CO2 capture and compression technologies were likely to apply CCUS to gas-fired units. To meet California’s GHG reduction goals, power producers are likely to apply CCUS to gas-fired units. 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 CO2 emitters, and thus are candidates for CCUS.

**Preliminary Evaluation**

- **CO2 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 CO2 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 CO2 storage were found.** See Geologic CO2 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 CO2 storage potential (shown in light green). CO2 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.

**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 CO2 emitters, and thus are candidates for CCUS

**Project Findings**

**Evaluation of Geologic Storage Prospects Near NGCC Plant Sites**

- CO2 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 drive 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? A: May be likely in rural areas.)
  - Legal frameworks for CO2 pipelines and various aspects of storage verification and accounting are not fully established in California

**Design Implications for CO2 Capture and Compression Systems**

- The most mature post-combustion CO2 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 CO2 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 CO2 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” CO2 capture costs led to design alternatives in a value engineering phase:
  - Relaxed to annual average the design ambient temperature for 90% CO2 capture efficiency
  - Examination of options to use degraded water (and water recovered from cooling of flue gas and CO2 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 CO2 concentration and reduce CO2 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 CO2 capture and compression equipment with base plant processes as well as better plant layout
- Adding post-combustion CO2 capture and compression systems capable of 90% capture on an average temperature day reduced net plant output by 14.5% for the retrofits 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 CO2 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:
  - 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, CO2 capture 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 concentrations and reduced CO2 absorber size, cost, energy inputs, and cooling requirements
  - Relaxed ambient temperature for 90% CO2 capture efficiency
  - Examination of options to use degraded water (and water recovered from cooling of flue gas and CO2 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 CO2 concentration and reduce CO2 absorber size, cost, energy inputs, and cooling requirements

**Potential pipeline routing for CO2 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, CO2 capture and compression equipment requires about four acres of plot space, with clear paths for ducting from the HRSGs to the CO2 absorber. Three acres (or more) may be required to provide sufficient heat rejection using indirect air cooling. Source: CB&I**