Deep and Near-Surface Monitoring for Enhanced CO_2 Storage Security*

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Search and Discovery Article #50285 (2010)
Posted July 23, 2010

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, April 11-14, 2010

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Abstract

Geologic storage is in a research and demonstration phase in preparation for commercialization. It is important that policy developers recognize that a monitoring program for a research project is intrinsically different from the monitoring program for a commercial site. A research project challenges hypotheses about the nature of the subsurface perturbation created by injection by comparison of response predicted by conceptual or numerical models to the response observed via monitoring. A demonstration also tests the performance and sensitivity of monitoring tools to determine the extent to which they are able to detect the perturbation, the conditions under which they are useful and the reliability under field conditions.

Monitoring at a commercial site where CO_2 is being injected can serve three functions. Monitoring is used to confirm that the predictions of containment made based on site characterization at the time of permitting are valid. This is conceptualized as making observations of change over time that are reasonably close to model predictions. From this monitoring result, confidence is gained to continue the injection. Secondly, monitoring could be used to confirm that no unacceptable consequences result from injection. Lastly, monitoring during injection could be designed to prove-up confinement so that monitoring frequency could be diminished through the life of the project and eventually stop, allowing the project to be closed.

Monitoring to be conducted during a commercial project needs to be sufficiently standardized so that both operator and regulator know what is required. Dependability and durability is needed for repeat measurements to be made over decades. Measurements should be designed to be reportable to the stakeholders so that oversight is obtained. Commercial sites should plan and budget for the possibility of detections that are not compliant with expected results.

Such an occurrence would likely require a follow-up testing program similar in some ways to a research program in that it would test hypothesis explaining non-compliance. Outcomes from this investigation could range from an improved model to documenting inadequacy of containment, requiring remediation of the project. To optimize commercial monitoring we should separate early research elements from activities that will be used over the life of a project so that research expectations do not cross into regulations for commercial projects.

Websites

CO_2 Capture Project: Web accessed 16 July 2010, http://www.co2captureproject.org/co2_storage_technical_book.html

DOE-National Energy Technology Laboratory (NETL), Best Practices for: Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations: Web accessed 16 July 2010, http://www.netl.doe.gov/technologies/carbon_seq/refshelf/MVA_Document.pdf

DOE-National Energy Technology Laboratory (NETL): Carbon Sequestration: Monitoring, Verification and Accounting (MVA): Web accessed 16 July 2010, http://www.netl.doe.gov/technologies/carbon_seq/core_rd/mva.html

World Resources Insititute, Guidelines for Carbon Dioxide Capture, Transport, and Storage: Web accessed 16 July 2010, http://www.wri.org/publication/ccs-guidelines

Deep and Near Surface Monitoring for Enhanced CO_2 Storage Security

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Why Monitor CO_2 injection? In case where injection is to enhance oil recovery - EOR

- Optimize economic performance
  - Balance flood
- Comply with regulation
  - Mechanical integrity testing
  - Comply with permits e.g. maximum pressure, volumes

Oil producer
Investor
Regulator

Monitor for CO_2 emissions reduction?

- More players
  - Policy driver – who will that be?
  - CO_2 source
    - electric utility
    - Public Utilities Commission
  - EPA/ state primacy
- Doesn't yet exist
  - May be under EPA class VI
  - conditions where CO_2 credits are verified

What's new about monitoring a CO2 injection?

Comparing Class V - VI to Class I-II

Higher environmental expectations 2009 than 1974?

- Role of high level nuclear waste storage research?
- Role of superfund experience?
- Role of field experiments.

- Many factors remain same
  - Well head pressure, injected volumes, injectate composition to assure compliance with maximum injection pressure
  - Mechanical integrity testing of engineered system

Possible to image the free-phase CO_2 in reservoir

Proposed Monitoring Strategy

An overview of some selected tools used in pilots or mentioned in EPA Class VI draft rules

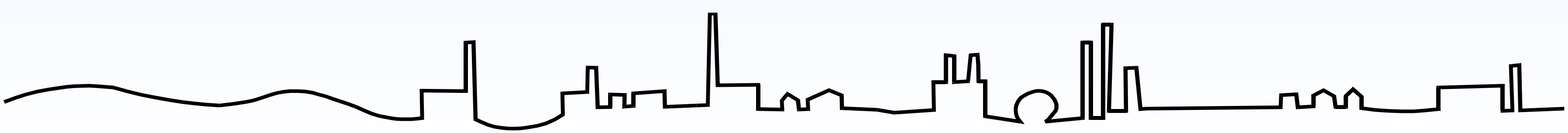
- DOE-NETL “MVA manual”, http://www.netl.doe.gov/technologies/carbon_seq/refshelf/MVA_Document.pdf)
- World Resources International Guidelines - http://www.wri.org/publication/ccs-guidelines
- Carbon Capture Project http://www.co2captureproject.org/co2_storage_technical_book.html

Goals of Monitoring a Commercial Project

- Confirm predictions of containment based on site characterization are valid.
  - Observations (reasonably) close to model predictions.
  - Confidence gained to continue the injection.

- Prove-up confinement
  - Monitoring diminished through the life of the project
  - Eventually stop, allowing the project to be closed.

- Confirm that no unacceptable consequences result from injection.



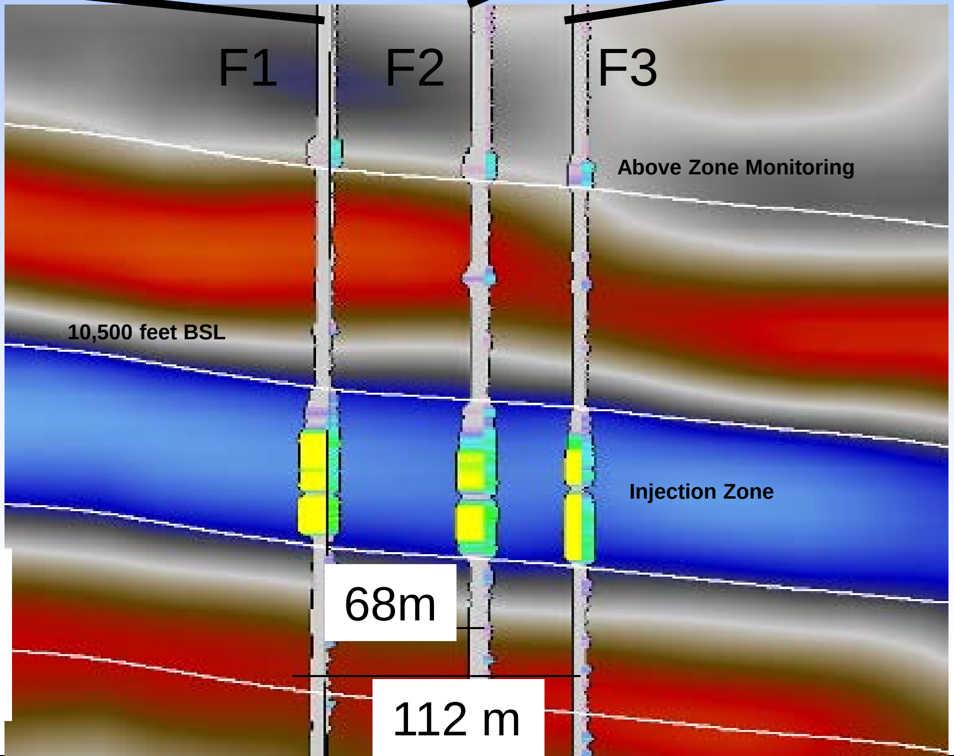
Research Monitoring Underway Now

- Research monitoring programs
  - Under EPA class V (experimental) or class II
  - Monitoring is mostly voluntary or negotiated
  - Improve current understanding and confidence in CCS

Research Monitoring: Improve current understanding and confidence in CCS

- Challenge hypotheses
- Comparison numerical models to the response observed via monitoring.
- Test performance and sensitivity of monitoring tools
  - Conditions under which they are useful
  - Reliability under field conditions
  - Redundant measurements

SECARB Early Experimental Monitoring At Detail Area Study



Closely spaced well array to examine flow in complex reservoir

Denbury Onshore LLC

Sandia Technologies, LLC

SECARB
Southeast Regional Carbon Sequestration Partnership

Southern States Energy Board

SECARB Cranfield Research: Theoretical Approaches Through Commercialization

Commercial Deployment by Southern Co.

Toward commercia-lization	Contingency plan Parsimonious public assurance monitoring	Subsurface perturbation predicted	
Hypothesis tested	CO_2 retained in-zone-document no leakage to air-no damage to water	CO_2 saturation correctly predicted by flow modeling	Pressure (flow plus deformation) correctly predicted by model
Field experiments	Surface monitoring: instrument verification Groundwater program CO_2 variation over time Above-zone acoustic monitoring (CASSM) & pressure monitoring	CO_2 saturation measured through time – acoustic impedance + resistivity Tomography and change through time 3- D time lapse surface/ VSP seismic Dissolution and saturation measured via tracer breakthrough and chromatography	Microseismic test, pressure mapping Acoustic response to pressure change over time
Theory and lab	Sensitivity of tools; saturated-vadose modeling of flux and tracers	Lab-based core response to EM and acoustic under various saturations, tracer behavior	Advanced simulation of reservoir pressure field

Commercial Monitoring System

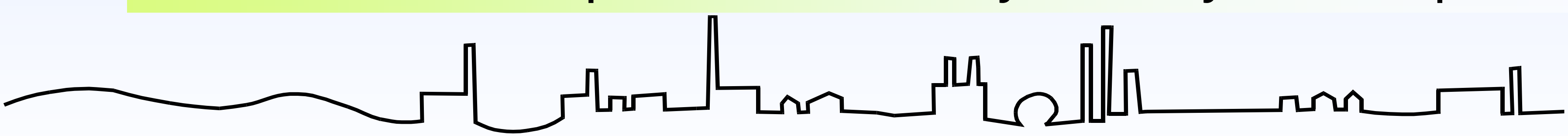
Tools selected to achieve specific goals

- Confirm expected performance “model validation”
- Confirm absence of unexpected performance “no leaks”

- Tools are staged
  - Time lapse – measure change over time
  - In response to previous events
    - Less monitoring needed as confidence builds
    - More monitoring needed if unexpected measurements are made

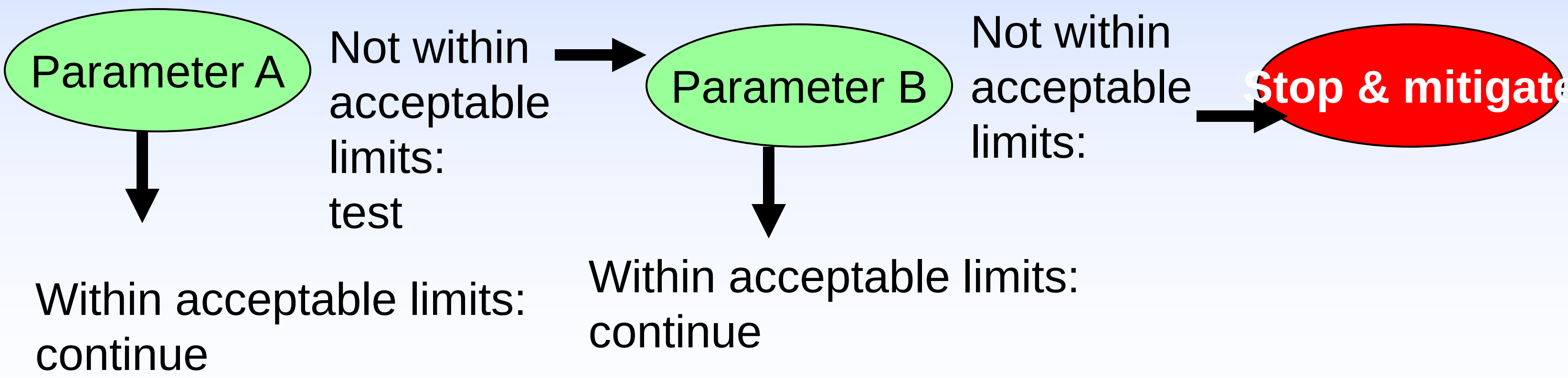
Tools tuned to site, especially to risks

- Tool location optimized vertically, aerially, with depth



Need for Parsimonious Monitoring Program in a Mature Industry

- Standardized, dependable, durable instrumentation, reportable measurements
- Possibility of above-background detection:
  - Need for a follow-up testing program to assure both public acceptance and safe operation
- Hierarchical approach:



Stages of a Project

Pre-Operation Phase: Project design is carried out, baseline conditions are established, geology is characterized, and risks are identified.

Operation Phase: Period of time during which CO2 is injected into the storage reservoir.

Closure Phase: Period after injection has stopped, during which wells are abandoned and plugged, equipment and facilities are removed, and agreed upon site restoration is accomplished. Only necessary monitoring equipment is retained.

Post-Closure Phase: Period during which ongoing monitoring is used to demonstrate that the storage project is performing as expected until it is safe to discontinue further monitoring. Once it is satisfactorily demonstrated that the site is stable, monitoring will no longer be required except in the very unlikely event of leakage, regulatory requirements, or other matters that may require new information about the status of the storage project.

Site selection, characterization:. Multi staged process, deep investment in selecting a site with geologic characteristics that provide high assurance of permanent storage.

Permitting via state/federal/other process:
Hydrologic characterization of reservoir, demonstration of well integrity
Determine max injection rate and pressure

Operational monitoring and reporting:
Extensive baseline data (part overlap with characterization).
Parsimonious monitoring program.
Reporting to regulator.
Additional testing to reduce uncertainly in permanence of trapping.
Follow up on any near surface anomalies.
Good operational monitoring
Proof of effective trapping = **site closure permit**

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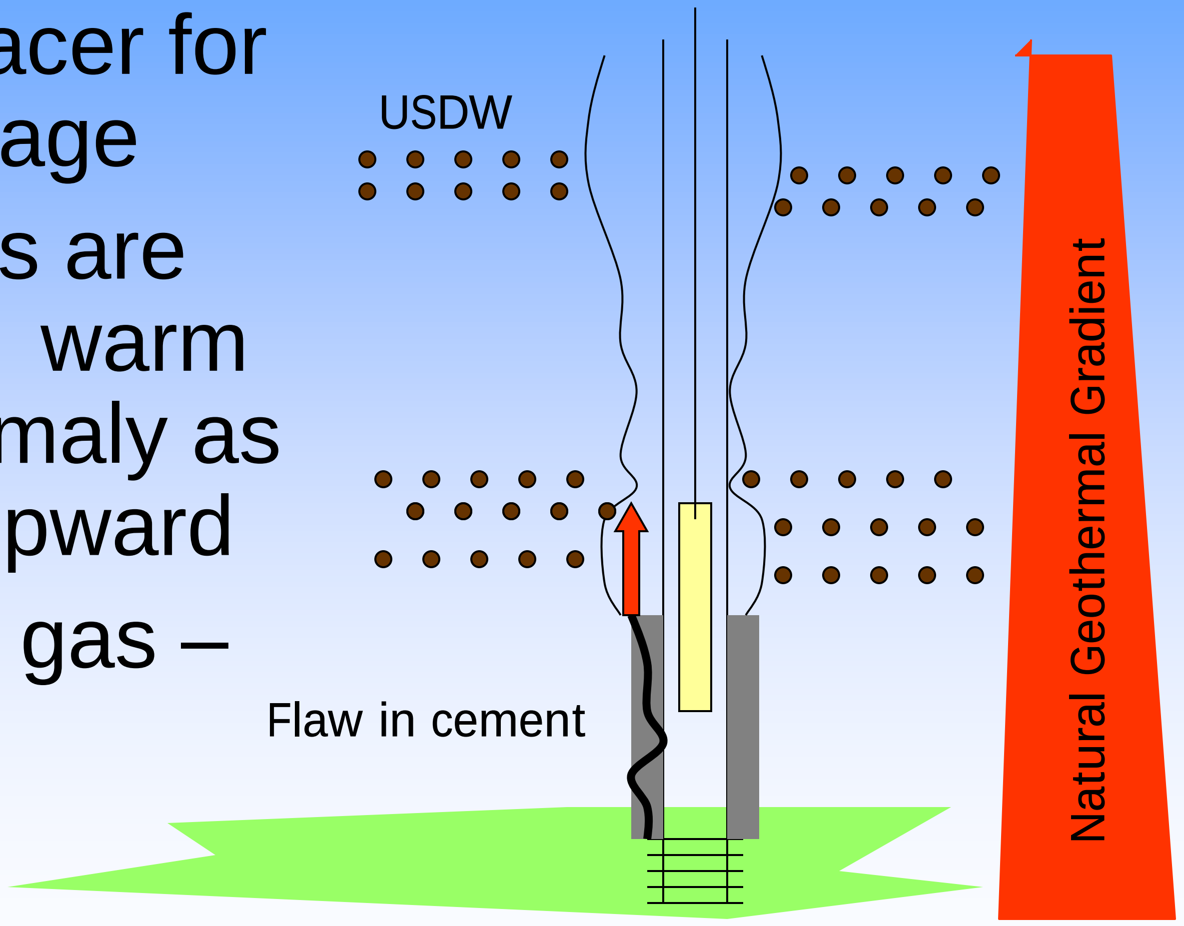
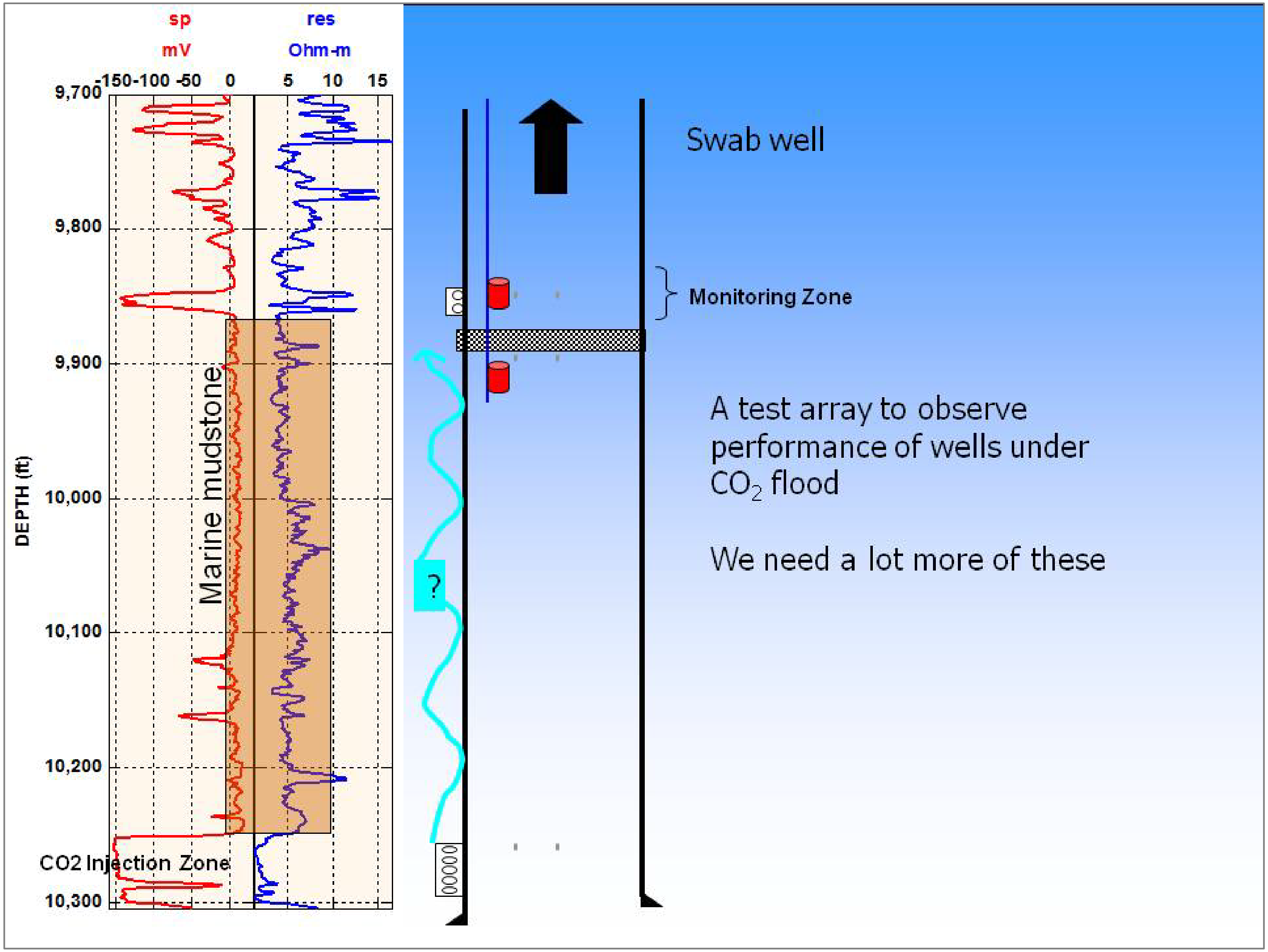
http://www.netl.doe.gov/technologies/carbon_seq/core_rd/mva.html

Testing wells – possible flaws

- Heat as a tracer for upward leakage
- Deeper fluids are warm, show warm thermal anomaly as they move upward
- CO_2 flash to gas – cool thermal anomaly.





Notes by Presenter: Just such an example is the EGL 7. Luckily, geology is such that we can use it as a test for the ability of cement, even ~60 year old cement to seal and restrict leakage of CO_2 being injected into the Tuscaloosa injection zone.

Separate Research (Now) from Commercial Practices (Later)

Research

- What is needed to develop technical and public confidence
  - Case specific
  - Innovative
  - Comprehensive

Commercial

- Only what is required to allow injection to continue and site to be eventually closed
  - Standardized
  - Parsimonious

Research Sponsors

Gulf Coast Carbon Center Sponsors

Parallel projects GCCC involvement

Other SECARB projects
SWP
BES - UT Center for Energy Frontiers
EPA projects
CCP
State of Texas Offshore Repository
-FOA 33
Industry sponsored projects
FOA 15