WESTCARB's Engineering-Economic Assessment of CCUS for California NGCC Power Plants – Retrofit and New Builds

West Coast Regional Carbon Sequestration Partnership
westcarb.org

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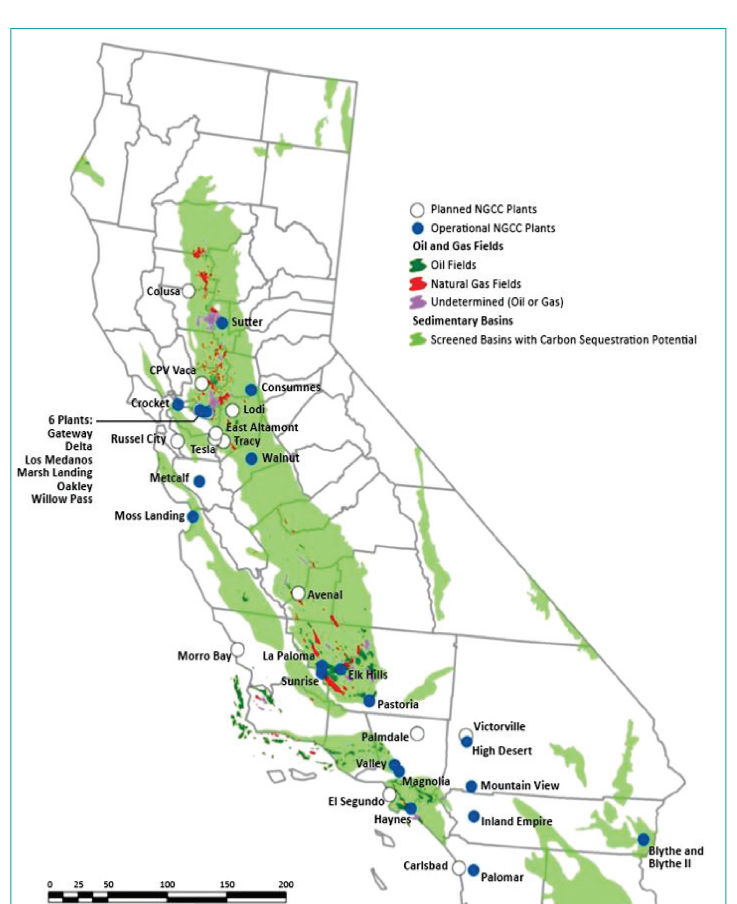
Drivers for the Study

- To meet California's GHG reduction goals, power producers are likely to apply CCUS to gas-fired units
  - California law requires GHG emissions to be 10–15% below today's levels by 2020; the state is targeting GHG reductions of >80% by 2050
  - ~50% of California's electricity is generated by natural gas power plants
  - California has >50 F- and H-class NGCC units that are relatively new; most operate at high capacity factors
  - Multi-unit NGCC plants rank among the state's largest CO_2 emitters, and thus are candidates for CCUS

Preliminary Evaluation

- CO_2 capture and compression technologies were screened for suitability to California NGCC units using information from literature searches, EPC experience, and vendor responses to questionnaires
- Existing and planned California NGCC plants were assessed for suitability to retrofit CO_2 capture and compression or to incorporate it in new-build units
  - Examined available space for equipment using plot plans and aerial images
  - Reviewed local geology underlying or near power plant sites; in most cases, formations favorable for CO_2 storage were found. See *Geologic CO_2 Sequestration Potential of 42 California Power Plant Sites: A Status Report to WESTCARB* (LLNL-TR-489273, June 2011)
  - Mapped potential pipeline rights-of-way corridors linking plant sites to promising storage formations

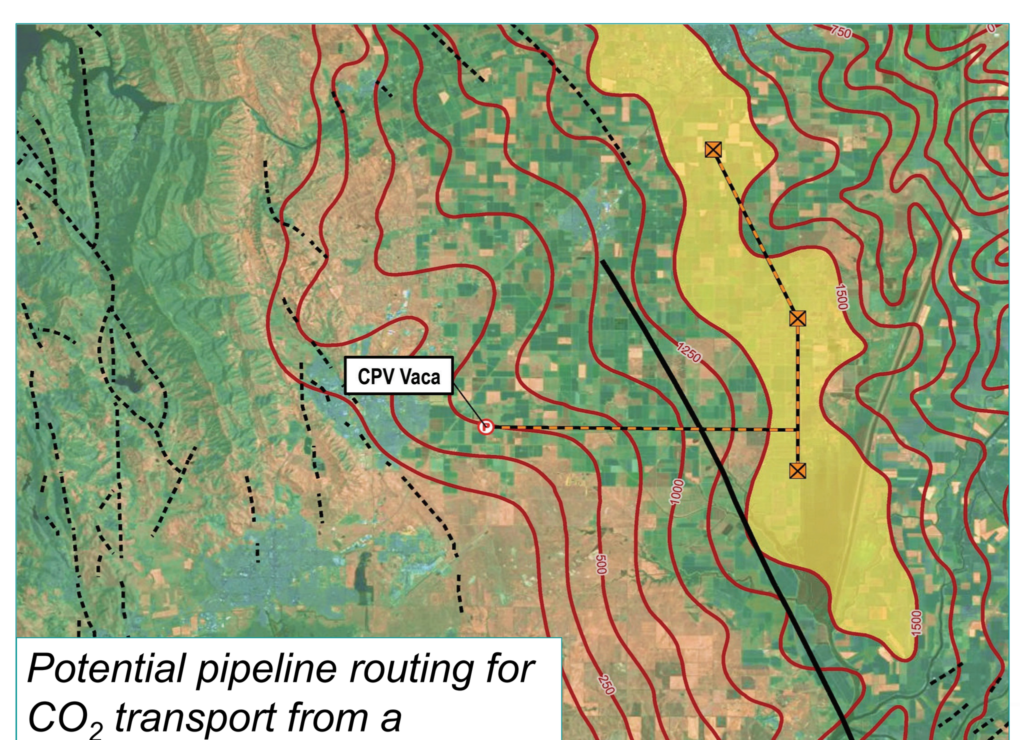


Many California NGCC plants (shown in blue and white circles) lie above or near sedimentary basins with CO_2 storage potential (shown in light green). CO_2 from NGCC plants could also be used for enhanced recovery operations in oil and natural gas fields (shown in dark green and red, respectively). Source: Lawrence Livermore National Lab and California Geological Survey

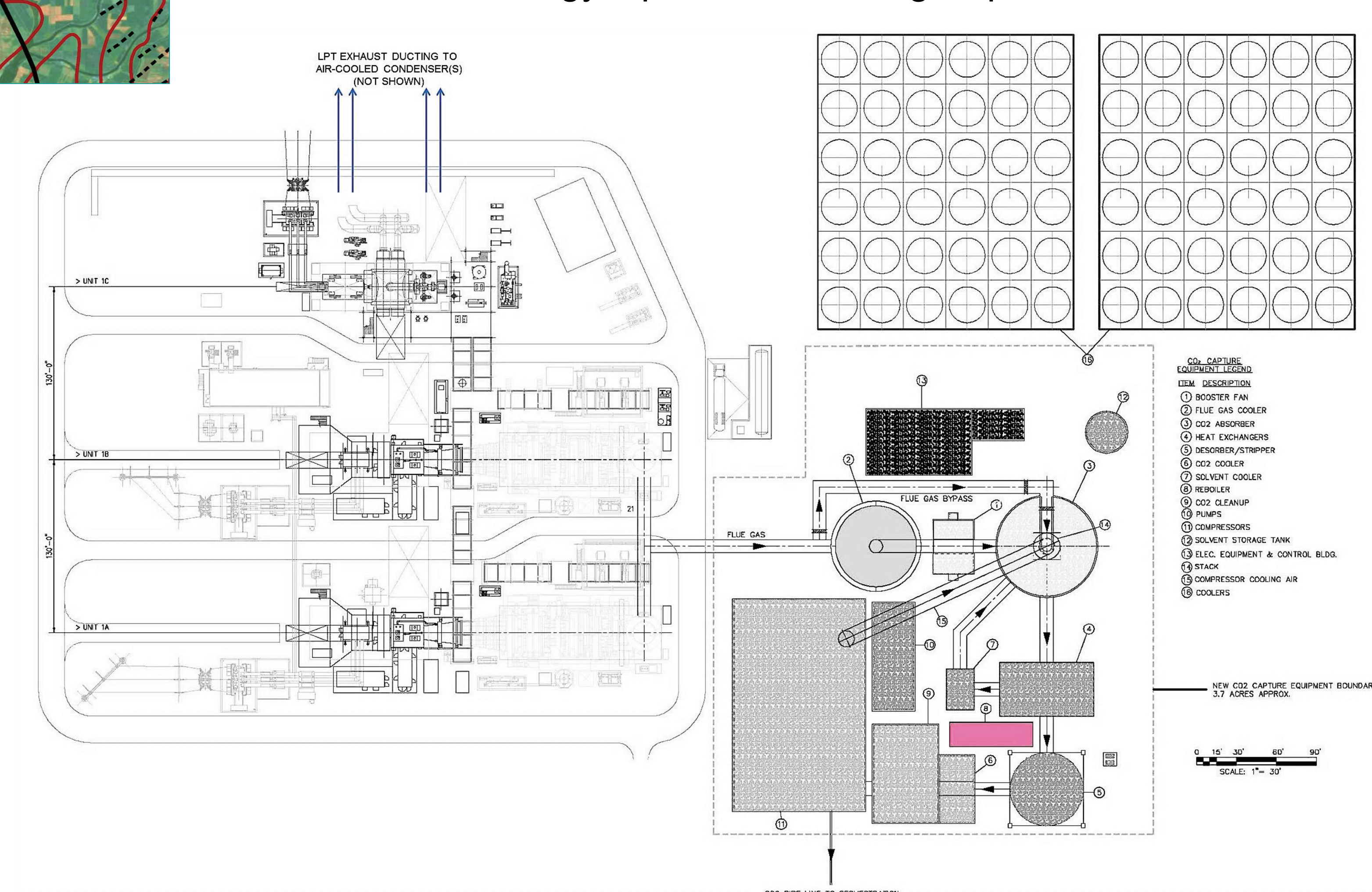
Project Findings

Evaluation of Geologic Storage Prospects Near NGCC Plant Sites

- CO_2 transportation, storage, and monitoring costs should be a relatively small part of total costs for NGCC-CCUS projects in California's Central Valley
- Design insights from the study include:
  - Well costs increase faster than pipeline costs as project size grows
  - Pipeline costs tend to driven more by distance and the need to cross roads, irrigation ditches, etc., than by carrying capacity
  - Well field costs vary with storage formation depth, thickness, injectivity, and drilling conditions
  - Project developers may need to assess cost trade-offs between well field development and pipeline construction (Q: Is it economical to build a longer pipeline to reach thicker, more injectable formations requiring less wells? A: May be likely in rural areas.)
  - Legal frameworks for CO_2 pipelines and various aspects of storage verification and accounting are not fully established in California



Potential pipeline routing for CO_2 transport from a proposed NGCC plant site near Vacaville, California, for injection into the thickest part of the Winters Formation (sandstone). Source: CB&I



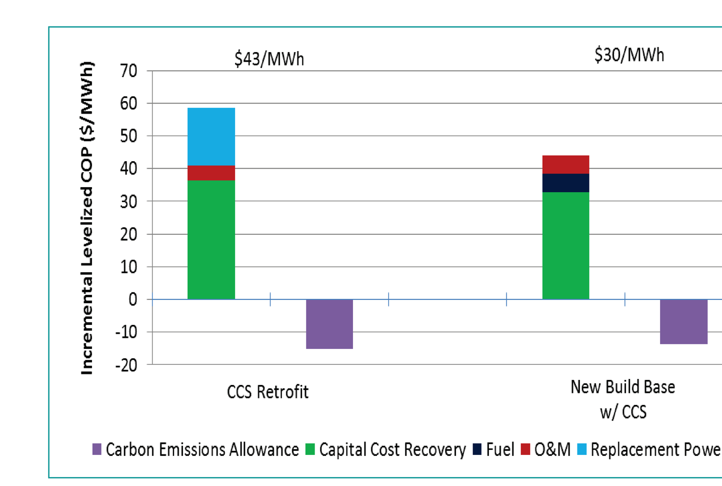
For a 2x2x1 NGCC power block, CO_2 capture and compression equipment requires about four acres of plot space, with clear paths for ducting from the HRSGs to the CO_2 absorber. Three acres (or more) may be required to provide sufficient heat rejection using indirect air cooling. Source: CB&I

Design Implications for CO_2 Capture and Compression Systems

- The most mature post-combustion CO_2 capture processes use temperature swing absorption with liquid sorbent (solvent) to treat cooled flue gas
- Technology screening activities also reviewed oxy-combustion, chemical looping, pre-combustion, membranes, and fuel-cell CO_2 capture systems. Generally, independent cost and performance data were limited or unavailable for these processes.
- California's hot dry summers and unavailable or expensive/degraded water supplies presented significant design challenges for solvent-based CO_2 capture systems
- For solvents requiring relatively cool absorber temperatures that cannot be achieved with dry cooling, chillers and fin-fan coolers were used in initial cost and performance models, but this added excessive cost and power demand
- High "first pass" CO_2 capture costs led to design alternatives in a value engineering phase:
  - Relaxed to annual average the design ambient temperature for 90% CO_2 capture efficiency
  - Examination of options to use degraded water (and water recovered from cooling of flue gas and CO_2 product) with wet or hybrid wet-dry cooling
  - Use of thermal integration within and between the NGCC, capture, and compression systems to minimize energy inputs and cooling requirements
  - Flue gas recirculation to increase flue gas CO_2 concentration and reduce CO_2 absorber size, cost, energy inputs, and cooling requirements

Performance and Economic Analysis Results

- Relative to a retrofit application, a "new build" NGCC plant allows for better thermal integration of CO_2 capture and compression equipment with base plant processes as well as better plant layout
- Adding post-combustion CO_2 capture and compression systems capable of 90% capture on an average temperature day reduced net plant output by 14.5% for the retrofit case and 11% for the new build
- Heat rate increased by 17% for the retrofit case and by 12% for the new-build case
- Levelized cost of CO_2 avoided (or cost of electricity) is roughly 45% higher for a retrofit versus a new build for the modeled sites; in actual applications, this differential will be highly site-specific
- EOR revenue can help support early NGCC-CCUS projects. However, it is expected that some form(s) of regulatory support will also be needed, such as:
  - a low-carbon electricity standard
  - a cap and trade mandate
  - a carbon tax
  - ISO "must run" designation



Levelized cost of electricity tabulations indicate that for both retrofits and new-builds, CCS capital cost is the most significant economic variable. Sensitivity analyses found that capacity factor and financing costs have a significant impact on levelized capital costs. For retrofits, replacement power is also costly in gas-dominated markets. Source: CB&I

Lessons Learned

- The study identified several RD&D focus areas relevant for NGCC-CCUS applications in gas-dominated electricity markets in hot, dry climates:
  - Development of sorbents with higher operating temperatures and/or lower regeneration energy
  - Modeling and optimization of cooling technology alternatives to maximize utilization of limited water
  - Modeling and optimization of flue gas recirculation arrangements; identification/development of corresponding GT modifications