

# California Energy Commission's R&D Activities in CCS for California

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Mike Gravely  
Deputy Division Chief  
Energy Research and Development Division  
California Energy Commission

# PIER CCS R&D and Techno-Economic Summaries of Key Activities



- 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 CO<sub>2</sub> injection (some ongoing)
- *Geologic Carbon Sequestration Strategies for California: Report to the Legislature (2008) and Assessment of the Barriers and Value of Applying CO<sub>2</sub> Sequestration in California (2015)*
- 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](http://www.climatechange.ca.gov/carbon_capture_review_panel/index.html)

# Key Recommendations of CCS Review Panel

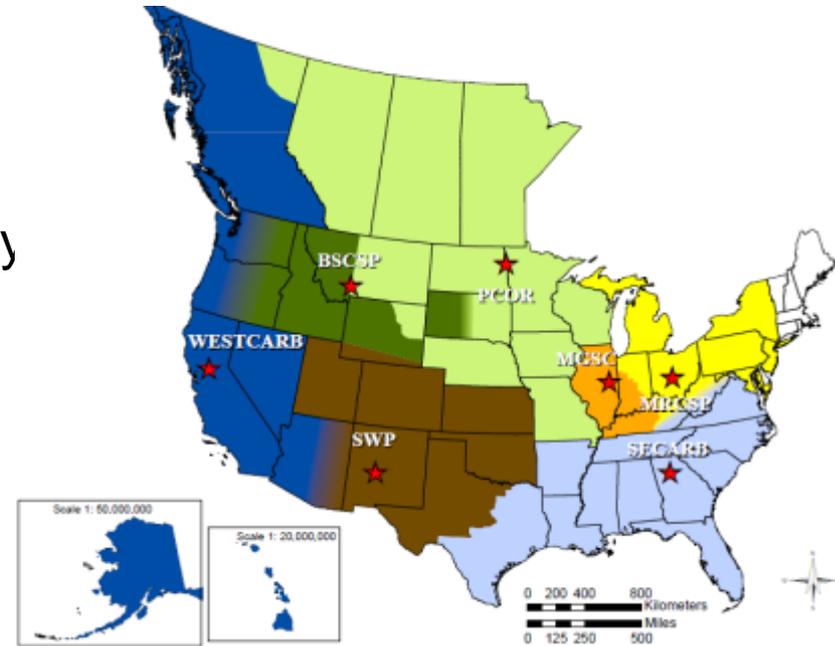


- Determine and coordinate permitting and regulatory authority for CCS projects including CEQA lead, site operations, and CO<sub>2</sub> pipelines
- Establish GHG “accounting protocols” for sequestered CO<sub>2</sub> to facilitate inclusion in AB 32 compliance programs
- Develop performance standards for the design and operation of CCS sites for environmental, health, and safety protection
- Clarify ownership and use of subsurface pore space for CO<sub>2</sub> storage
- Assign financial responsibility for long-term stewardship of CO<sub>2</sub> 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)



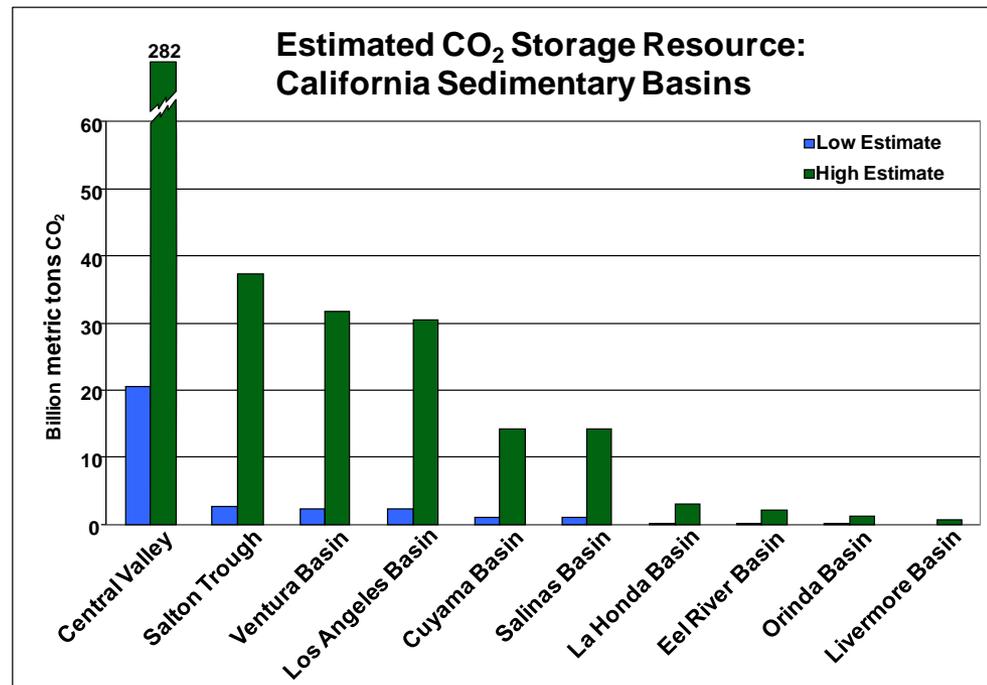
- Collaborative R&D team with >100 partners, led by Energy Commission
- One of 7 DOE “regional partnerships,” each charged with conducting regionally focused research and public outreach
- Basic questions answered for geologic and terrestrial carbon storage:
  - Is there ample, affordable, widely distributed 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



**WESTCARB territory includes AK, AZ, BC, CA, HI, NV, OR, and WA**

# California's Geologic CO<sub>2</sub> Storage Capacity Is Very Large

- On-shore sedimentary basins conducive to storage represent capacity for roughly 1000 years of current point source CO<sub>2</sub> emissions
- Central Valley's Sacramento and San Joaquin Basins have the largest capacity
- Opportunities for CO<sub>2</sub> storage also exist in the state's oil and natural gas fields – many have potential for CO<sub>2</sub>-enhanced oil recovery
- Off-shore basins identified and partially characterized



**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 CO<sub>2</sub> behavior in pore spaces (below)

# WESTCARB Criteria for Site Selection



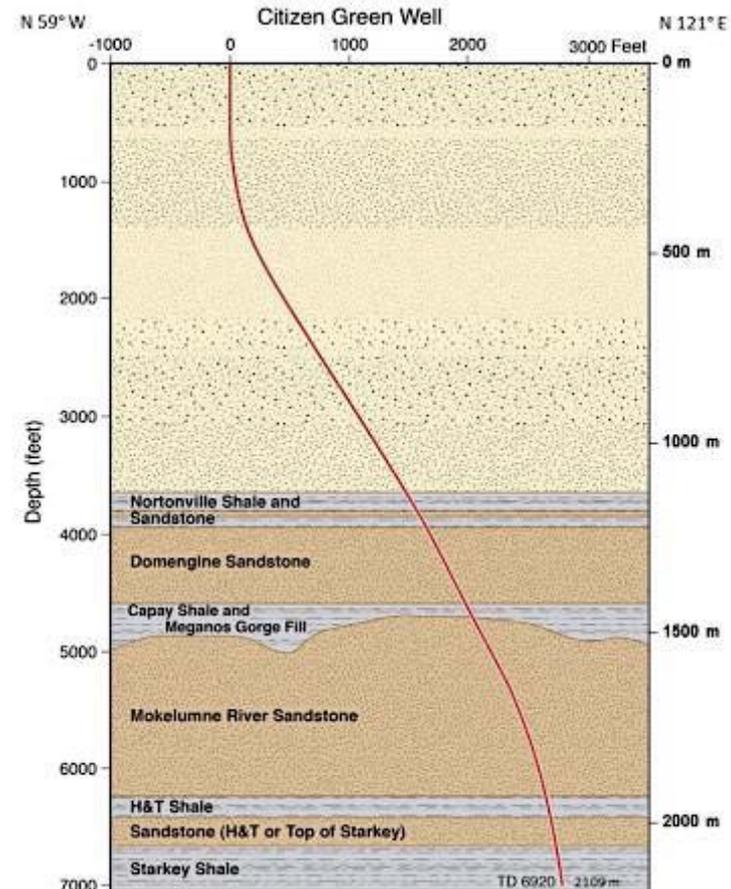
- Well-defined stratigraphy or geologic structure to confine CO<sub>2</sub> to target strata
- No impact on low-salinity (<10,000 mg/L TDS) aquifers
- Location unlikely to cause public nuisance (noise, traffic, dust, etc.)
- Proximity to large CO<sub>2</sub> point sources (future commercial potential)
- 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<sub>2</sub> 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<sub>2</sub> injectability

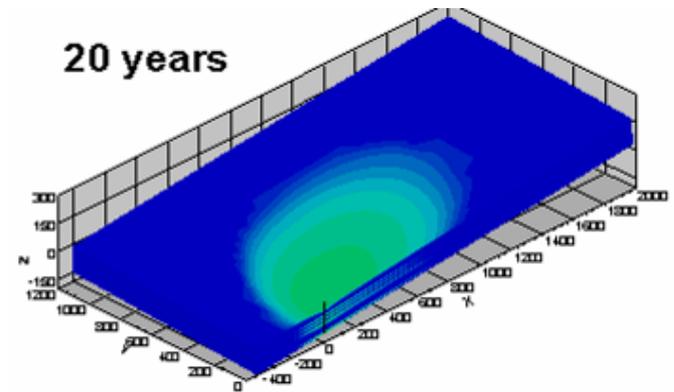
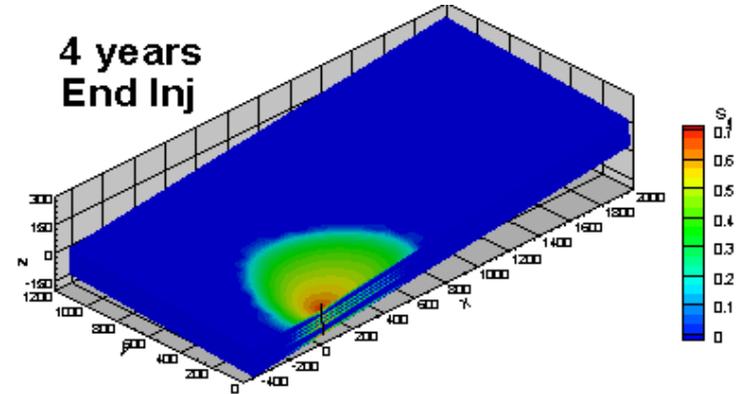


# Modeling and Simulation Results for the San Joaquin Basin



**Kimberlina Power Plant north of Bakersfield**

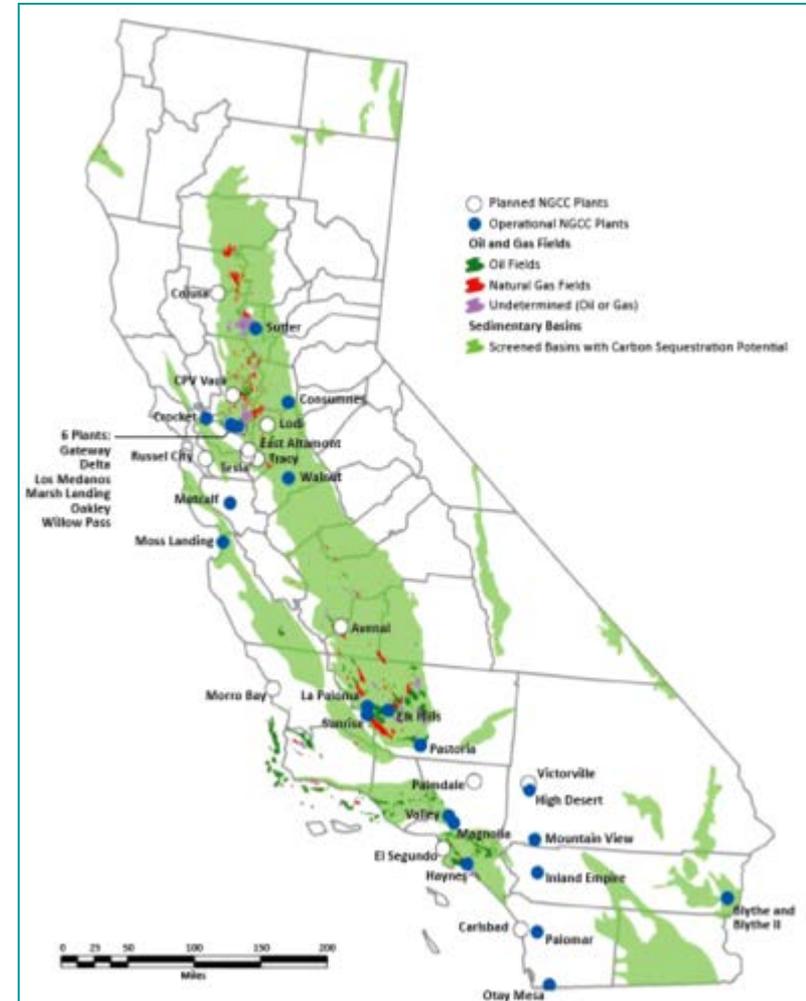
- Site of Clean Energy Systems' 5 MW oxy-combustion power plant with inherent CO<sub>2</sub> separation; on-site injection well planned but not drilled
- 85-square-mile geologic model developed by Lawrence Livermore; regionally continuous Vedder Formation at a depth of 8000 feet appears best storage site
- Lawrence Berkeley simulation of a 4-year, 1 million-ton CO<sub>2</sub> injection showed plume stabilization within 20 years with little migration



**Initial LBNL simulation of CO<sub>2</sub> 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 CO<sub>2</sub> Storage

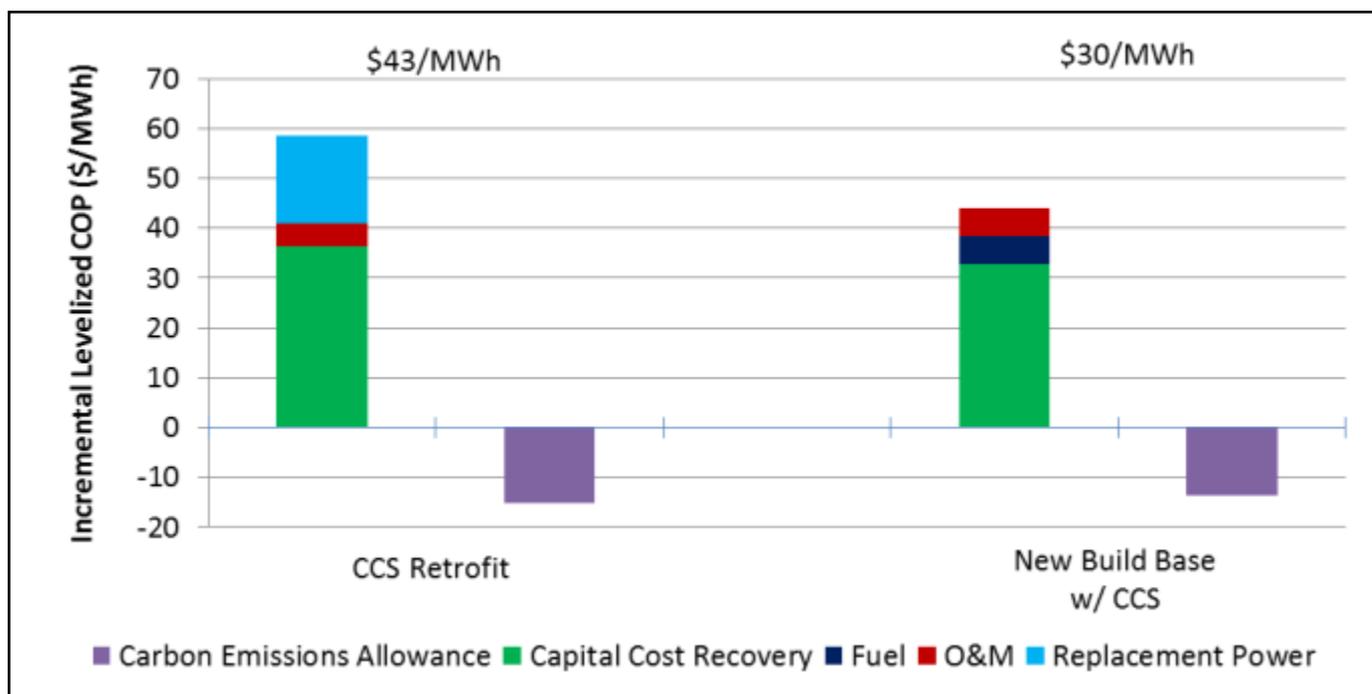
- Initial review of geology beneath 42 NGCC plant sites found 33 with underlying sedimentary basins having sand thickness and depth suitable for CO<sub>2</sub> storage
- About 20 sites also had oil and gas fields within 12 miles
- Most are in flat, rural terrain, suggesting CO<sub>2</sub> pipeline construction 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 CO<sub>2</sub> 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

# CO<sub>2</sub> Storage Integrity and Seismicity

- Could earthquakes release CO<sub>2</sub> or could CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> storage and historic basin pressure changes



**Active faults in the vicinity of a proposed pilot CO<sub>2</sub> injection well in the Montezuma Hills were identified and the pressure change effects simulated by LBNL**

# WESTCARB Outreach to California Communities



- Thornton – pilot-scale CO<sub>2</sub> injection proposed; CEQA declaration published
- Rio Vista – pilot-scale CO<sub>2</sub> injection proposed; draft permit issued
- Bakersfield – 1 million ton CO<sub>2</sub> 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>



# How WESTCARB Results Can Support ARB Storage Protocol Development



- Project site geologic characterization procedures
- Risk, EHS, and surface and subsurface monitoring plans
- Geologic models and CO<sub>2</sub> injection simulations
- Data from permit applications and CEQA declarations
- Stakeholder network and engagement experience
  
- For more information, contact Mike Gravely at (916) 327-1370 or [Mike.Gravely@energy.ca.gov](mailto:Mike.Gravely@energy.ca.gov)