Carbon Management

Sequestration

EOR

FT

Synthesis Gas

WGS

H₂

IGCC

Gasification

Coal

Crushed

Normal

Pulverized Coal

Super Critical

Ultra Super Critical

CO₂ Capture

Flue Gas

CO₂

Multiple Purposes

Ultra Super Critical

FT

Transmission

Liquid Methane

Methane

Transmission
UW’s role in carbon sequestration in Wyoming

Carol Frost
Associate Vice President
Research and Economic Development

Photo by A.W. Snoke
The Global Energy Landscape

- World energy demand will increase by 45% between now and 2030
- Coal accounts for a third of the overall rise

IEA World Energy Outlook 2008
Energy and Climate

- Anthropogenic CO$_2$ emissions have raised atm. CO$_2$ levels to 385 ppm
- Atm. CO$_2$ correlates with global T

Oelkers & Cole 2008
Climate regulation

- CO₂ is taken up in surface and deep ocean, in sediment, by weathering of rocks
- Rate of CO₂ rise is unprecedented
- Uncertain climate response

Kump et al. 2004
Wyoming’s Energy Landscape

- 53 million barrels of oil
- 2.1 trillion cubic feet of natural gas
- 467 million tons of coal
- 40% of US coal production
- Wyoming coal generates 30% of US electricity

Net Domestic Energy
Export vs. Import

Wyoming State Geological Survey
Wyoming’s carbon footprint

- Individual CO$_2$ emissions: autos

- CH$_2$ + 1.5 O$_2$ = CO$_2$ + H$_2$O
- CH$_2$: 14 g/mol  CO$_2$: 44 g/mol
- 1 kg gasoline produces 3.1 kg CO$_2$
- 0.73 kg/l gas x 100 l (25 gal) tank = 73 kg gas per tank ---> 226 kg CO$_2$ per tank
- 24 fill-ups per year = 5.4 metric tons CO$_2$
- U.S. per capita CO$_2$ emissions = 20.6 tons CO$_2$/yr
Wyoming’s carbon footprint

- Per capita CO\(_2\) emissions:
  - U.S. 20.6 tons CO\(_2\)/yr
  - Wyoming **127** tons CO\(_2\)/yr
- Wyoming emissions per capita are #1 in U.S.

*Wyoming's coal-fired power plants produce more carbon dioxide in just eight hours than the power generators of more populous Vermont do in a year.*

*Seth Borenstein, Associated Press, 2007*
Wyoming’s pro-active position on energy and climate

- Legislation
  - Pore space ownership, liability, unitization

- Regulation
  - DEQ regulatory authority, CSWG financial assurance mechanisms

- Science and Technology
  - EORI
  - Clean Coal Research Program
  - High Plains Gasification Advanced Technology Center
  - Geologic carbon sequestration
Geologic carbon sequestration

- **Essential elements**
  - Porous rock formations at > 1 km depth
  - Saline water
  - Impermeable cap rock
  - No leakage pathways (faults, wells)

- **Wyoming’s situation**
  - Many suitable saline formations
  - Multiple caprocks
  - Oil, gas, CO$_2$, He suggest no leakage

![Image source: Dan McGee, Alberta Geological Survey](image.png)
Carbon sequestration in Wyoming

- **Big Sky:**
  - La Barge Anticline

- **UW/WSGS:**
  - Moxa Arch

- **WSGS/SWP:**
  - Rock Springs uplift

The numbers for the Salt Creek pipeline:
- Full capacity: 250 MMcf/d (91 BCF/y)
- Salt Creek delivery rate: 125 MMCF/d (45 BCF/y)
- Anticipated Salt Creek production increase: from 5,700 BO/d to 35,000 BO/d
- Value added: ~$250 MM/y
Moxa Arch project

- Funded by DOE-NETL through $1.56 M congressional directive & $570K UW match
- Modeled on DOE Regional Partnerships
- First one-year project:
  - Geologic characterization
  - Laboratory experiments
  - Modeling
  - Preliminary performance assessment model
- 11 groups of faculty, post-docs, students from 3 colleges + WSGS
- State and industrial partners
- Project started Sept. 1, 2008
Focus on deep reservoirs

✦ Below oil and gas and drinking water
✦ Distinctive fracture and dissolution properties determined from field and experimental study
Creative, innovative researchers

Innovative multi-component seismic waveform inversion to detect and monitor CO₂ in deep subsurface

Unique tomographic imaging of pore networks

New, more flexible modeling approach optimized for NCAR Supercomputing facility
Critical industry and state support

- ExxonMobil Shute Creek facility produces CO₂ for EOR
- 0.6 million tons CO₂/yr sequestered
- HB/SF 1 Supplemental Budget allows WY CS to proceed
- Further DOE support in place, more sought
- Future work: location, permits, design of sequestration demonstration in WY
Wyoming’s energy and climate challenge

- Climate legislation is upon us
  - 9/29/06 California SB 1368 standard for power: not to exceed CO₂ emissions of gas power plants
  - 2/17/09 EPA reconsidering regulating CO₂ from coal-fired power plants
  - FY2010 budget includes carbon cap-and-trade
  - UN Climate Summit Copenhagen, Dec 2009

- Coal is under special scrutiny
  - Gas 117 lb CO₂/million Btu energy
  - Coal 208 lb CO₂/million Btu energy 78% more than gas

- Wyoming coal-fired power plants produce >42 million tons CO₂/yr.
Wyoming’s energy and climate challenge

- Wyoming coal-fired power plants produce >42 million tons CO₂/yr.
- To meet “clean coal” standards, Wyoming must capture and store 18.5 million tons CO₂/yr.
- Equivalent to 37 Shute Creek-size sequestration sites.
- Wyoming’s future is carbon sequestration NOW.
...there is one outstandingly important fact regarding Spaceship Earth, and that is that no instruction book came with it.

*R. Buckminster Fuller (1895-1983)*