

Utah Sustainable Transportation and Energy Plan (STEP)

Clean Coal Research Projects

Solar Thermal Integration & Enhanced Coal Bed Methane Recovery



Let's turn the answers on.

STEP Clean Coal Technology Research Plan

- Mission
 - SB115-54-20-104: "...a program to investigate, analyze, and research clean coal technology"
- 54-2-1 Definitions: "**Clean coal technology**" means a **technology that may be researched, developed or used for reducing emissions or the rate of emissions from a thermal electric generation plant that uses coal as a fuel source.**
- Budget
 - An average of \$1 million per year over a five year period for the clean coal technology program (\$5 million total)

STEP Process to Engage Stakeholders

- Compiled Clean Coal Research team consisting of: Huntington & Hunter plant personnel, Technical Services, Utah university academia: Chem. Eng./Mech. Eng. (BYU, USU, UofU), Utah Office of Energy Development, USTAR, UofU, Energy & Geoscience Institute, Reaction Engineering International and Sustainable Energy Solutions
- Multiple workshops/locations
- Identified key *Areas of Research* in the areas of CO₂ capture and sequestration (projects presented today)

Preferences, Objectives and Requirements – Message to Clean Coal Team

- Preferences:
 - Technology demonstrations (hardware)
 - Advance existing technology
 - Utah centric
 - Leverage other funding sources (US DOE, state, local)
- Objectives:
 - Benefits customers, technology/commercialization advancement and emissions improvements
- Commission review to determine if the expenditures were prudently incurred in accordance with the purposes of the program

Utah STEP Clean Coal Research

Previous Technical Conferences (10/18/16 & 11/7/16)

Proposed Projects

1. Neural Net Optimization – Huntington 2 (Approved)
2. Low NOx Technology Pilot Demonstration, RFI/RFP – Huntington Plant (Approved)
3. CarbonSAFE Commercial Sequestration Feasibility Assessment – Emery County
4. Biomass Co-firing Test Burn – Hunter 3
5. Sustainable Energy Solutions' Cryogenic Carbon Capture Demonstration – Hunter 3

Utah STEP Clean Coal Research Technical Conference #3 Areas of Interest

1. Solar Thermal Power Plant Integration
2. Use of CO₂ for Enhanced Coal Bed Methane Recovery (ECBMR)

CO₂ Capture

1. Reduction: Solar Thermal Augmentation (study)

- Study to evaluate the feasibility, performance, cost, environmental benefit and land requirements of solar thermal augmentation to produce steam at the Hunter Plant.
- BYU submitted a proposal; principal investigator: Dr. Brian Iverson.

CO₂ Capture

1. Reduction: Solar Thermal Augmentation (study)

- Evaluate solar and land resource for solar thermal integration at the Hunter Plant
- Solar thermal system would generate steam or high temperature water for use in the existing steam cycle
- Would reduce coal consumed by the solar thermal contribution thereby decreasing combustion related emissions
- Will focus on parabolic trough technology; may consider power towers
- Will evaluate different fluid conditions and injection points in the existing steam cycle

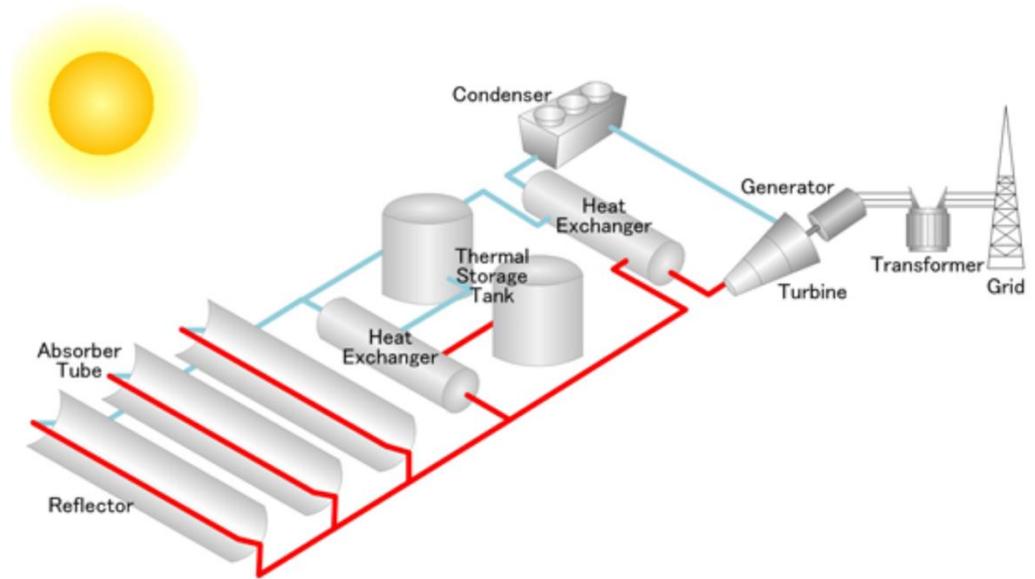
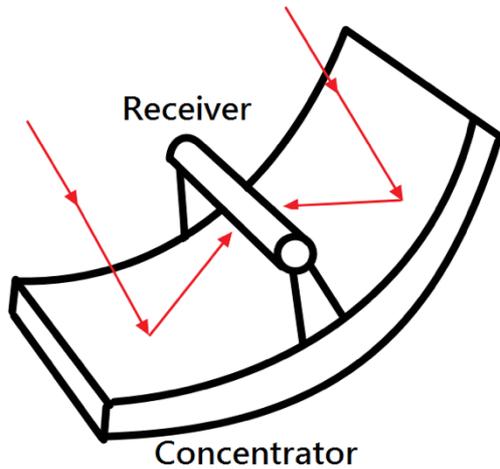
CO₂ Capture

1. Reduction: Solar Thermal Augmentation (study)

- Description of Preliminary Investigator activities
- Description of student activities
- 3rd party consultant would be incorporated into project study for system costing and validation

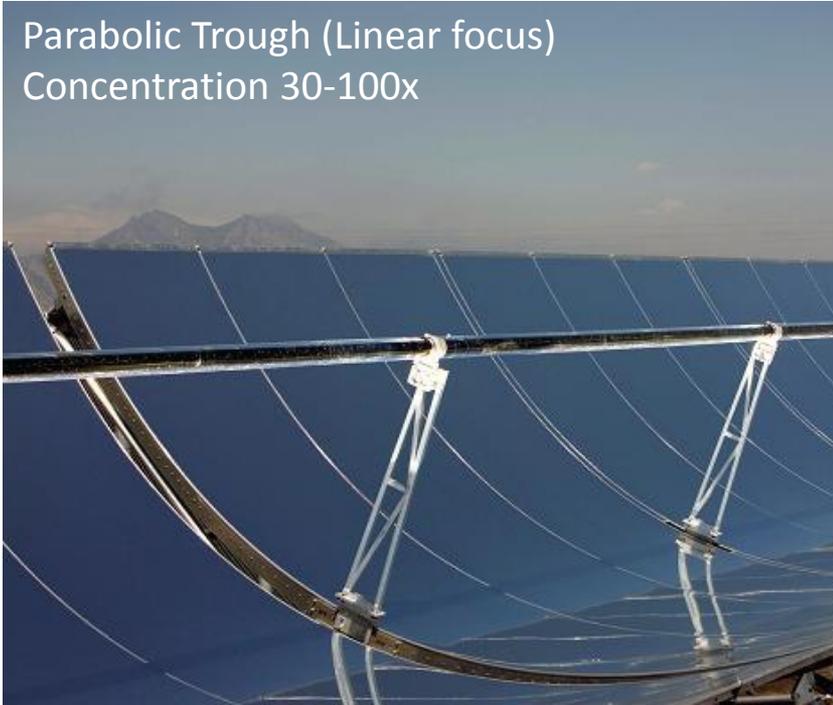
Concentrated Solar Power

The “other” solar energy



Concentration

Parabolic Trough (Linear focus)
Concentration 30-100x



Nevada Solar One
<http://www.seia.org/policy/solar-technology/concentrating-solar-power>

Power Tower (Point focus)
Concentration 100-1000x



Ivanpah, CA
<https://wordlesstech.com/ivanpah-solar-electric-generating-system/>

Hybrid Solar/Coal Plants

Colorado Integrated Solar Project - Cameo

- Opened in 2010
- Trough demo plant used until the coal plant was retired (now decommissioned)
- 77 MW plant (1 MW solar)

Liddell Power Station – Australia

- Opened in 2012
- Compact Linear Fresnel
- 2000 MW plant (9 MWth solar)

Kogan Creek Solar Boost – Australia

- Scheduled to open in 2016
- Compact Linear Fresnel
- 750 MW plant (44 MWth solar)



Cameo Plant – World's 1st
<https://en.openei.org>

Solar Assisted Steam Generation

- 12 solar-assisted hybrid systems
- Various integration points for the steam

Solar integration projects

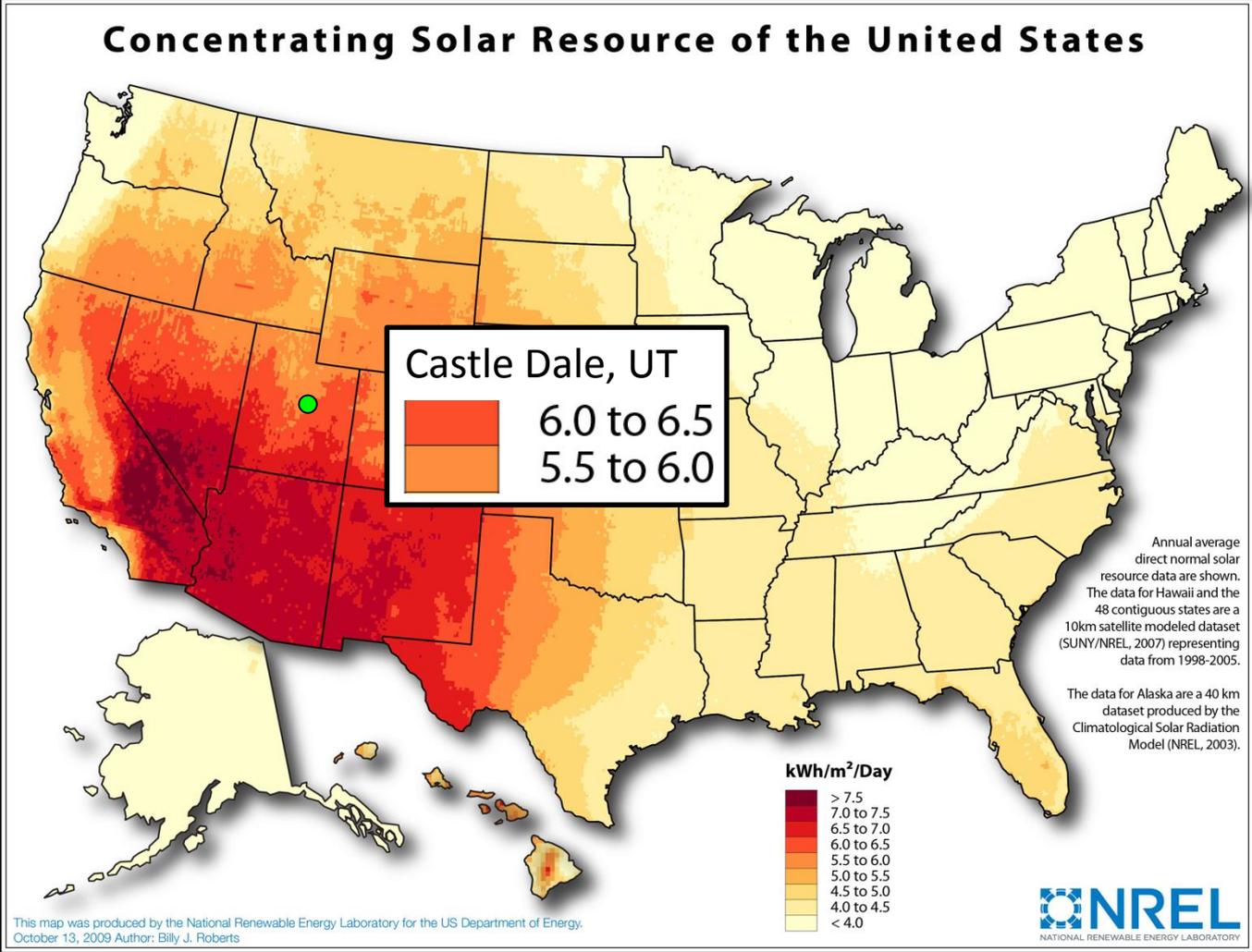
Plant name	Net output, MW (fossil fuel/solar)	Location	Year online
Martin	1050/75	Indiantown, Fla	2010
Palmdale	555/62	Palmdale, Calif	2013
Cameo	77/1	Palisade, Colo	2010*
Agua Prieta	535/31	Mexico	NAv
Ain Beni Mathar	450/20	Morocco	2010*
Kuraymat	95/20	Egypt	2010
Hassi R'Mel	130/25	Algeria	2010
Yazd	406/17	Iran	2010
Liddell	2000/3	Australia	2008*
Kogan Creek	750/23	Australia	2012
Archimede	130/5	Italy	2010*
Wellington	400/100	Australia	NAv

Source: Electric Power Research Institute, Palo Alto, Calif

Notes: Liddell and Kogan Creek use CLFR technology, all others trough; Cameo, Liddell, and Kogan Creek are coal-fired plants, all others combined cycle; coal-fired plants use solar energy for feedwater heating; at combined-cycle plants it is integrated into the Rankine cycle; asterisks in last column identify plants already operating

Armistead, 2010, "Integrating solar, conventional energy resources," *Combined Cycle Journal*.

Solar Resource



Solar Resource

- **Annual Average DNI**
- Prime locations have 7 kWh/m²/day
- Plants with a DNI less than 4 kWh/m²/day were not considered
- Solar resource has a significant effect on plant performance and economics, it was given the highest weighting in the evaluation.

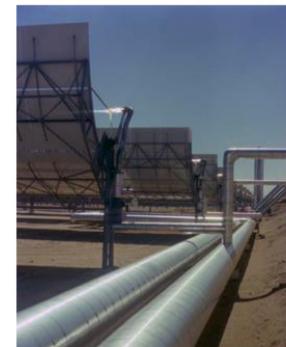
Castle Dale, UT	
	6.0 to 6.5
	5.5 to 6.0



Solar-Augment Potential of U.S. Fossil-Fired Power Plants

Craig Turchi and Nicholas Langle
National Renewable Energy Laboratory

Robin Bedilion and Cara Libby
Electric Power Research Institute



NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-5500-50597
February 2011

Contract No. DE-AC36-08G028308

Hunter Plant, Castle Dale UT



Hunter Plant

PacifiCorp Owned Lands

Legend

PacifiCorp Facility Points

- Distribution Pole
- ⊗ Other Utility
- Private Pole
- ⊗ Tree Pole
- ⊗ Decorative Pole
- ⊗ Transmission Pole
- ⊗ Manhole
- Pad Only
- ⊗ Pad Mntd Recloser
- ⊗ Pad Mntd 1 Ph Xfmr
- ⊗ Pad Mntd 3 Ph Cfmnr
- ⊗ Pad Mntd Fuse Cab
- ⊗ Pad Mntd Sect Cab
- ⊗ Pad Mntd Switch Gear
- ⊗ Pull Vault
- ⊗ SS Sect Cab
- ⊗ SS Switch Gear
- ⊗ SS 1, 2 Ph Xfmr
- ⊗ SS 3 Ph Xfmr
- ⊗ UG 1, 2 Ph Xfmr
- ⊗ UG 3 Ph Xfmr
- ⊗ GPS
- ⊗ Other

PacifiCorp Ownership

- ⊗ PacifiCorp Ownership

County

- County

Section

- Section

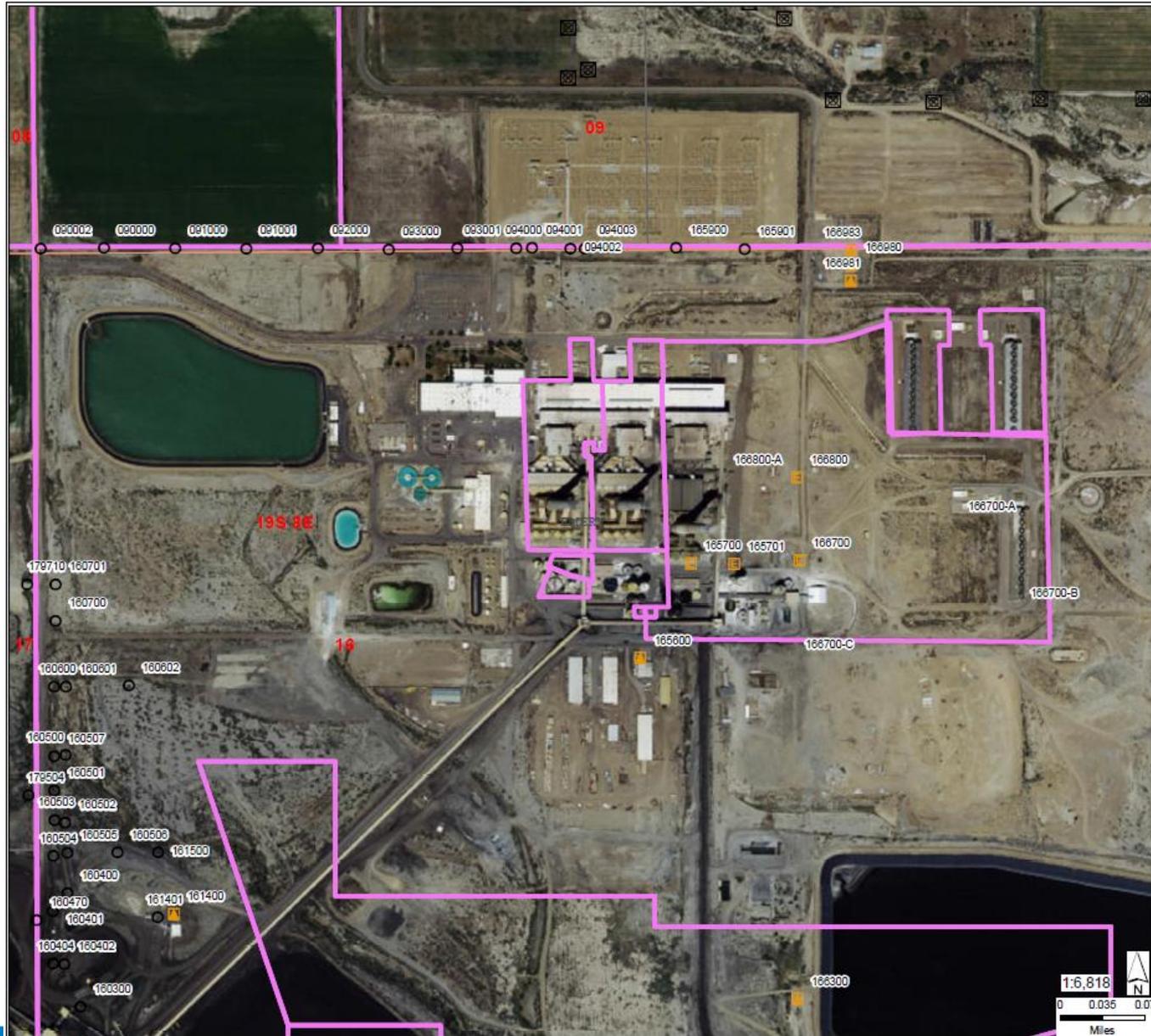
Township

- Township

County Parcels

- Taxlots

Data is projected to NAD 1983 UTM Zone 12N
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Thursday, July 28, 2016 9:55:38 AM

Solar Thermal Augmentation – Coal Fired Power Plant

	2017	2018	2019	2020	2021	Total
Student (2 years)			\$ 19,000	\$ 19,000		\$ 38,000
Summer Internship @ National Lab			\$ 7,000			\$ 7,000
Tuition			\$ 5,500	\$ 5,500		\$ 11,000
Faculty			\$ 15,000	\$ 15,000		\$ 30,000
Supplies			\$ 1,500	\$ 1,500		\$ 3,000
Travel			\$ 3,250	\$ 3,250		\$ 6,500
Indirects			\$ 13,833	\$ 13,833	\$ 13,833	\$ 41,500
NREL Support				\$ 7,500	\$ 7,500	\$ 15,000
External Consulting				\$ 17,500	\$ 17,500	\$ 35,000
Total	\$ -	\$ -	\$ 65,083	\$ 83,083	\$ 38,833	\$ 187,000

Solar Thermal Integration – Auditing Process

- Reporting Practices
 - Project milestones mapped
 - Project deliverables well defined
 - Regular updates, briefings/reports, review sessions, technical presentations
 - Detailed budgeting and justification
 - By task
 - By quarter

CO₂ Capture

2. Sequestration: regional/ commercial use of CO₂ for enhanced coal bed methane recovery (study)

- Study to evaluate the potential for using captured CO₂ from Emery County coal-fired power plants for use in enhanced coal bed methane recovery.
- University of Utah Earth Geosciences Institute (EGI) submitted draft proposal; Principal Investigator: Dr. John McLennan

CO₂ Capture

2. Sequestration: regional/ commercial use of CO₂ for enhanced coal bed methane recovery (study)

- Availability of unmineable coals in Emery County
- CO₂ affinity for coal and concurrent production of methane
- Benefits include:
 - Geologic CO₂ sequestration
 - Additional methane recovery – economic benefit compared to standalone geologic sequestration
 - Utilization of existing infrastructure

CO₂ Capture

2. Sequestration: regional/ commercial use of CO₂ for enhanced coal bed methane recovery (study)

Study Objectives

- Technical, economic and environmental study on costs and benefits including CO₂ from power plants to specific coalbed methane sources
- Determine whether local coalbeds are conducive to CO₂ recovery (laboratory scale testing at the University of Utah Combustion Research Facility)
- Propose technologies for improving injection efficiency
- Evaluate risks for induced seismicity compared to CO₂ injection deep saline aquifers

CO₂ Capture

2. Sequestration: regional/ commercial use of CO₂ for enhanced coal bed methane recovery

- **Description of Student activities**
 - **Described on Following Slides**
- **Description of PI activities**
- **Project Management**
 - **Reporting**
 - **Technical Oversight**
 - **QA/QC**

CO₂ Supply



Pipeline Transportation

- Leakage
- Fugitive Losses
- Supplemental Compression
- Venting



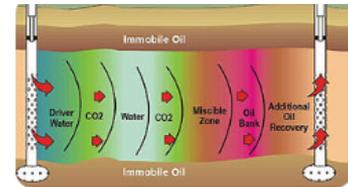
Upstream Infrastructure

- Distribution Network
- Injection Facilities
- Venting
- Fugitive Losses



Reservoir

- Sequestered CO₂
- Desorbed/Produced Methane
- Losses in Other Formations
- Breakthrough
- Override and Swelling



Pipeline Transportation



Gas to Market

Downstream Infrastructure

- Gathering Systems
- Separation
- Metering
- CO₂ Recovery
- Reinjection



Challenges

Volumetrics:

- Available subsurface volume

Swelling:

- CO₂ adsorption causes coal matrix to swell
- Override

Sequestration:

- Hybridized with technology to permanently sequester CO₂
- Water injected to inhibit or restrict desorption
- Injecting treated water to encourage precipitation/cementation

Induced Seismicity:

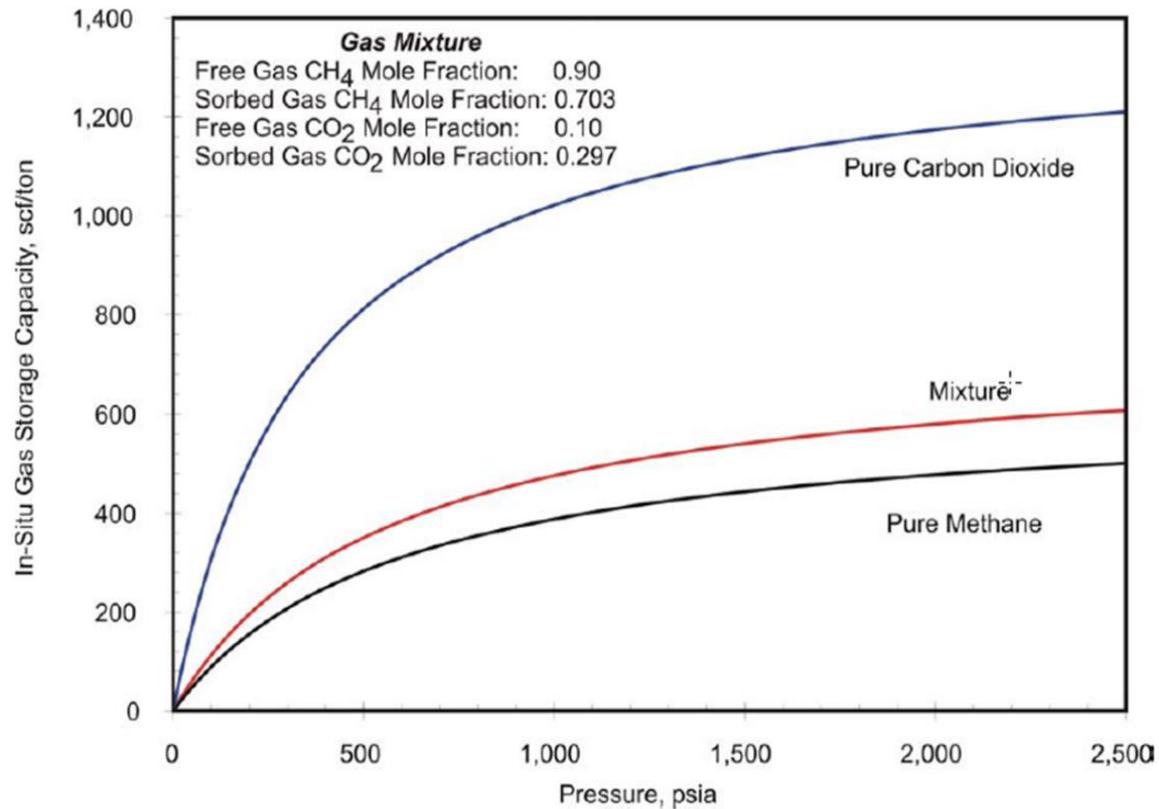
- De-risk occurrence of induced seismicity

Breakthrough:

- Efficacy and sequestration potential of flue gas

Opportunities

Preferential Storage of CO₂ and Production of Methane



Tasks

- **Resource Evaluation:**
 - From public domain sources (UGS data in particular)
 - Possible injection locations, capacities, advantages and challenges
- **Bench Scale Demonstrations:**
 - CO₂, flue gas (and N₂ alone)
 - Measurements to assess sorptive capacities
 - Representative Utah coals
- **Permanent Sequestration:**
 - How can CO₂ be more permanently be sequestered in coal seams?

Tasks (continued)

Economic Viability:

- First order estimate of economics of sequestration
- Offset partially by methane production

Simulations:

- Confirm storage capacity

Pilot Program:

- Five spot injection and monitoring program

Reporting

Sequestration: regional/ commercial use of CO₂ for enhanced coal bed methane recovery

- \$250,000 to University of Utah/EGL
- University of Utah will monitor and report expenditures

	2017	2018	2019	2020	2021	Total
Resource Evaluation		\$ 25,000				\$ 25,000
Bench Scale Demonstrations		\$ 37,500	\$ 37,500			\$ 75,000
Permanent Sequestration			\$ 37,500	\$ 37,500		\$ 75,000
Economic Viability				\$ 25,000		\$ 25,000
Simulations					\$ 50,000	\$ 50,000
Pilot Program						\$ -
Consulting/Final Report					\$ 25,000	
Total	\$ -	\$ 62,500	\$ 75,000	\$ 62,500	\$ 75,000	\$ 275,000

Sequestration: regional/ commercial use of CO₂ for enhanced coal bed methane recovery

- Reporting Practices
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Questions?