Future of Carbon Storage Research

NETL Geological Storage Program Review

August 12th, 2014, Pittsburgh, PA

Dr. S. Julio Friedmann

Principal Deputy Assistant Secretary (FE) and
Deputy Assistant Secretary, Office of Clean Coal

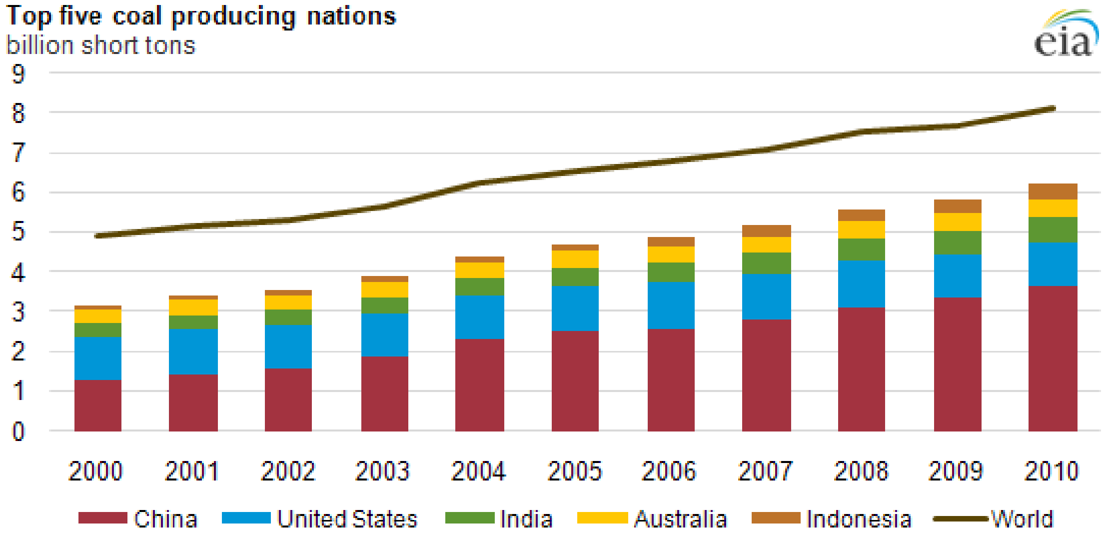
U.S. DEPARTMENT OF
ENERGY
Fossil
Energy

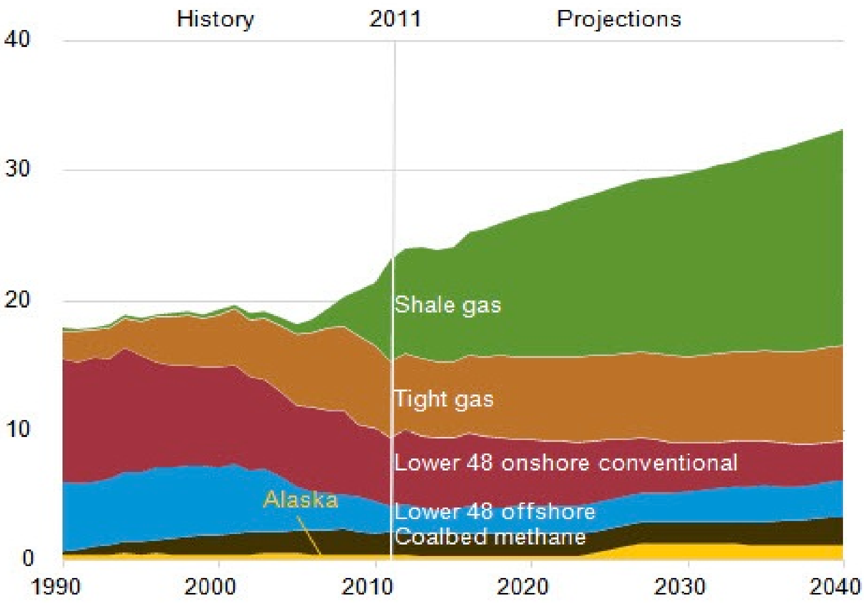
This is a time of fossil energy abundance

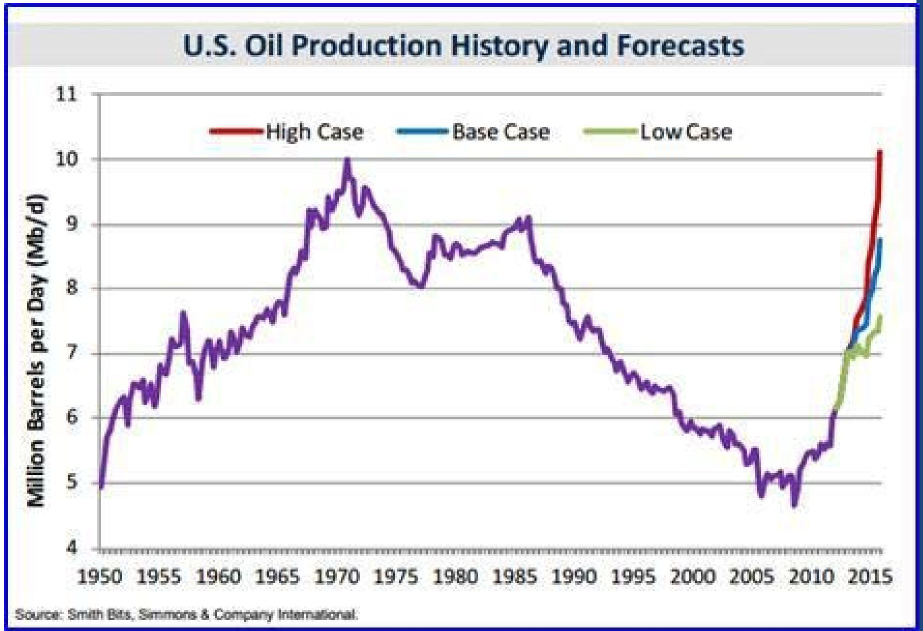
We must harness this age of abundance

Once in a generation opportunity to build

Abundant Coal, Gas, and Oil


Top five coal producing nations
billion short tons




U.S. Oil Production History and Forecasts

Source: Smith Bits, Simmons & Company International.

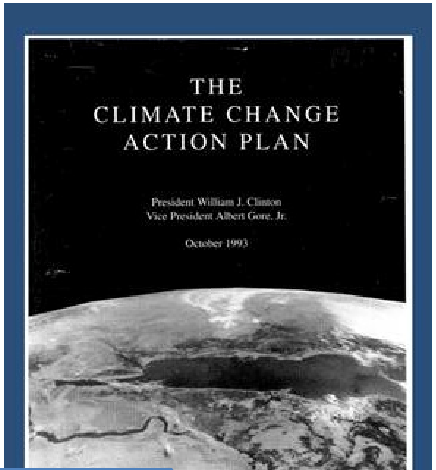
CCS/CCUS is the key technology for this era of fossil energy abundance

Policy drivers

- President’s Climate Action Plan
- EPA: NSPS (draft) and ESPS (draft)
- State actions (AB32 etc.)

Global economic context

- Investors speak
- Global coal increase
- US-China dominance



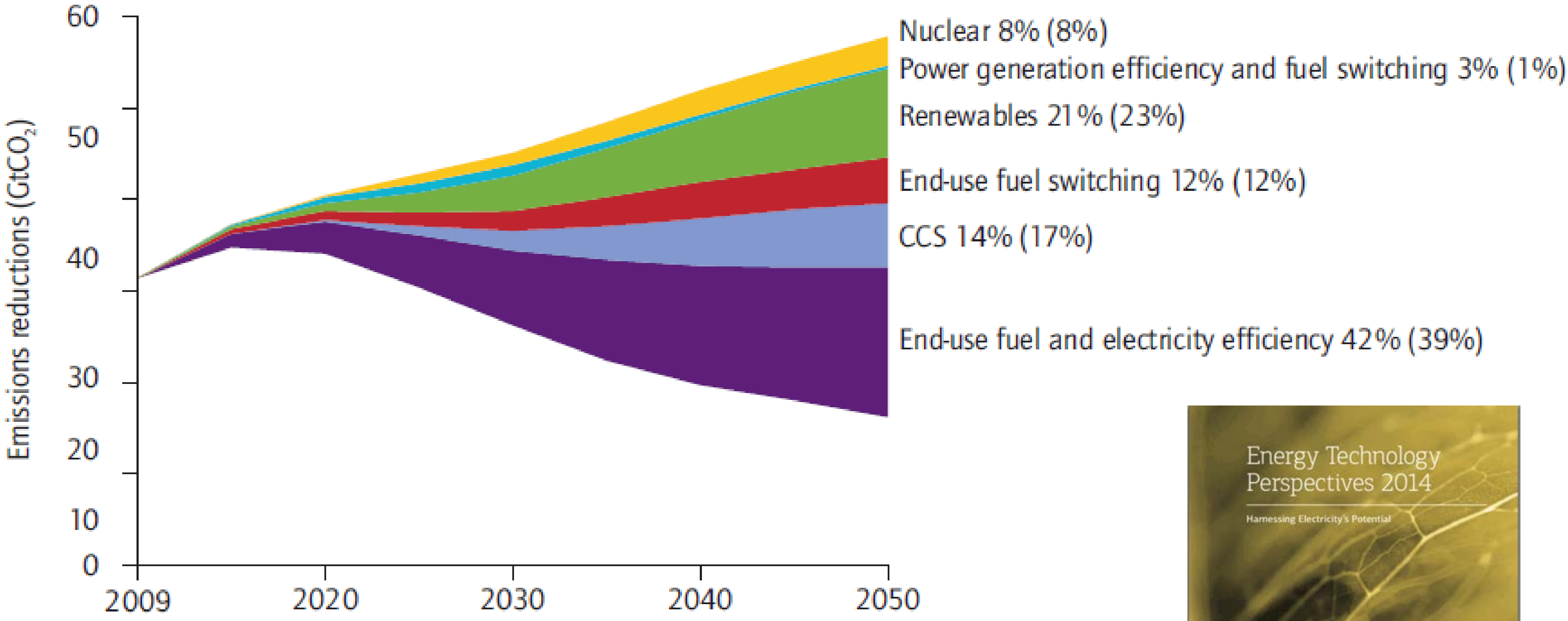
THE
CLIMATE CHANGE
ACTION PLAN

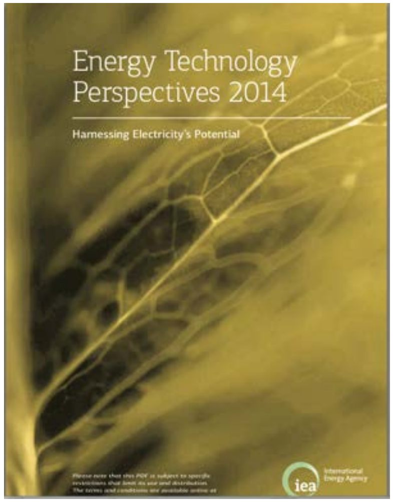
President William J. Clinton
Vice President Albert Gore, Jr.

October 1993

A $6B climate mitigation program at DOE

IEA CCS Roadmap 2013: Key Technologies for Reducing Global CO_2 Emissions




Energy Technology Perspectives 2014

Harnessing Electricity's Potential

Most 2050 climate budgets require CCUS from natural gas power and biofuels

Source: IEA Roadmap 2013.

Note: Numbers in brackets are shares in 2050. For example, 14% is the share of CCS in cumulative emission reductions through 2050, and 17% is the share of CCS in emission reductions in 2050, compared with the 6DS.

ROBOT GARDENERS!

Take the Work Out of Yard Work

HAULING ASSETS

Google's Brilliant Tax Shenanigans

MIKE JUDGE

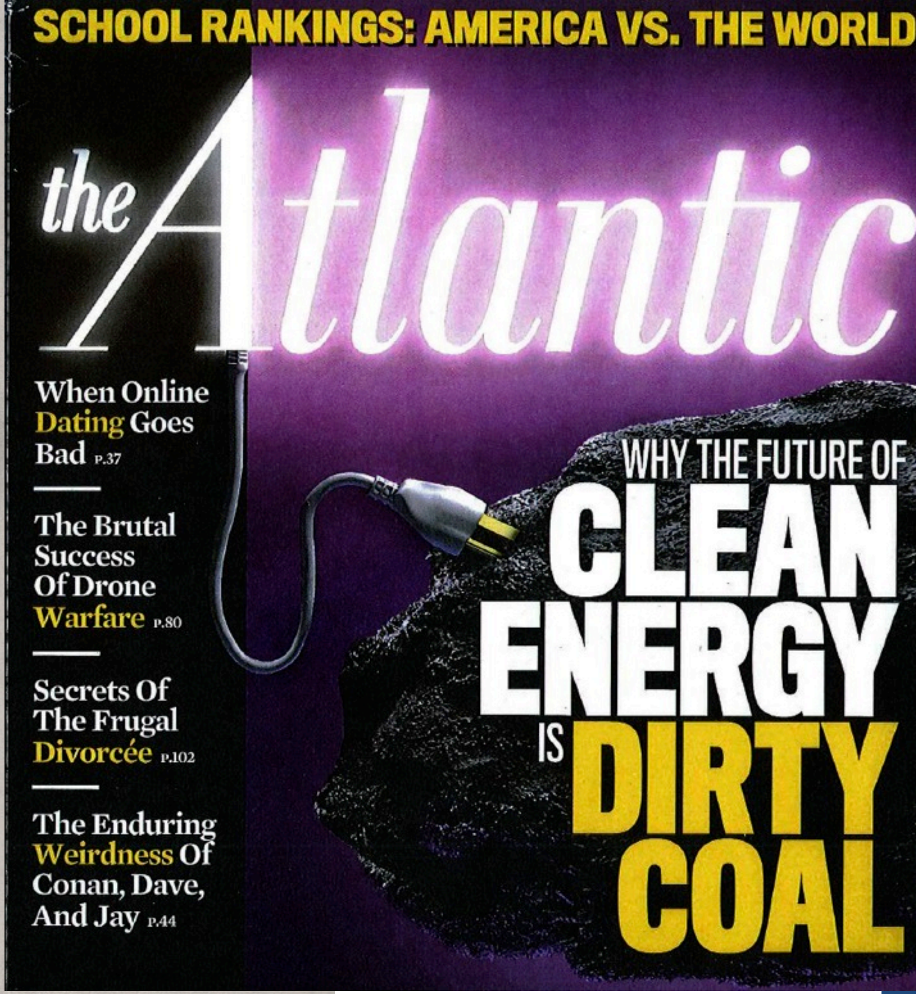
From Beavis to Bitcoin

BLACK MAGIC

Coal: It's Dangerous, It's Dirty, and It's the Future of Clean Energy

BY CHARLES C. MANN

superpower | apr 2014



SCHOOL RANKINGS: AMERICA VS. THE WORLD

the Atlantic

When Online Dating Goes Bad P.37

The Brutal Success Of Drone Warfare P.80

Secrets Of The Frugal Divorcée P.102

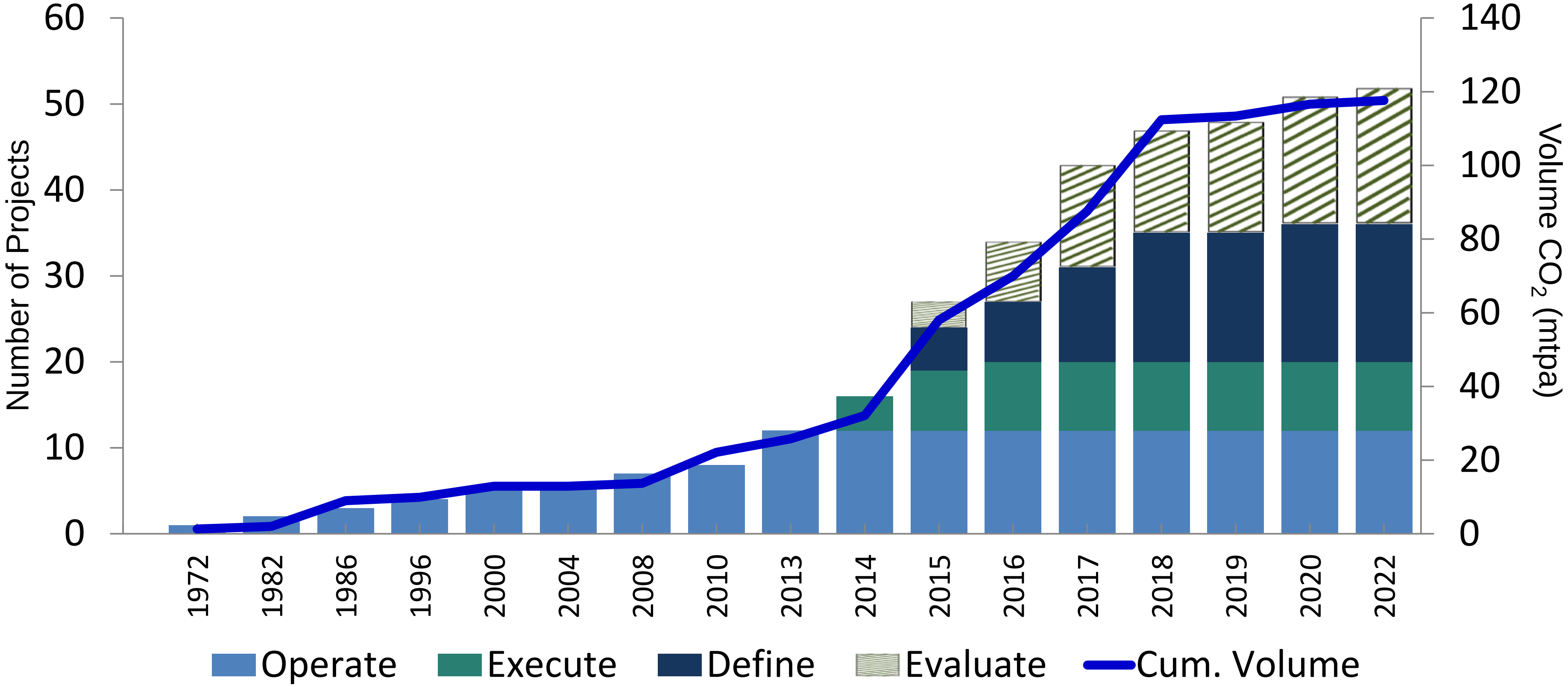
The Enduring Weirdness Of Conan, Dave, And Jay P.44

WHY THE FUTURE OF CLEAN ENERGY IS DIRTY COAL

Brief history and roadmap for CCS

	Then CCS Program Initiated (1997)	**Now** Progress to Date	**Future (2030)** Broad Commercial Deployment
CCS R&D	• Niche commercial efforts • 1930’s and 1970’s tech for capture • Little known for storage	• Much knowledge gained • Major tech development • Tools being developed and tested	• “Commercial toolbox” developed • Dramatic cost reductions • 1000’s of sites worldwide
Storage Infrastructure/ Field Tests	• Little known outside of oilfield services • Sleipner project initiated	• Increased visibility; • Knowledge gained and lessons learned • 12 large projects world-wide	• Market frameworks in place • Novel regulatory mechanisms • Turnkey operation

Large Scale Integrated Projects World Wide



Data from Global CCS Institute

U.S. DEPARTMENT OF ENERGY | Fossil Energy

Major learning matter

Geochemical risks are small and manageable

- Cap-rocks tend to get better over time
- Well-bore geochemistry risks smaller than first thought

Far-field hydrology risks are small (e.g., brine volume displacement

Many effective options for characterization and monitoring

- Seeking lower cost/higher certainty options
- Sorting types and terranes

These findings require explicit publication

CCS Best Practices Manuals

Critical Requirement For Significant Wide Scale Deployment - Capturing Lessons Learned

the ENERGY lab

BEST PRACTICES for:

Public Outreach and Education for Carbon Storage Projects

the ENERGY lab

BEST PRACTICES for:

Site Screening, Site Selection, and Initial Characterization for Storage of CO_2 in Deep Geologic Formations

BEST PRACTICES for

Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations – 2012 Update

Second Edition

Best Practices Manual	**Version 1 (Phase II)**	**Version 2 (Phase III)**	**Final Guidelines (Post Injection)**
Monitoring, Verification and Accounting	2009/2012	2016	2020
Public Outreach and Education	2009	2016	2020
Site Characterization	2010	2016	2020
Geologic Storage Formation Classification	2010	2016	2020
**Simulation and Risk Assessment	2010	2016	2020
**Carbon Storage Systems and Well Management Activities	2011	2016	2020
Terrestrial	2010	**2016 – Post MVA Phase III**	

Key challenges for GCS deployment

Geomechanics

- Induced seismicity (with attendant fluid migration)
- Cap-rock and well-bore fracture mechanics

Unconventional EOR

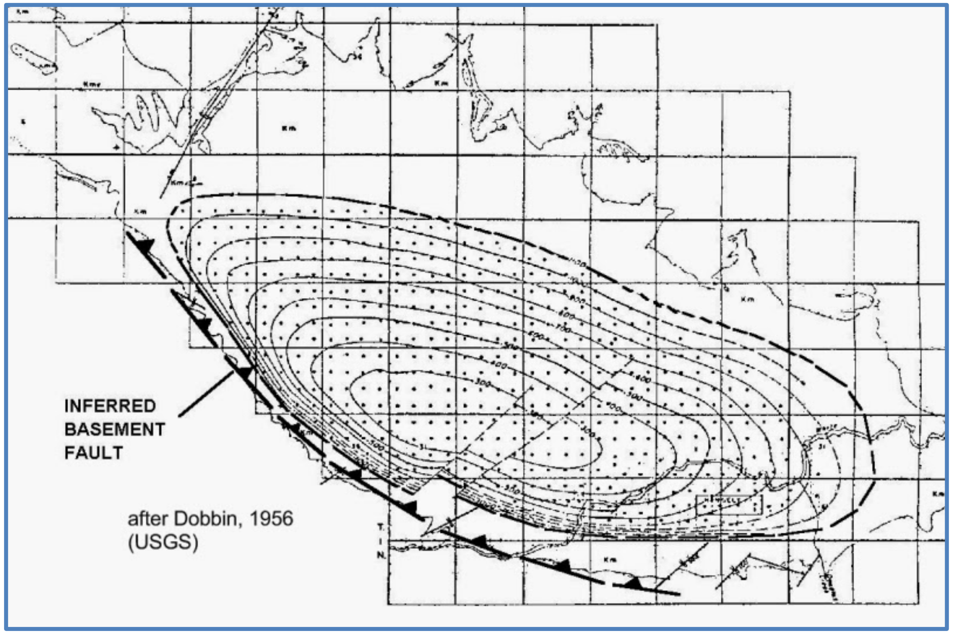
- ROZ and negative carbon oil
- Low-permeability reservoirs

Tools for the non-experts

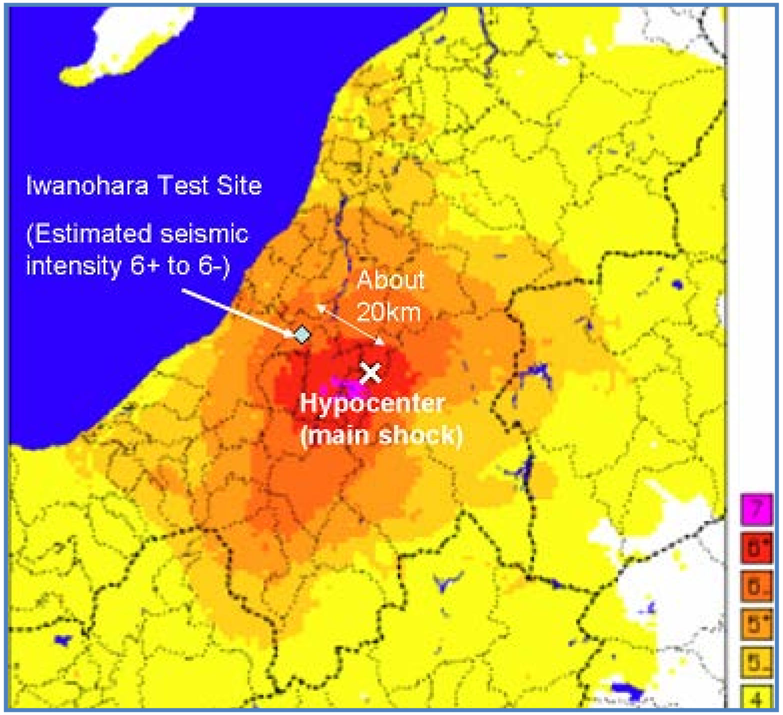
- Data infrastructure
- Mod-sim for regulators and would-be operators
- Protocols and tools for PISC

Lead to widespread, turn-key commercial ops

Geomechanics risks are real, but smaller than often portrayed



after Dobbin, 1956 (USGS)



Sustained water and CO2 injections at Rangely
No leakage; no large M induced seismicity

M6.8 event near Nagaoka CO2 injection
No leakage; no large M induced seismicity

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

Regardless, we must treat induced seismicity and flow as a substantial risk

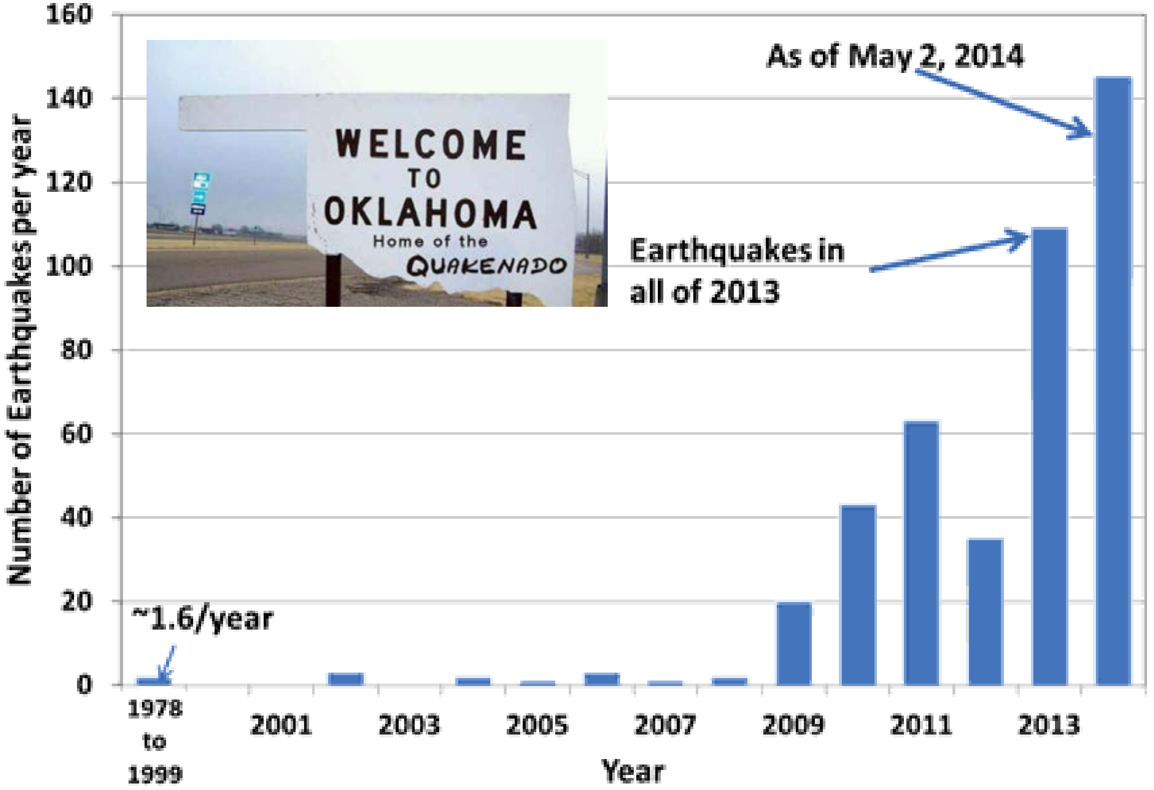
Oklahoma: Now #2

- **Events over 4.5 in US**
- **Associated with brine injection**

Large number of induced events in populated areas

Geothermal events: Geysers and Basel

Oklahoma Earthquakes Magnitude 3.0 and greater



Source: USGS-NEIC ComCat & Oklahoma Geological Survey; May 2, 2014

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

A few key issues merit deep consideration

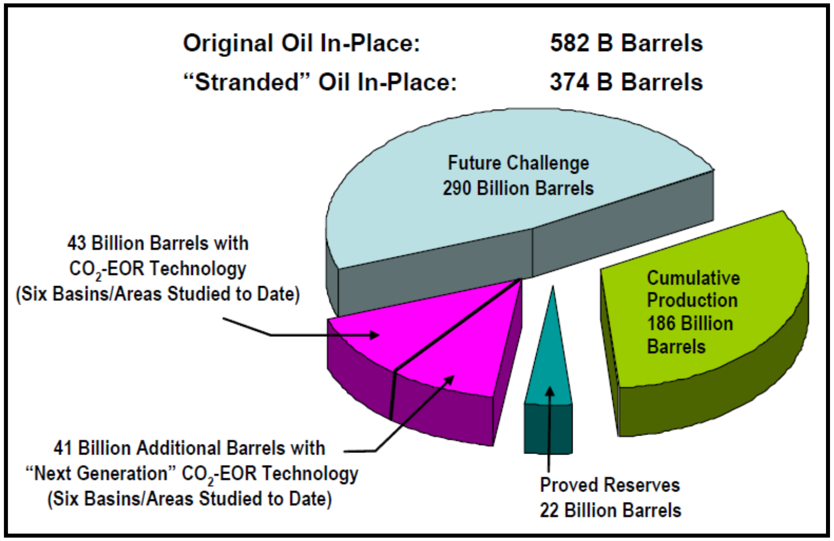
- **Accurate characterization of faults & fracture networks**
- **Accurate assessment of stress state**
- **Pressure management (strategies and technologies)**

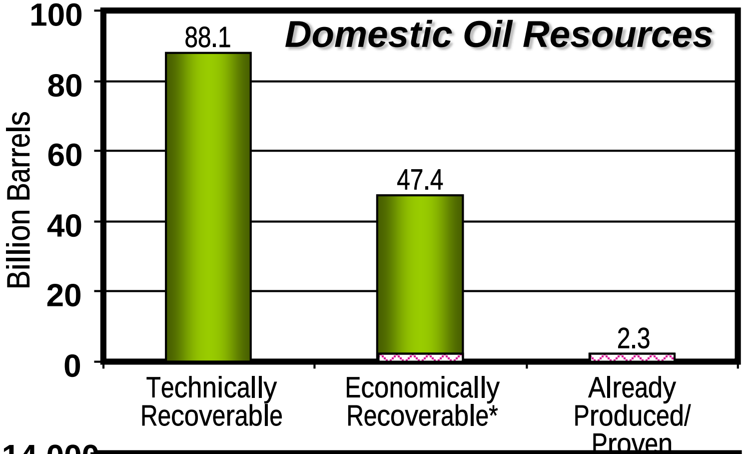
We know both more (and less) than we think

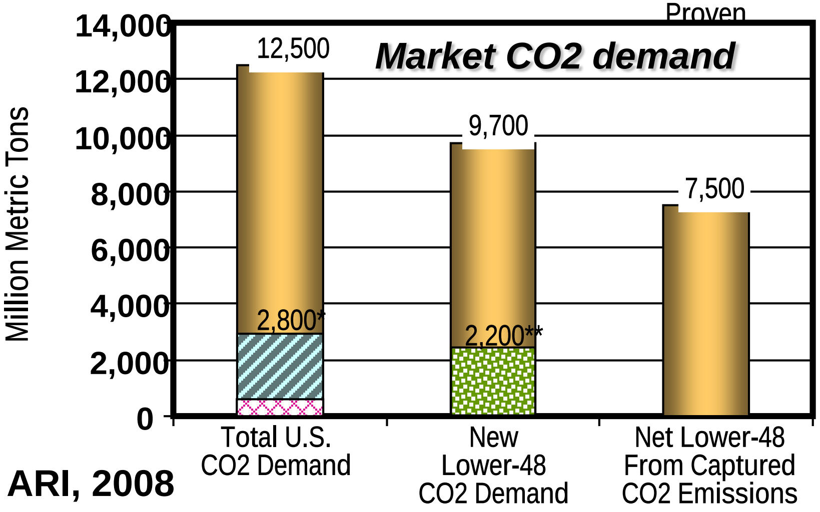
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

EOR is a critical bridging step that brings near-term benefits to the US

- **Many 10’s of billions producible in US (100’s of billions worldwide)**
- **Required to finance first set of projects; drive down costs through deployment**
- **Additional domestic supply, revenues; reduced imports**



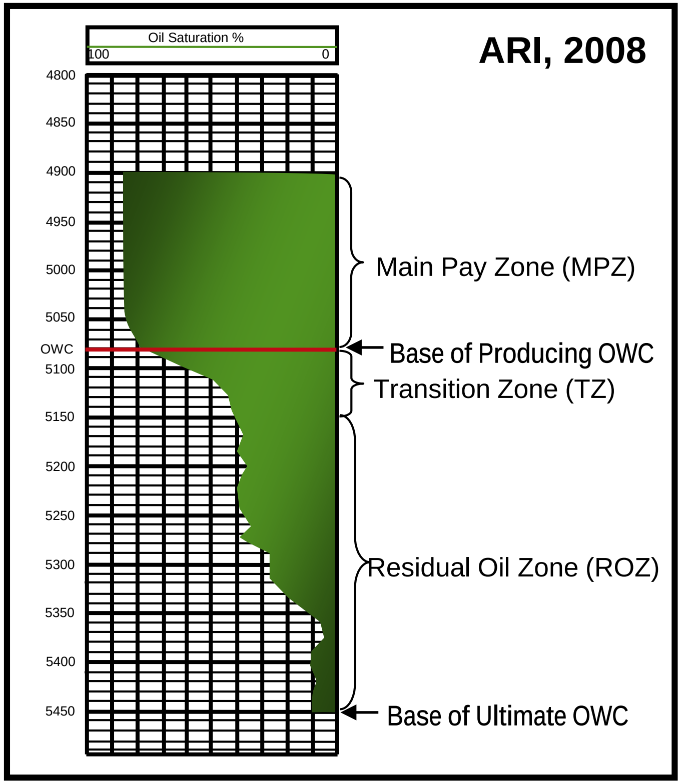




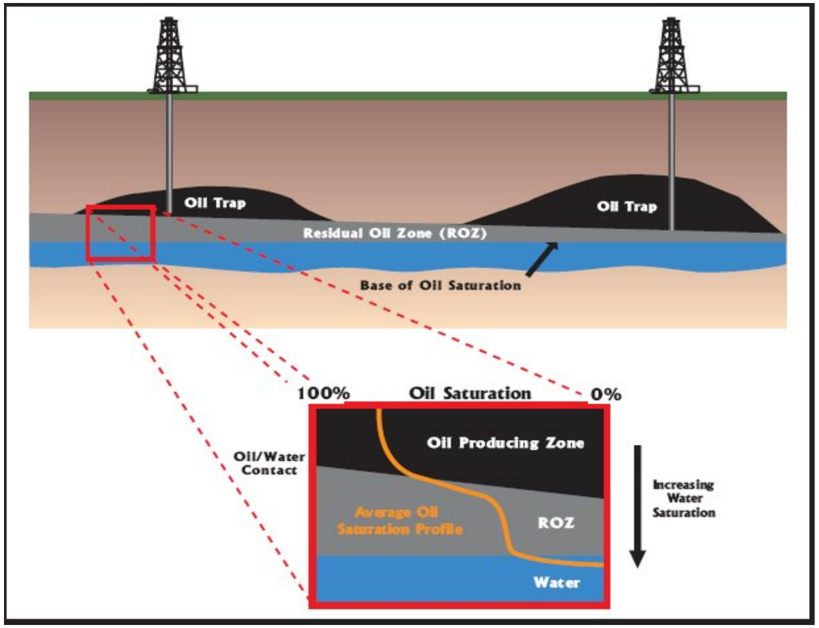
ARI, 2008

ROZ as a new and emerging endeavor

- **2x-3x recovery potential and storage potential (12-18 Gt in ROZ vs. 6.4 for main pay zones, PB)**
- **Possibility for carbon-negative HC**



ARI, 2008



	"State of the Art"	"Next Generation"
	(millions)	(millions)
CO_2 Storage (tonnes)	19	109
Storage Capacity Utilization	13%	76%
Oil Recovery (barrels)	64	180
% Carbon Neutral ("Green Oil")	80%	160%

ARI, 2008

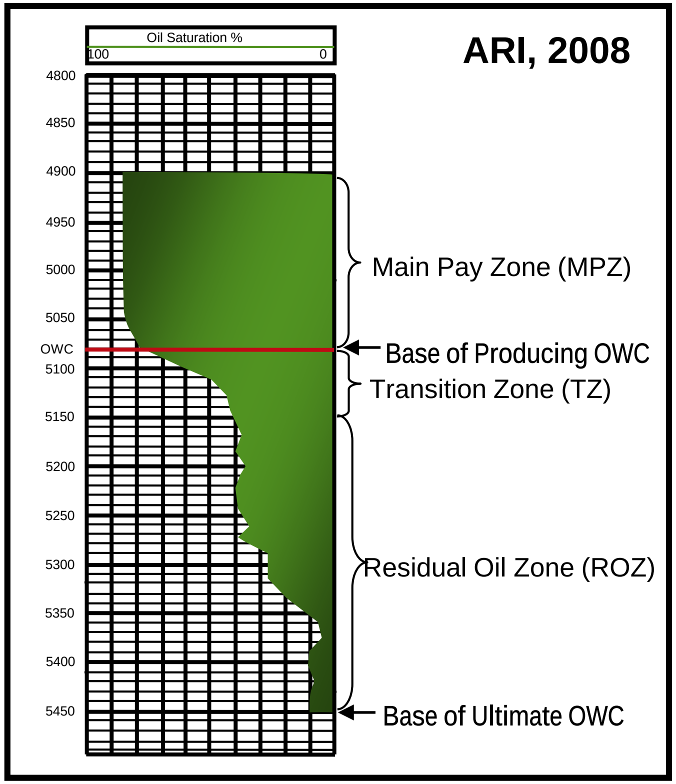
Sources: MIT, 2010; ARI 2007 and 2010; NETL 2008

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

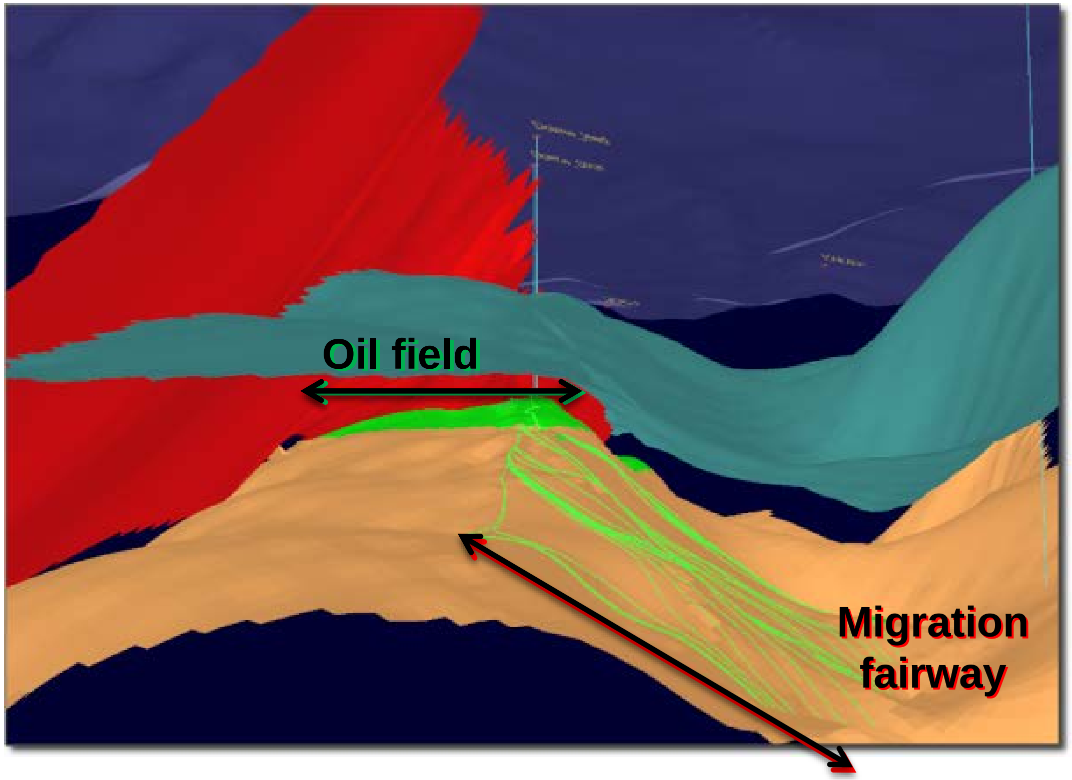
Two kinds of ROZ zones

- **Beneath main pay zones in regular oil fields**

- **Ancient migration fairways: NOT conventional closures**



ARI, 2008



These are new resources AND new reserves

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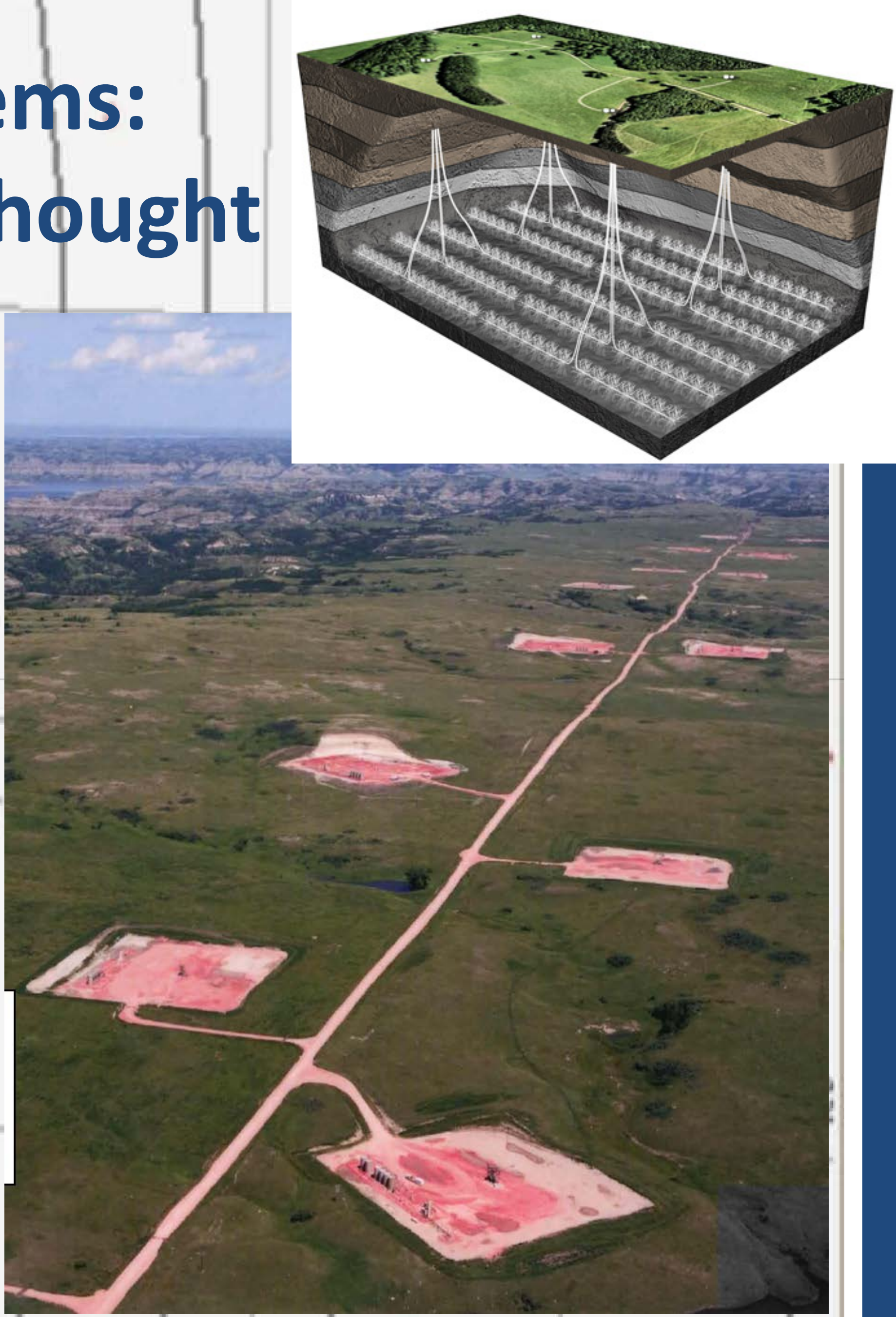
EOR in tight HC systems: more viable that first thought



Production scales to fracture surface area

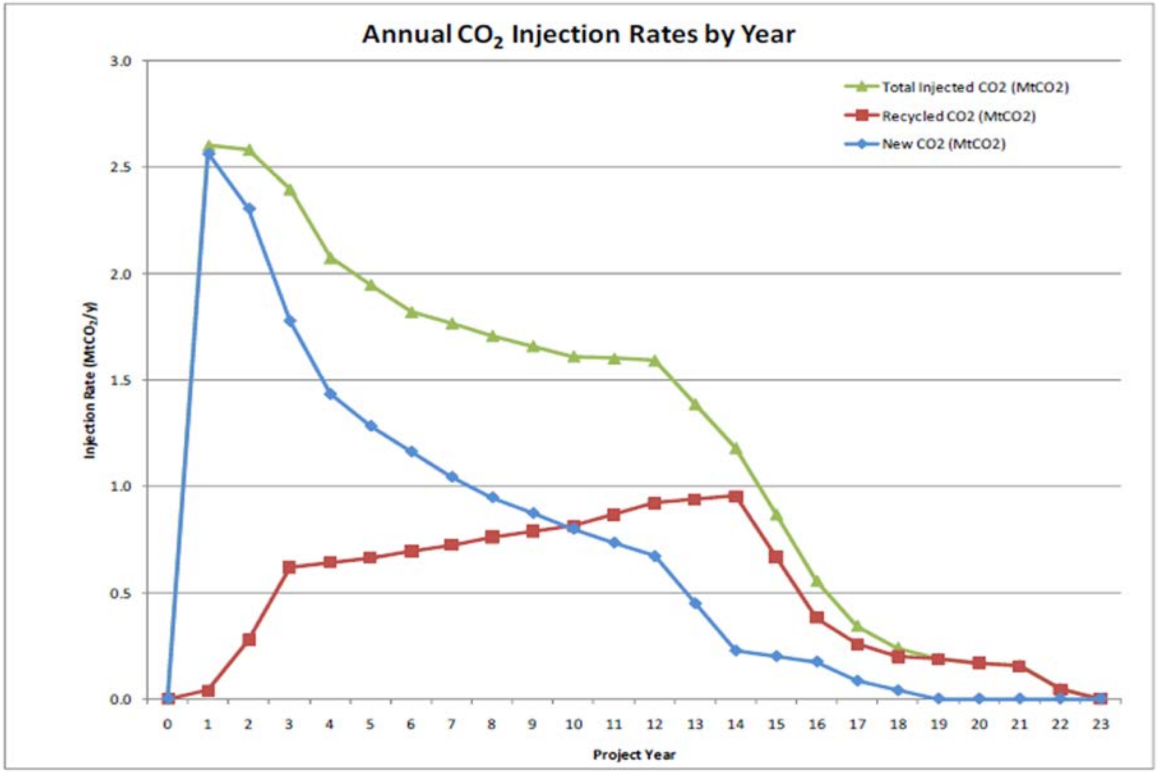
- **Microdarcy systems still yield additional production**
- **Storage volumes not yet well understood**

New play; new tools; new opportunity

EOR and ROZ can produce *negative carbon oil*

Conventional CO2-EOR

- **Carbon balance = 82-95% (by mass and energy)**
- **Must inject more CO2 for many settings**
    - **Tight reservoirs**
    - **Moderate-low saturation zones**

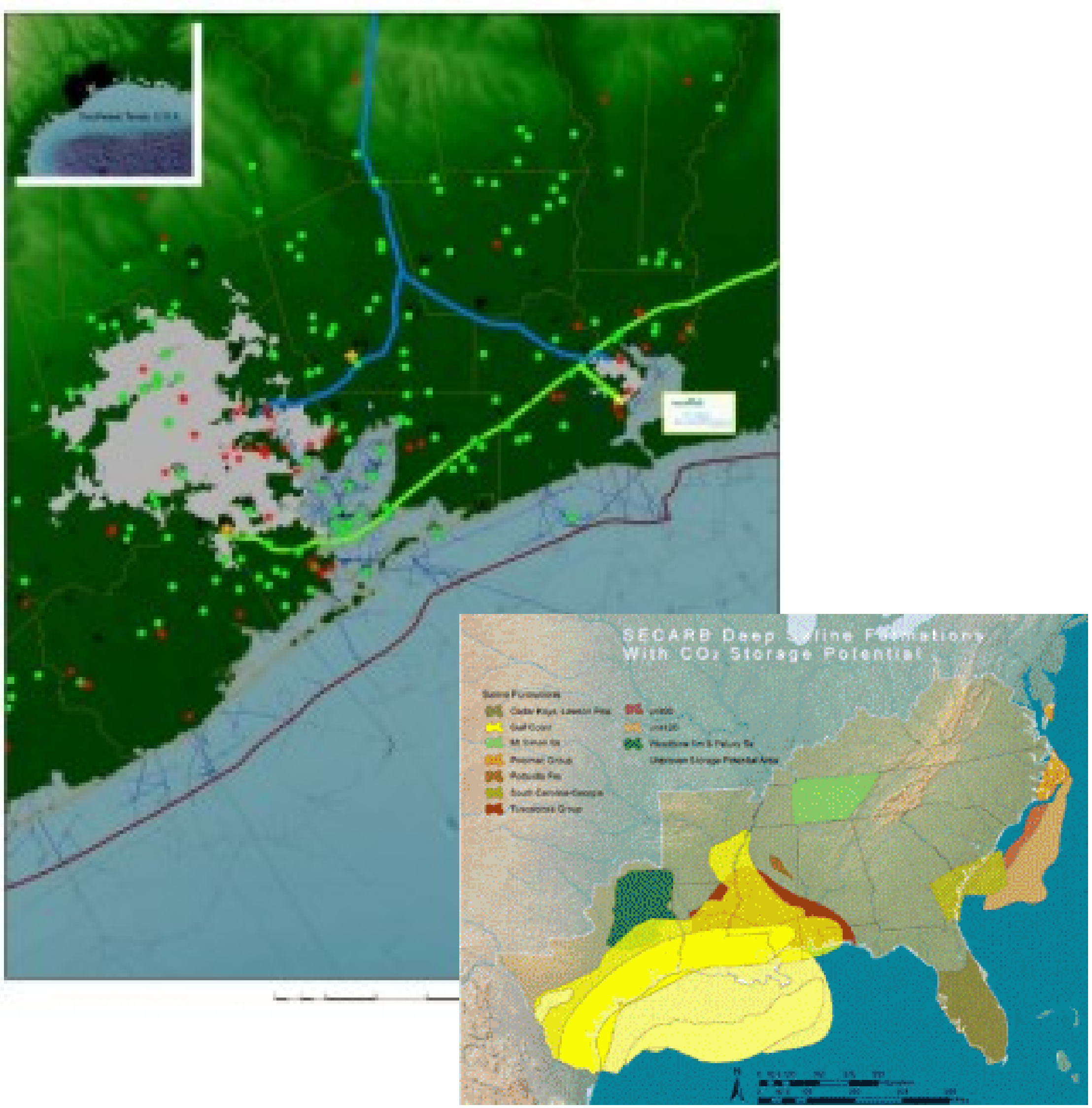


Can store more carbon than is produced!!!

Offshore: Potential and infrastructure needs

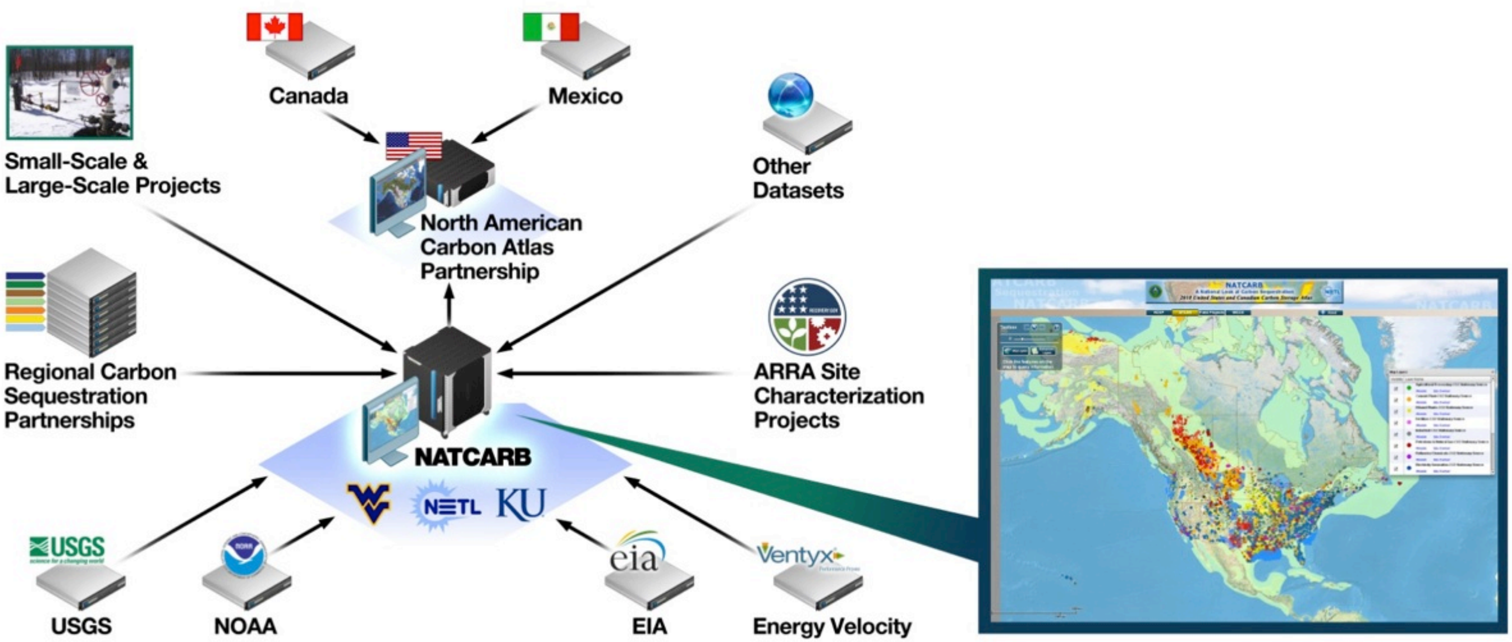
Current actions & issues

- East coast exploration
- Denbury "green" pipeline
- Aging platforms
- Renewed activity in UK



Knowledge Sharing

National Carbon Sequestration Database and Geographic Information System (NATCARB)



Canada

Mexico

Small-Scale & Large-Scale Projects

North American Carbon Atlas Partnership

Other Datasets

Regional Carbon Sequestration Partnerships

ARRA Site Characterization Projects

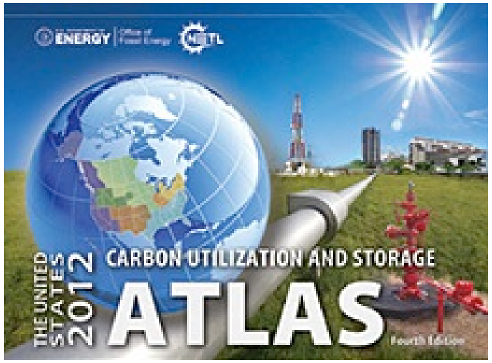
NATCARB

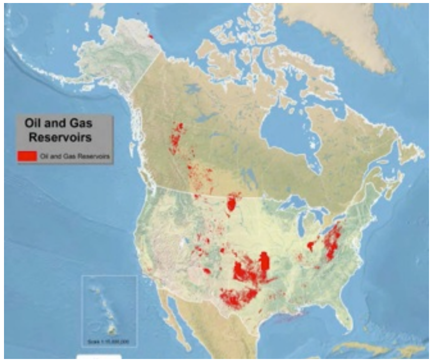
USGS

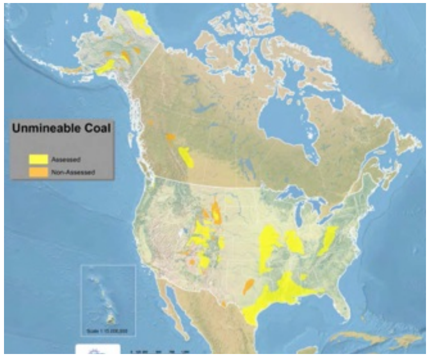
NOAA

EIA

Energy Velocity







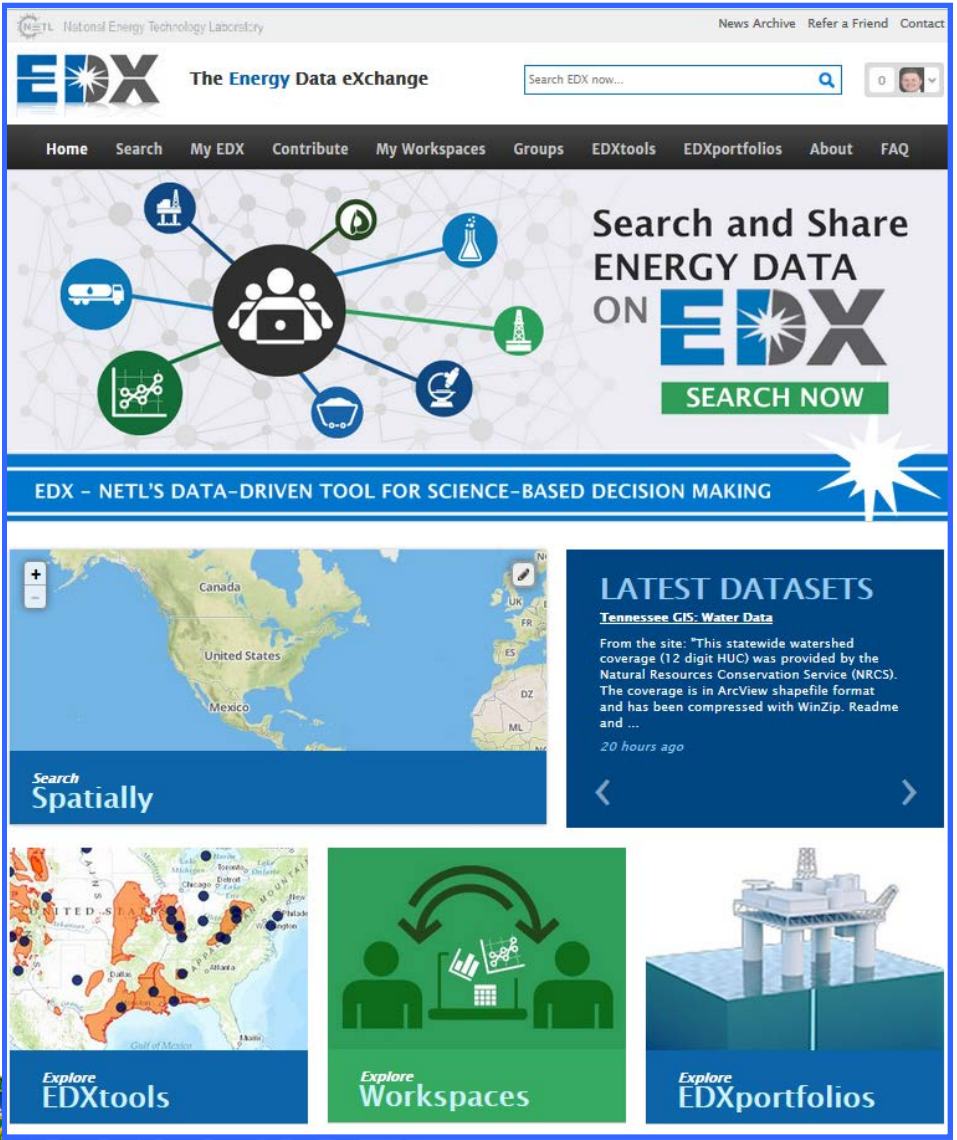
U.S. DEPARTMENT OF ENERGY

Oil and Gas Reservoirs
226 BMT CO$_2$
Storage Resource

Saline Formations
2,102 - 20,043 BMT CO$_2$
Storage Resource

Unmineable Coal Seams
56 – 114 BMT CO$_2$
Storage Resource

Central Point for Access to Research Data



Tennessee GIS: Water Data

From the site: "This statewide watershed coverage (12 digit HUC) was provided by the Natural Resources Conservation Service (NRCS). The coverage is in ArcView shapefile format and has been compressed with WinZip. Readme and ...

20 hours ago

Purpose

- Rapid searches for subsurface data
- Archive for data developed by DOE-FE programs
- Portal for data housed on other databases (NATCARB is integrated with EDX)
- Secure platform for researchers to develop collaborative, data-driven products

Current Functionality:

- Controlled access to:
  - Datasets & tools
- Open access to:
  - Portfolio information (e.g., publications)
- Upload/download large datasets
- Data storage for ongoing projects
- Data archiving for completed projects

New DOE initiative: Subsurface S&T

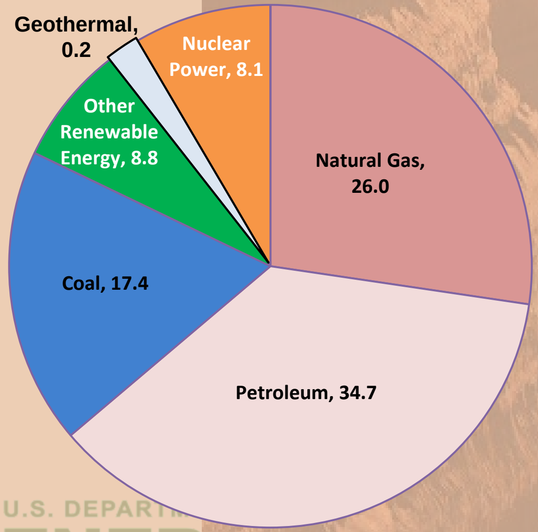
Discovering, Characterizing, and Predicting subsurface conditions

Accessing through wells

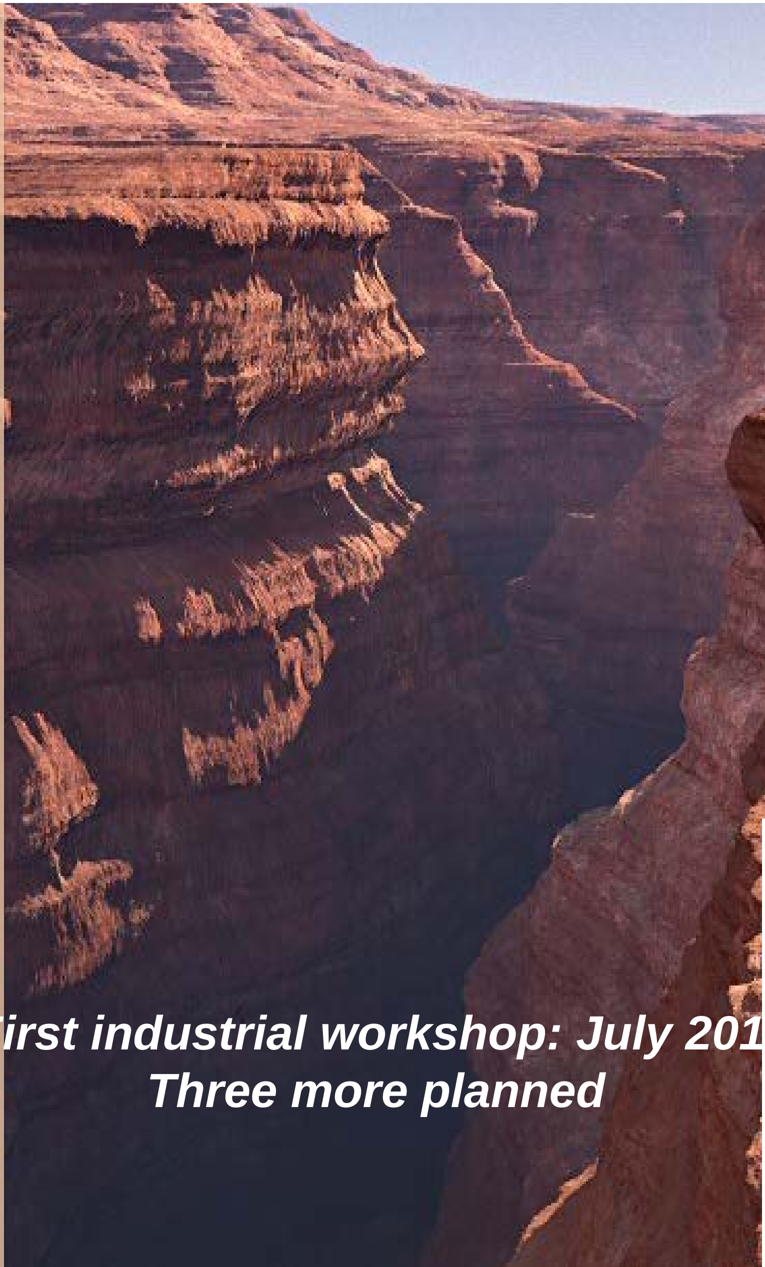
Engineering and permeability control

Sustained production and a sustainable environment

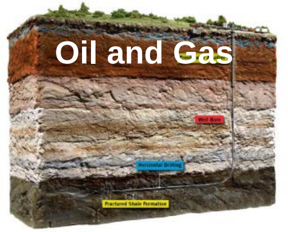
Monitoring

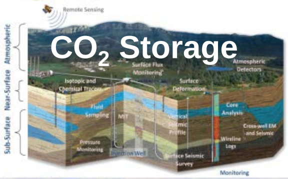


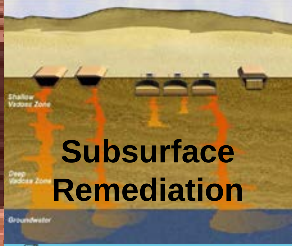
Primary Energy Use by Source, 2012
Quadrillion Btu [Total U.S. = 95.1 Quadrillion Btu]

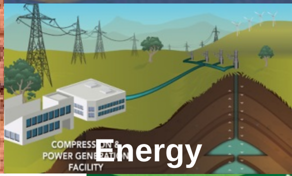


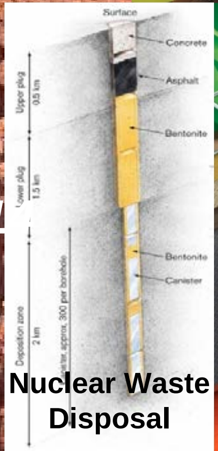
First industrial workshop: July 201
Three more planned

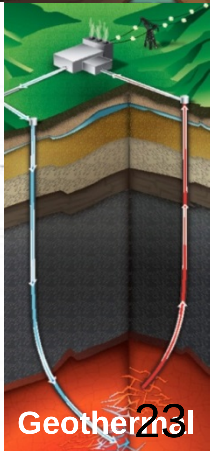












Tech Team identified key R&D targets

Adaptive Control of Subsurface Fractures and Fluid Flow

Intelligent Wellbores

- Materials: adaptive cements, muds, casing
- Real time, in-situ data acquisition and transmission system
- Diagnostics tools, remediation tools and techniques
- Quantification of material/seal fatigue and failure
- Advanced drilling and completion tools (e.g., anticipative drilling & centralizers)
- Well abandonment analysis/ R&D

Subsurface Stress & Induced Seismicity

- Stress state beyond the borehole
- Signal acquisition and processing and inversion
- Localized manipulation of subsurface stress
- Risk assessment

Permeability Manipulation

- Physicochemical rock physics, including fluid-rock interactions
- New approaches to remotely characterize in-situ fractures and to monitor fracture initiation/branching and fluid flow
- Manipulating (enhancing, reducing and eliminating) flow paths
- Novel stimulation methods

New Subsurface Signals

- Diagnostic signatures of system behavior and critical thresholds
- Autonomous acquisition, processing and assimilation approaches
- Integration of different measurements collected over different scales to quantify critical parameters and improve spatial and temporal resolutions

Energy Field Observatories: (Wells, Ops and Logistics)

Fit For Purpose Simulation Capabilities: (ACTT Coordination)

Personnel Needs:

Targets of opportunity

Large demonstrations

Regulatory revision and amendment

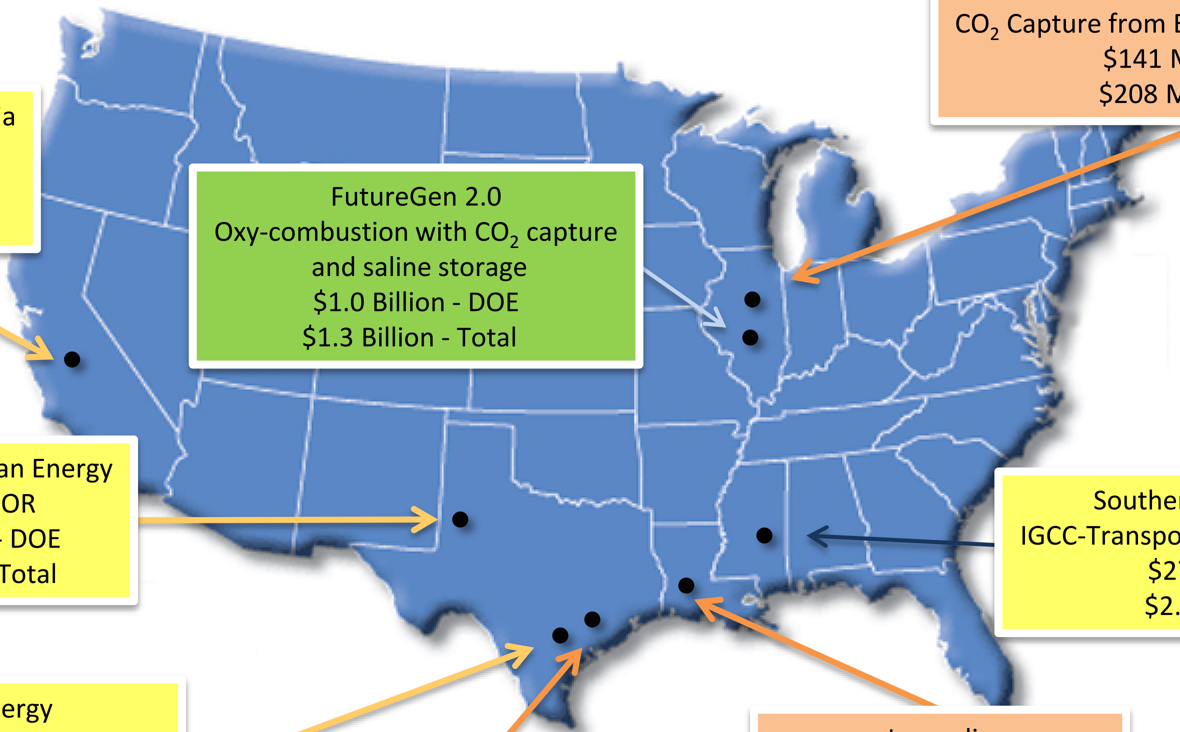
- Class VI update (every 7 years)
- Input to class II/class VI discussion
- Input into PISC determination

International efforts

- China
- Emerging projects and actors (e.g., Europe; middle east)

DOE CCUS Demonstration Projects

Focus – Large-scale commercial demonstration of CCUS integrated with coal power generation and industrial sources.



Archer Daniels Midland
CO_2 Capture from Ethanol w/ saline storage
$141 Million - DOE
$208 Million - Total

Hydrogen Energy California
IGCC with EOR
$408 Million - DOE
$4.0 Billion - Total

FutureGen 2.0
Oxy-combustion with CO_2 capture and saline storage
$1.0 Billion - DOE
$1.3 Billion - Total

Summit Texas Clean Energy
IGCC with EOR
$450 Million - DOE
$1.7 Billion - Total

Southern Company Services
IGCC-Transport Gasifier w/CO2 pipeline
$270 Million - DOE
$2.67 Billion - Total

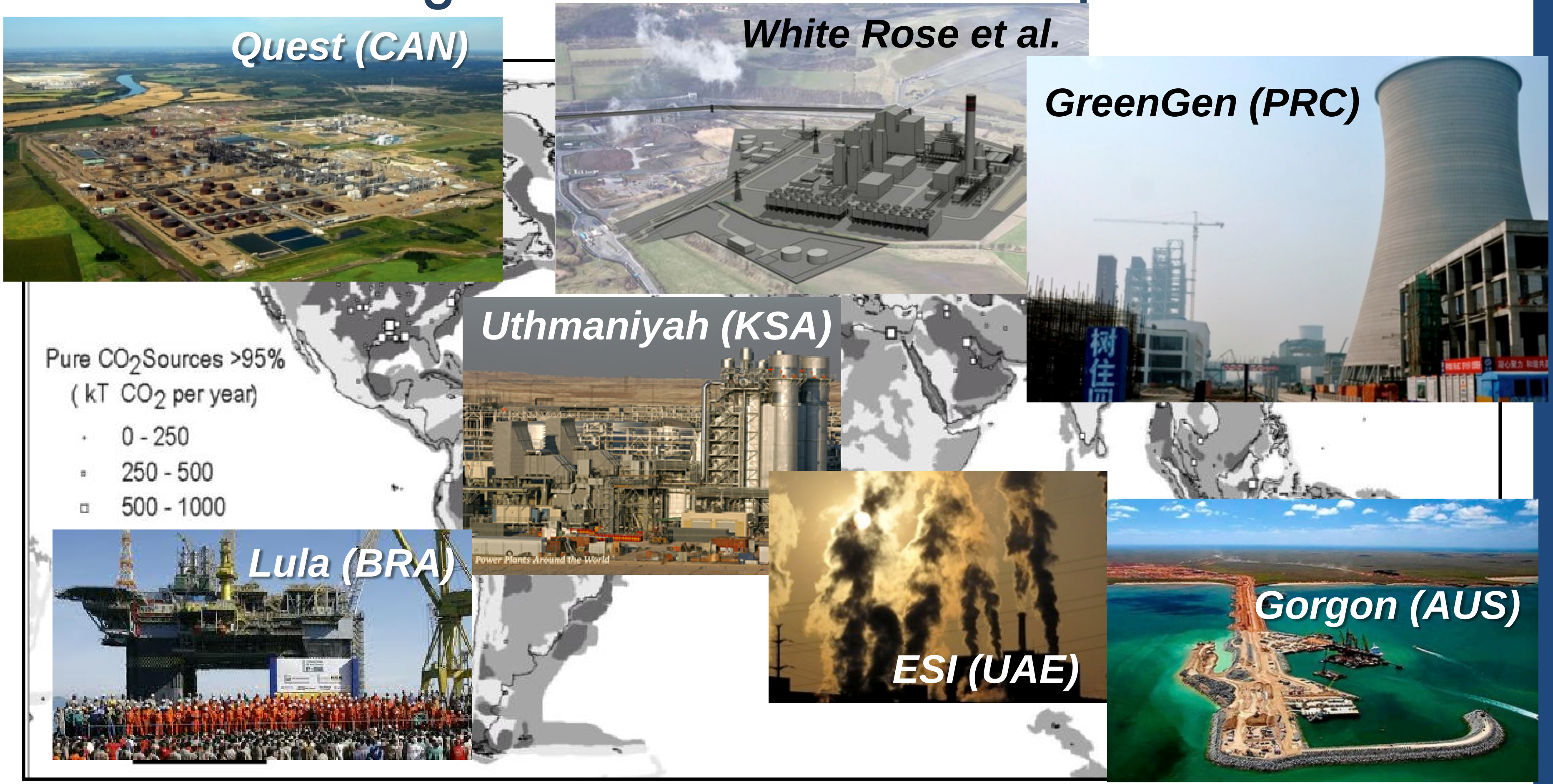
NRG Energy
Post Combustion with CO_2 Capture with EOR
$167 Million – DOE
$339 Million - Total

Air Products
CO_2 Capture from Steam Methane Reformers with EOR
$284 Million - DOE
$431 Million - Total

Leucadia
CO_2 Capture from Methanol with EOR
$261 Million - DOE
$436 Million - Total

🟩 FutureGen
🟨 CCPI
🟧 ICCS (Area I)

Global challenge ⟹ global progress: new global solutions still required



We just need more projects and more information

The work: *Drive to deployment*

Comprehensive publication of what we know

- Overall, risks well understood and manageable
- Identification of key unresolved risks and their state of knowledge

Discrete work on key challenges required

Many effective options for characterization and monitoring

- Seeking lower cost/higher certainty options
- Sorting types and terranes

Bridge technical and commercial operation