California Energy Commission’s
R&D Activities in CCS for California

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• California Carbon Capture and Storage Review Panel (2010), including Technical Advisory Team

• WESTCARB – West Coast Regional Carbon Sequestration Partnership (2003–2015); collaborative R&D with DOE NETL, state agencies, national labs/universities, EPRI, industry, and others

• PIER projects on potential for induced seismicity, groundwater impacts, etc., from CO₂ injection (some ongoing)


• Staff workshop on CCS for natural gas power plants (2015)

• CEC Siting Division-siting activities with HECA
California Agencies Convene Expert Panel to Examine CCS Policy

• California Carbon Capture and Storage Review Panel was created in 2010 by the Energy Commission, CPUC, and ARB, with involvement of DOGGR, Dept. of Water Resources, and others

• Panelists included experts from academia, NGO, utilities, industry associations, law firms, and a former state legislator. Chaired by Carl Bauer, former Director of DOE’s National Energy Technology Laboratory

• Five public meetings held; Energy Commission team developed topical white papers for panelists

• Panel developed recommendations to guide CCS policy formulation and regulatory role coordination in California

• http://www.climatechange.ca.gov/carbon_capture_review_panel/index.html
Key Recommendations of CCS Review Panel

- Determine and coordinate permitting and regulatory authority for CCS projects including CEQA lead, site operations, and CO₂ pipelines
- Establish GHG “accounting protocols” for sequestered CO₂ to facilitate inclusion in AB 32 compliance programs
- Develop performance standards for the design and operation of CCS sites for environmental, health, and safety protection
- Clarify ownership and use of subsurface pore space for CO₂ storage
- Assign financial responsibility for long-term stewardship of CO₂ storage sites
- Establish cost allocation mechanisms and/or incentives to support early CCS projects
- Develop public education materials and programs
West Coast Regional Carbon Sequestration Partnership (WESTCARB)

- Collaborative R&D team with >100 partners, led by Energy Commission
- One of 7 DOE “regional partnerships,” each charged with conducting regionally focused research and public outreach
- Basic questions answered for geologic and terrestrial carbon storage:
  - Is there ample, affordable, widely distributed storage capacity for the types of emission sources in the region?
  - Will storage be secure given the region’s seismicity (geologic storage) and history of wildfires (terrestrial storage)?
  - Does geologic storage pose any risk to hydrocarbon or groundwater resources?
  - California applications are promising
- Pilot-scale field tests validate technology
California’s Geologic CO₂ Storage Capacity Is Very Large

- On-shore sedimentary basins conducive to storage represent capacity for roughly 1000 years of current point source CO₂ emissions
- Central Valley’s Sacramento and San Joaquin Basins have the largest capacity
- Opportunities for CO₂ storage also exist in the state’s oil and natural gas fields – many have potential for CO₂-enhanced oil recovery
- Off-shore basins identified and partially characterized

### Estimated CO₂ Storage Resource: California Sedimentary Basins

- 30–460 Gt onshore saline formation capacity
- 3.3–5.7 Gt natural gas reservoir capacity
- 1.4–3.7 Gt oil reservoir capacity
WESTCARB Drilled Wells to Validate Formation Permeability at Promising Sites (CA and AZ)

• Site screening and selection
• Project planning; industry host engagement
• Subsurface modeling and injection simulation
• Risk assessment
• Monitoring plan
• Permitting
• Community outreach
• Safety plan and training
• Field measurements, laboratory analysis of core samples
• Site closure and restoration

Rock core collected at Citizen Green well (above) sent to LBNL scientists for laboratory analysis of CO₂ behavior in pore spaces (below)
WESTCARB Criteria for Site Selection

- Well-defined stratigraphy or geologic structure to confine CO\textsubscript{2} to target strata
- No impact on low-salinity (<10,000 mg/L TDS) aquifers
- Location unlikely to cause public nuisance (noise, traffic, dust, etc.)
- Proximity to large CO\textsubscript{2} point sources (future commercial potential)
- Available hydrogeologic, well log, seismic, and rock/fluid properties to inform site suitability and initial modeling
- Major faults understood for evaluating potential leakage pathways
- Depth of storage greater than ½ mile to keep CO\textsubscript{2} in dense (low buoyancy) phase
Characterization Well Results for the Sacramento Basin

Citizen Green well on King Island near Lodi

- Location in northern California’s natural gas producing region allowed use of experienced local drillers, mudloggers, etc.
- Reuse of pad and surface casing from an inactive natural gas well saved money and simplified CEQA
- Deviated well drilled to 7000 foot depth
- Core samples and logging data showed unconsolidated sands with high permeability in primary target formation, as well as good sealing properties in the shales
- Laboratory analyses of core samples at LBNL indicated good CO$_2$ injectability
Modeling and Simulation Results for the San Joaquin Basin

Kimberlina Power Plant north of Bakersfield

- Site of Clean Energy Systems’ 5 MW oxy-combustion power plant with inherent CO₂ separation; on-site injection well planned but not drilled
- 85-square-mile geologic model developed by Lawrence Livermore; regionally continuous Vedder Formation at a depth of 8000 feet appears best storage site
- Lawrence Berkeley simulation of a 4-year, 1 million-ton CO₂ injection showed plume stabilization within 20 years with little migration

Initial LBNL simulation of CO₂ plume in the Vedder formation at end of the 4-year, 1 million ton injection period (top) and after 20 years (bottom)
California NGCC Plants Align Well with Sedimentary Basins Screened for CO₂ Storage

- Initial review of geology beneath 42 NGCC plant sites found 33 with underlying sedimentary basins having sand thickness and depth suitable for CO₂ storage
- About 20 sites also had oil and gas fields within 12 miles
- Most are in flat, rural terrain, suggesting CO₂ pipeline construction may be feasible
- Similar result expected for cement, biofuels, and ag processing plants

Source: Lawrence Livermore National Lab and California Geological Survey
Capital Cost Is the Most Significant Economic Variable for Adding CCS to NGCC Plants

- Adding CO₂ capture and compression reduced net output by 11% and increased net heat rate by 12%
- Cost for full CCS system is $900 million for 600 MW plant; for retrofits, replacement power is also costly

Source: CB&I
CO₂ Storage Integrity and Seismicity

• Could earthquakes release CO₂ or could CO₂ injection cause earthquakes? Both have been studied.

• California Geological Survey issued seismic hazard map classifying faults according to age since last activity

• WESTCARB analyzed the risk of induced seismicity from small-scale CO₂ injection in the Montezuma Hills of Solano County. Results yielded an approach to risk assessment for induced seismicity as part of the permitting process.

• LBNL examined the potential for induced seismicity in the San Joaquin Valley from geologic CO₂ storage and historic basin pressure changes

Active faults in the vicinity of a proposed pilot CO₂ injection well in the Montezuma Hills were identified and the pressure change effects simulated by LBNL.
WESTCARB Outreach to California Communities

- Thornton – pilot-scale CO₂ injection proposed; CEQA declaration published
- Rio Vista – pilot-scale CO₂ injection proposed; draft permit issued
- Bakersfield – 1 million ton CO₂ injection proposed; permit application developed
- Well attended public meetings in all three communities; no formal comments to CEQA or draft permit
- WESTCARB also conducted public official and business/civic/EJ group briefings, science teacher training, opinion surveys, media interviews, etc.
- Citizen Green well videos at http://www.westcarb.org/videos.html
• Project site geologic characterization procedures
• Risk, EHS, and surface and subsurface monitoring plans
• Geologic models and CO₂ injection simulations
• Data from permit applications and CEQA declarations
• Stakeholder network and engagement experience

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