Public Workshop
Carbon Capture and Sequestration

California Air Resources Board
Sacramento, California
February 12, 2016
Agenda

• Introductory presentation on CCS - ARB
• Overview of CCS related activities in California - California Energy Commission
• CCS in California regulations and Quantification Methodology development - ARB
• Overview of U.S. Department of Energy’s CCS program – U.S. Department of Energy
• Next steps - ARB
WHAT IS CARBON CAPTURE AND SEQUESTRATION?
Carbon Capture and Sequestration

Source: CO₂CRC
CO$_2$ Capture Technologies

Current capture technologies are well understood but relatively expensive

Source: IPCC
CO$_2$ Transport

- Movement of CO$_2$ by pipeline, truck, rail, ship, or barge to a storage facility
- Transport is the most technically mature step in CCS
- Currently no CO$_2$ pipeline in California
- U.S. has 50 individual CO$_2$ pipelines and with a combined length over 4,500 miles, primarily dedicated to enhanced oil recovery
CO$_2$ Geologic Sequestration Options

Overview of Geological Storage Options:
1. Depleted oil and gas reservoirs
2. Use of CO$_2$ in enhanced oil and gas recovery
3. Deep saline formations — (a) offshore (b) onshore
4. Use of CO$_2$ in enhanced coal bed methane recovery

Source: CO2CRC; IPCC, 2005
CO$_2$ Utilization

- Use captured CO$_2$ or convert it to useful products such as chemicals, cements, or plastics.
- Life-cycle approach is necessary
- Most uses are currently small scale, need to understand the market potential
- Potential supply of anthropogenic CO$_2$ is very much larger than potential demand
WHY IS CARBON CAPTURE AND SEQUESTRATION IMPORTANT?
California's GHG Challenge

<table>
<thead>
<tr>
<th>Year</th>
<th>1990 Emission Baseline</th>
<th>40% Reduction</th>
<th>80% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>450 Million Metric Tons (CO₂ Equivalent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>400 Million Metric Tons (CO₂ Equivalent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>250 Million Metric Tons (CO₂ Equivalent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td>100 Million Metric Tons (CO₂ Equivalent)</td>
<td></td>
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</tbody>
</table>
Long-term Targets

• IPCC (2014) found that models could not limit likely warming to below 2°C if bioenergy, CCS and their combination (BECCS) are limited
• Capable of achieving large CO₂ emission reductions
• Can be used in combination with other GHG reduction strategies
• Applicable to both the power and industrial sectors
• 2050 and 2100 scenarios without CCS have increased overall costs
• CCS combined with bioenergy may offer “negative emissions”
California Studies

- California’s Energy Future – The View to 2050 (CCST, 2011) Findings:
  - CCS is an important technology for electricity generation
  - CCS is a key strategy for achieving economywide low-carbon fuels
  - California will require substantial CO$_2$ in-state storage capacity in 2050, with saline aquifers required by end of century
- California PATHWAYS: GHG Scenario Results (2015)
  - CCS scenario showed potential cost savings when compared to the straight line scenario
  - CCS scenario was a relatively higher risk strategy when compared to the straight line scenario
Policy Challenges for California

• Infrastructure investment is a pre-requisite for CCS being a large scale climate mitigation option
• Who is taking long-term liability and responsibility for injected CO₂
• Interaction with policy goals of achieving a larger renewables portfolio
• Further understanding geologic storage assets is needed
• Public trust and education- test and demonstrate technologies
POTENTIAL RISKS OF GEOLOGIC STORAGE OF CO$_2$
CO₂ Leakage - Potential Risk Factors

• Aliso Canyon leak provides a cautionary lesson- need to identify, minimize, and mitigate risks
• Existing wells in the injection area
  • Includes active, closed, and orphaned wells
  • Well depth
  • Well integrity, casing and condition of well abandonment
• Transmissive faults or fractures in the surrounding rock formations
• Lateral and upward movement into connected reservoirs
• Quality of the cap rock, or other seals
• Permeability characteristics of the rock layers overlying or adjacent to the reservoir
CO₂ Leakage - Potential Impacts

• Impacts dependent on:
  • How much, at what concentration, and over what time?
  • What are the current conditions of the surface and subsurface environment? Underground sources of drinking water?

• Health - effected at:
  • Acute exposures to concentrations > 3%
  • Prolonged exposures to concentrations > 1%

• Groundwater
  • Potential for increased heavy metals, acidity, turbidity, organics, changes in groundwater flow, brine displacement

• Environment
  • Impact vegetation due to high root-zone CO2
  • Impact burrowing animals, basements, vaults
Induced Seismicity

• Caused by human activities and is commonly related to the injection or extraction of fluids into or out of the subsurface.

• Induced seismicity associated with wastewater disposal, geothermal operations

• Existing CCS projects provide limited direct data on induced seismicity

• Factors to consider:
  • Pressure changes to critically stressed faults
  • Injection proximity to basement rock
  • Reservoir permeability
  • Injection rate
Risk Management

- Site Characterization
  - Identifying risks helps define proper management
  - Reservoir characteristics
  - Identify pressure limits for the surrounding geology
- Active injection site and pressure management
- Corrective Action and Remediation Plans
- Monitoring
  - In conjunction with modeling
  - Small leaks are a challenge due to plume size and detection limits
  - Monitoring prior to injection useful to establish a baseline
OVERVIEW OF LARGE-SCALE ONGOING CCS PROJECTS
Current Large-Scale CCS Projects

- Saline
- CO2 EOR
- Depleted Gas

Fertilizer Production
- Enid Fertilizer
- Coffeyville
- Boundary Dam

Power Generation
- Great Plains Weyburn-Midale

Coal Gasification
- Val Verde
- Shute Creek

Gas Processing
- Sleipner
- Snohvit
- In Salah*
- Great Plains Weyburn-Midale
- Centennial Plant
- Port Arthur Air Products

Steam Methane
- Uthmaniyah
- Lula
- Lost Cabin
- Quest

~ 1 MMT/yr CO2 capture capacity

* Injection suspended
## North American CCS Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Location</th>
<th>Operational date</th>
<th>CO₂ source</th>
<th>Capture type</th>
<th>Capture capacity (MMT CO₂/yr)</th>
<th>Sequestration type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Century Plant</td>
<td>Texas</td>
<td>2010</td>
<td>Gas Processing</td>
<td>Pre-combustion</td>
<td>8.4*</td>
<td>CO₂-EOR</td>
</tr>
<tr>
<td>Shute Creek/LaBarge</td>
<td>Wyoming</td>
<td>1986</td>
<td>Gas Processing</td>
<td>Pre-combustion</td>
<td>6</td>
<td>CO₂-EOR</td>
</tr>
<tr>
<td>Val Verde</td>
<td>Texas</td>
<td>1972</td>
<td>Gas Processing</td>
<td>Pre-combustion</td>
<td>1.3</td>
<td>CO₂-EOR</td>
</tr>
<tr>
<td>Boundary Dam</td>
<td>Saskatchewan</td>
<td>2014</td>
<td>Power Generation</td>
<td>Post-combustion</td>
<td>1**</td>
<td>CO₂-EOR</td>
</tr>
<tr>
<td>Quest</td>
<td>Alberta</td>
<td>2015</td>
<td>Steam Methane</td>
<td>Industrial Separation</td>
<td>1</td>
<td>Saline</td>
</tr>
<tr>
<td>Port Arthur/Air Products</td>
<td>Texas</td>
<td>2013</td>
<td>Steam Methane</td>
<td>Industrial Separation</td>
<td>1</td>
<td>CO₂-EOR</td>
</tr>
<tr>
<td>Lost Cabin</td>
<td>Wyoming</td>
<td>2013</td>
<td>Gas Processing</td>
<td>Pre-combustion</td>
<td>1</td>
<td>CO₂-EOR</td>
</tr>
<tr>
<td>Coffeyville</td>
<td>Kansas</td>
<td>2013</td>
<td>Fertilizer Production</td>
<td>Industrial Separation</td>
<td>1</td>
<td>CO₂-EOR</td>
</tr>
</tbody>
</table>

* 5 MMT CO₂/yr currently being captured
** 0.4 MMT captured in first year of operation
Projects Anticipated in 2016

- Illinois Industrial CCS Project- ADM corn-to-ethanol production facility, with saline injection (capture capacity of ~1 MMT/yr)
- Full commercial operation at the Kemper County Energy Facility, Mississippi (capture capacity of ~3 MMT/yr)
- Petra Nova Carbon Capture Project at the W.A. Parish power plant, Texas, CO$_2$ capture anticipated by the end of 2016 (capture capacity of ~1.4 MMT/yr)
ROLE OF FEDERAL AND STATE GOVERNMENT IN CCS
U.S. Department of Energy

- Research funding (ARRA, CCPI)
  - Industrial capture and storage projects, including innovative usage
- Seven Regional Carbon Sequestration Partnerships
- Lessons learned during the validation phase small-scale field tests generated a series of Best Practices Manuals:
  - Monitoring, Verification and Accounting (2012)
  - Public Outreach and Education (2009)
  - Site Characterization (2010)
  - Geologic Storage Formation Classification (2010)
  - Simulation and Risk Assessment (2012)
  - Carbon Storage Systems and Well Management Activities (2011)
U.S. Environmental Protection Agency

• Underground Injection Control (UIC)
  • Class II - oil and gas
  • Class VI - geologic sequestration of CO$_2$
• GHG Reporting Program (40 CFR Part 98)
  • Subpart UU - injection of CO$_2$
  • Subpart RR - geologic sequestration of CO$_2$
• New Source Performance Standards- Carbon Pollution Standards
  • Sets carbon pollution emission performance rates for new, modified and reconstructed power plants
  • New coal power plants can emit no more than 1,400 lbs CO$_2$/MWh, compliance possible with partial CCS
State Agencies

- California Air Resources Board
  - Cap and Trade, GHG Mandatory Reporting
  - Low Carbon Fuel Standard
- California Energy Commission
  - SB 1386- Emission Performance Standards
  - WESTCARB
- California Department of Conservation Division of Oil, Gas and Geothermal Resources
  - Oil and gas well permitting
- State Water Resources Control Board
- California Public Utilities Commission
  - SB 1386- Emission Performance Standards
  - Could potentially consider CCS when establishing electricity rates
OVERVIEW OF CCS RELATED ACTIVITIES IN CALIFORNIA
CCS IN CALIFORNIA REGULATIONS AND QUANTIFICATION METHODOLOGY DEVELOPMENT
Cap and Trade Program

- Covers ~450 entities that emit more than 25,000 MTCO2e per year, including:
  - large industrial sources,
  - electricity generation and imports,
  - transportation fuels, and
  - residential and commercial use of natural gas
- Regulates direct emissions from facilities and upstream for fuels/some uses of NG
- Annual emissions reporting and third-party verification by ARB-approved verifiers
- Linked with Québec’s Cap-and-Trade System
Potential Role of CCS in Cap and Trade

<table>
<thead>
<tr>
<th>CO₂ capture location</th>
<th>onsite at regulated facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ storage location</td>
<td>not currently specified</td>
</tr>
<tr>
<td>Quantification methodology</td>
<td>must be adopted into the Regulation</td>
</tr>
<tr>
<td>Results in...</td>
<td>reduction in Cap and Trade compliance obligation at covered entities</td>
</tr>
<tr>
<td>Benefits to...</td>
<td>source of CO₂ captured emissions</td>
</tr>
<tr>
<td>Other</td>
<td>not eligible to generate offsets; consideration of reversals, enforceability, and long term liability in market program</td>
</tr>
</tbody>
</table>
Low Carbon Fuel Standard

- Nearly 160 active entities have registered for reporting in the LCFS Reporting Tool (LRT)
- Compliance tracked through a system of “credits” and “deficits.”
  - Credits are generated from fuels with lower CI than the standard
  - Credits may be banked and traded within the LCFS market to meet obligations; do not expire
- Uses a life cycle assessment (LCA) approach for determining fuel CI, includes direct and indirect emissions
## CCS in the Low Carbon Fuel Standard

<table>
<thead>
<tr>
<th></th>
<th>Tier 2 Fuel Pathway</th>
<th>Innovative Crude Provision</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ capture location</strong></td>
<td>anywhere along the fuel production pathway</td>
<td>onsite at the crude oil production facilities</td>
</tr>
<tr>
<td><strong>CO₂ storage location</strong></td>
<td>not specified</td>
<td>not specified; if third-party storage, must be joint applicant</td>
</tr>
<tr>
<td><strong>Quantification methodology</strong></td>
<td>required by ARB policy</td>
<td>required in regulation</td>
</tr>
<tr>
<td><strong>Results in</strong></td>
<td>carbon intensity (CI) determination</td>
<td>credits, prorated on amount to California</td>
</tr>
<tr>
<td><strong>Benefits to</strong></td>
<td>fuel pathway applicant(s)</td>
<td>crude oil producer opt-in as a regulated party or by the California refinery(ies) that purchase the crude</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>consideration of reversals, enforceability, and long term liability in market program</td>
<td></td>
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California’s Emission Performance Standard

- Administered by the California Energy Commission and the California Public Utilities Commission
- Establishes a facility based standard for baseload generation of 1,100 lbs/MWhr CO₂
- Regulatory requirements for CCS project:
  - Includes capture, transport, and geologic injection of CO₂ emissions
  - Complies with all applicable laws and regulations
  - Includes plan that will result in permanent sequestration of CO₂
- Compliance based on projections of net emissions over the life of the power plant.
ARB’S REGULATORY ADOPTION PROCESS
ARB’s Regulatory Adoption Process

• Informal development process
  • Public workshops; technical and policy discussions
  • Stakeholder outreach
  • Draft proposals
  • Process can take several years

• Rulemaking proceedings
  • 45-day public notice and comment period on proposed regulation
  • Public hearing(s)
  • Responses to relevant comments
  • Submit rulemaking action to the Office of Administrative Law
Post- Board Adoption

- Integrate newly adopted Regulation or Program into existing ARB or other entities’ programs
  - Coordinate existing programs’ needs
  - Possible regulatory updates to existing regulations

- Program Implementation
  - Stakeholder outreach, education
  - Develop reporting tools, other guidance documents
  - Establish contracts or MOU/MOA’s, if necessary

- Program Review/Expansion
  - Evaluate implementation of program
  - Make necessary program updates to reflect new technologies
DEVELOPMENT OF ARB’S QUANTIFICATION METHODOLOGY FOR CCS
ARB’s Quantification Methodology

• Mechanism for CO$_2$ reductions from CCS to be recognized in CARB regulations
• Ensure CO$_2$ reductions are:
  • Real
  • Permanent
  • Quantifiable
  • Verifiable
  • Enforceable
• Could potentially be used for both Low Carbon Fuel Standard and Cap-and-Trade, and possibly for Emission Performance Standard
ARB’s Quantification Methodology

• Initial focus on geologic sequestration
  • Saline reservoirs
  • Depleted oil and gas reservoirs
  • CO2- enhanced oil recovery

• Future efforts will include:
  • Conversion to building products (e.g., cement, plastics)
  • Conversion to fuels
  • Direct air capture
Guiding Principles

Provisions of the QM should strive for:

- Protection of human health and the environment, safety
- Accurate accounting
- Permanent storage
- Leak prevention over mitigation
- Rigor and comprehensiveness with flexibility
- Robust scientific basis
- Verifiability and enforceability
- Exportability
ARB’s Quantification Methodology

- Accounting and reporting protocols
  - Currently evaluating existing frameworks
  - LCFS requires a LCA approach - define project boundaries
  - Data verification requirements
- Site selection and characterization
  - Identify and assess long- and short-term risks
  - Define area of review
  - Requirements for remedial actions
  - Define requirements for monitoring and contingency plans
ARB’s Quantification Methodology

• Site and injection operations
  • Injection well design- Class II vs. Class VI
  • Injection quantity and pressure limits
  • Monitoring, reporting and active site management

• Site Closure/Post Closure
  • Decommissioning
  • Monitoring
    • How long?
    • How often?
    • How comprehensive?
ARB’s Quantification Methodology

- Long-Term Stewardship
  - Responsibility
    - Ensure emission reductions remain whole
    - Ownership transfer requirements
  - Financial liability
CO₂ Enhanced Oil Recovery

- Additional challenges
  - Potential for overall increased oil production, conflict with California’s petroleum reduction goals
  - Uncertainty with site closure, unclear responsibilities for permanent CO₂ sequestration
  - Maximize for CO₂ storage vs. oil production
- Potential benefits
  - Additional revenue to offset costs of CCS
  - Potentially large storage potential
  - Reservoir pressure controlled by production
  - Historical knowledge of the storage reservoir
- ARB plans to include requirements more strict than Class II or similar
OVERVIEW OF U.S. DEPARTMENT OF ENERGY’S CCS PROGRAM
NEXT STEPS
Public Process

• Public workshops-
  • Will cover QM development, Environmental Analysis of the QM, CCS policy development
  • Multiple locations in California

• ARB hosted technical and policy discussions-
  winter through summer 2016

• Ongoing stakeholder meetings

• Written comments will be posted online
Development Timeline *(tentative)*

- **Initial Kickoff Workshop**
  - Winter 2016

- **Concept Paper, Public Workshops**
  - Fall 2016

- **Draft Proposal, Public Workshops**
  - Winter/Spring 2017

- **Proposed QM, and Draft Environmental Assessment**
  - Fall 2017

- **Board Hearing**

- **Adopt Final QM and Environmental Analysis; begin implementation**
  - Winter/Spring 2018
Technical and Policy Discussions

- ARB hosted discussions on a variety of topics; receive feedback on concepts
- Format:
  - ARB established topics, identify specific questions for discussion
  - Webinar, conference call, and in-person
  - Provide advance notice of date/time ~ 30 days
  - Presentations by stakeholders and open discussion
- April 5, 2016 - Accounting protocols
- April 28, 2016 - Well integrity, construction
- Contact person: Sara King, (916) 323-1009 or Sara.King@arb.ca.gov
Contact Info

• http://www.arb.ca.gov/cc/ccs/ccs.htm

• List Serve:
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COMMENTS AND DISCUSSION