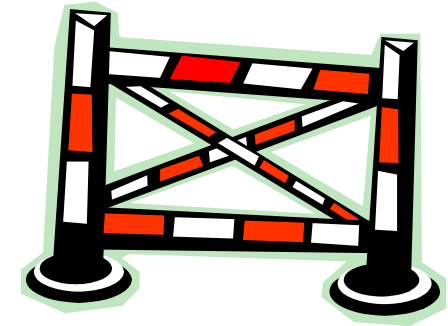
Risk of “Leakage” NOT Zero



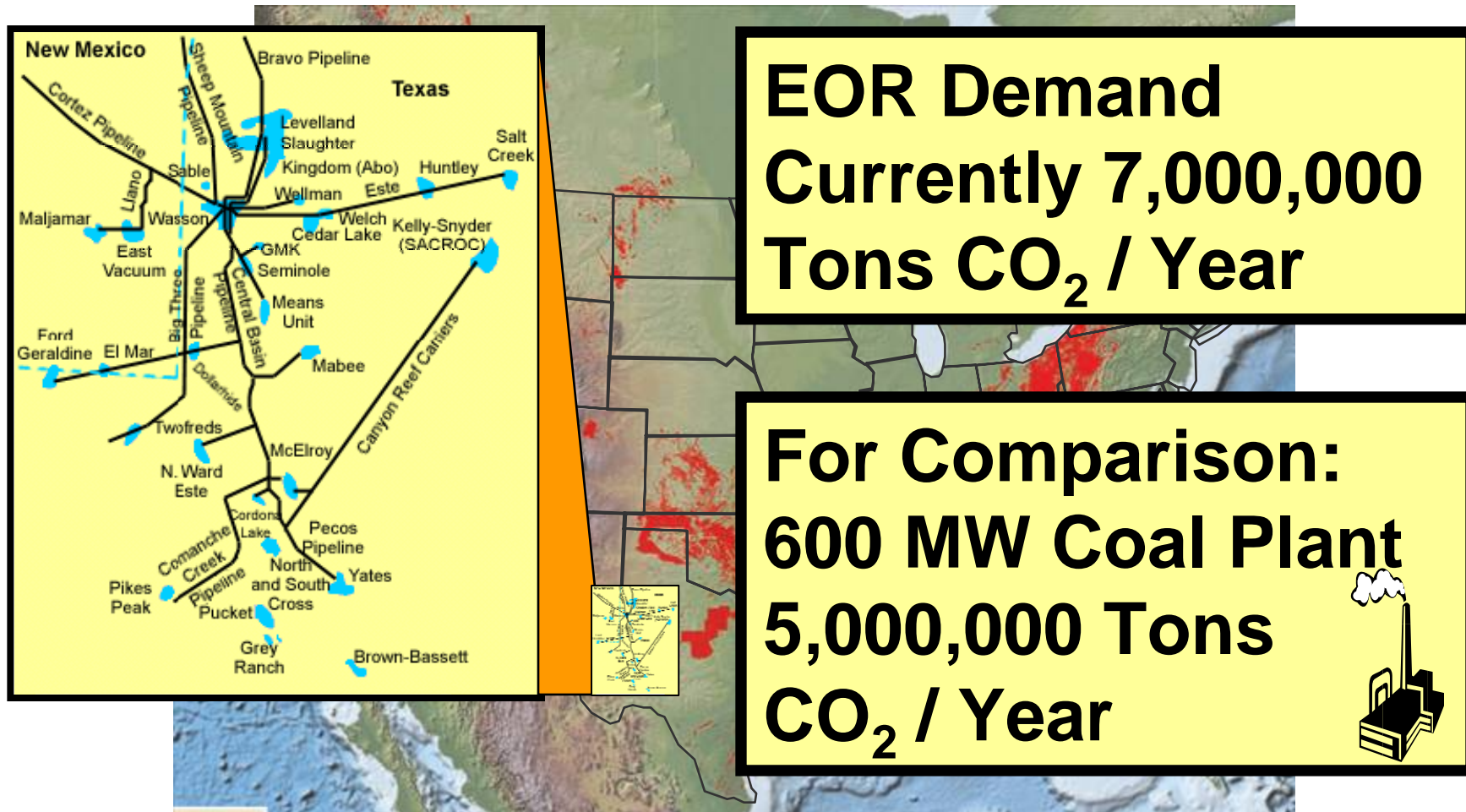
- EPA Developing Permitting Requirements Under the Safe Drinking Water Act

Permitting Will Be Extremely Difficult

- Federal Programs
 - Clean Water Act
 - Endangered Species Act
 - National Parks
- Acceptable Storage Standards
 - Yucca Mountain – 10~~0~~000 → 1,000,000 years
- States / Local
 - Reluctant to be a “Dump” for other states
 - Not Under My Back Yard (NUMBY)
- Land Owners
 - Restrictive covenants on property
 - Pipeline right-of-way

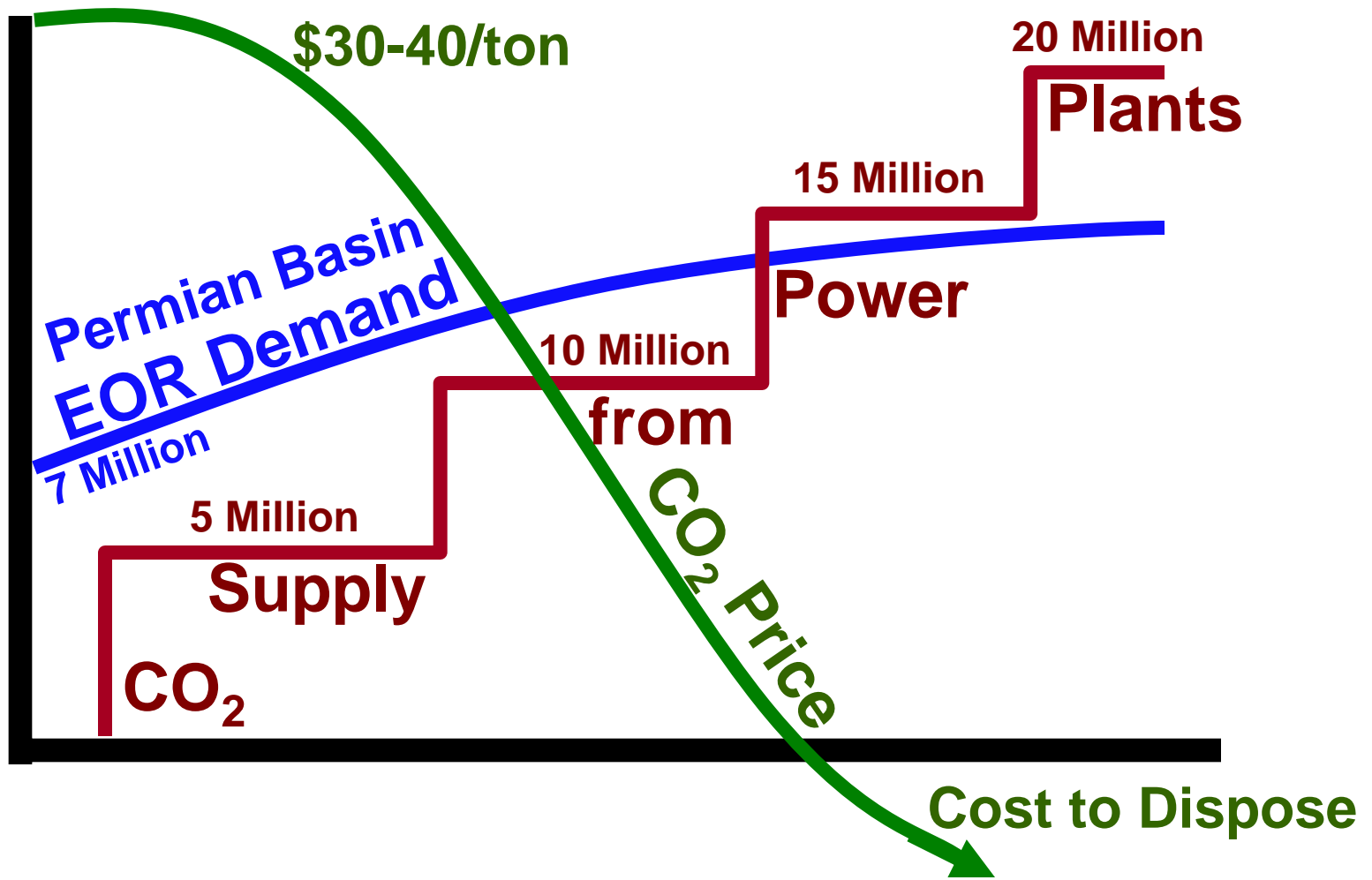


Permian Basin

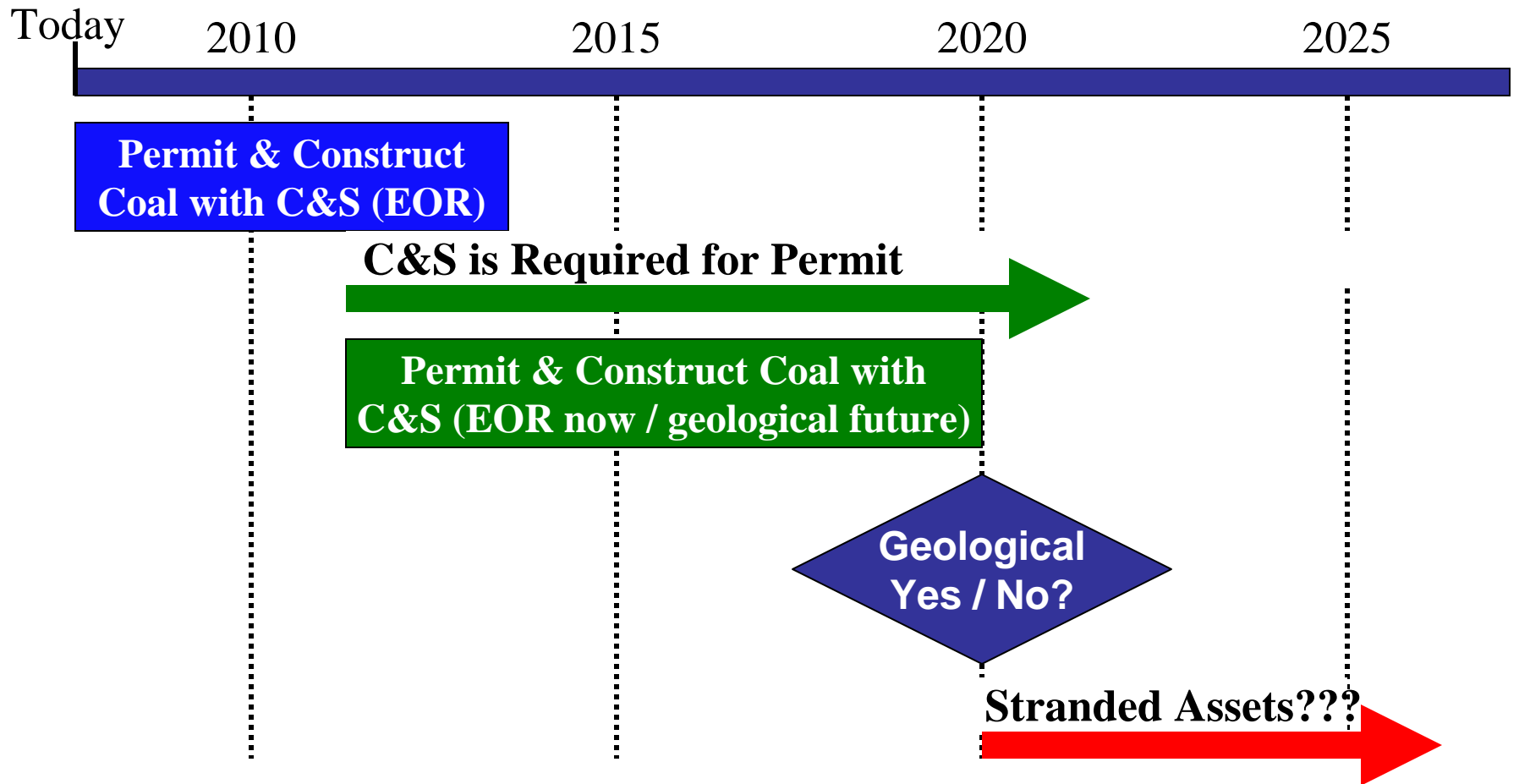


Source: DOE/NETL Carbon Sequestration Atlas

Power Plant Supply vs. CO₂ Demand



Stranded Asset Risk



High Risk = Big Players

- Fortune 250 Company
 - \$10+ billion revenue
 - Higher risk profile than debt & equity markets



Conclusions

- Capture Commercial by 2020
- EOR is Limited, but Commercial Today
- Geological Commercial by 2030
- Public Acceptance – Fatal Flaw?
- Financial Risk Will Limit Investment

Thank You



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