Carbon Dioxide Capture and Separation Technologies Assessment and Evaluation for the Southwest Partnership Region

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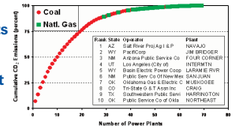
Southwest Partnership Region

> Region Covered
  – New Mexico, Colorado, Arizona, Utah, Oklahoma and parts of: Texas, Wyoming, Nevada, Kansas

> Sources
  – Electrical power plants
  – Cement and other processing plants
  – Urban centers
  – Non-point sources (agriculture, automobiles)
> Sinks
  – Geologic (oil/gas reservoirs, deep saline aquifers, coalbeds, natural CO_2 reservoirs)
  – Terrestrial (agriculture, forests)
  – Mineralization engineering (surface)
> Infrastructure
  – Extensive CO_2 pipeline networks

10 largest power plants in region contribute 50% of plant emissions



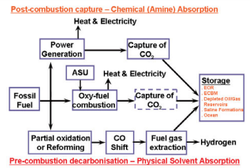
Southwest Partnership Objectives

> Phase I of the partnership project: Evaluate and rank options, including
  – Practicality/feasibility
  – Safety/regulatory issues
  – Public perception and acceptance
  – Monitoring and verification
  – Develop proposal for Phase II
> Phase II of the partnership project:
  – Outline possible specific pilot tests of the most promising options evaluated in Phase I

Southwest Partnership Goals

> Characterize the Southwest Region
> Assess and initiate public outreach and acceptance
> Identify and address implementation issues for Phase II
> Identify and rank sequestration options

CO_2 Capture and Storage Options



Separation and Capture: Key Facts

> More than 2 billion metric tons of CO_2/yr emitted from U.S. power plants (31% of U.S. emissions)
> About 25 plants using separation and capture from power plants worldwide
> Amine (MEA) is the predominant technology approach from power plants
> Natural gas treating plants remove excess CO_2 which is usually vented to the atmosphere
  – More than 25% of the natural gas produced requires some degree of CO_2 removal
> Most industrial plants do not recover the CO_2 in their combustion or process operations
> Cost of recovery from flue gases (post-combustion) is higher than from process gases (pre-combustion)
> IGCC is more expensive than pulverized coal (PC) without capture, but is expected to become cheaper than IGCC eventually with or without capture

Problems with Current CO_2 Capture Technology

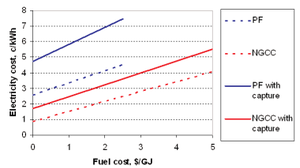
> High cost of operation
> Oxygen degrades the solvent
> Solvent losses
> Corrosion
> Parasitic pumping losses from high circulation rates
> Large physical scale and capital cost

CO_2 Capture Costs: General

> CO_2 capture from power plant increases costs and reduces efficiency
  – Capital cost increases:
    NGCC: 100%
    Coal: 80%
    IGCC: 50%
  – Electricity generation costs increases:
    NGCC: + 1.0 US ¢/kWh
    Coal: + 2.5 US ¢/kWh
    IGCC: + 2.0 US ¢/kWh
  – Cost of avoided emissions:
    U.S. $30-50/tonne of CO_2

Source: Carbon Dioxide Capture and Storage, IEA/OECD, 2000

CO_2 Capture Cost: Post Combustion



Costs exclude CO_2 storage

CO_2 Capture Cost: Retrofit

> Findings of studies (ref. CMU)
  – Higher CO_2 avoidance cost than new plant even after capital has been amortized
  – COE is lower than new plant
  – Requires SO_2 and NO_x emission reductions upstream
  – Difficult heat integration and other site-specific issues
  – $60 - $120 per ton of CO_2 mitigation
> Need more efficient, lower-cost solvent, better heat integration, lower heat requirements

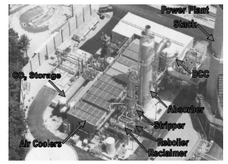
CO_2 Capture Cost: Pre-Combustion

> Handful of IGCC plants
  – Several utility power plants, some coal-fired
  – Mostly in refineries or making chemical feedstocks from petcoke or heavy resids
> U.S. plants
  – Wabash River Gasification Power Plant (ConocoPhillips)
  – Farmlands (chemicals)
  – TECO Energy Polk Power Station
  – A few others
> IGCC is best option for environmental impact and CO_2 capture
> But slow utility acceptance without incentives because of risk, cost, maturity, mandates
> In high-pressure gasification, CO_2 capture raises the cost of electricity:
  – By 40 to 50% for IGCC
  – By 80 to 90% for PC with bituminous coals (EPRI)
  – Less difference between IGCC and PC for low-rank coals

Examples of Current Technologies

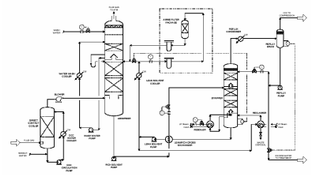
Fluor Econamine FG Process

> 23 plant applications on flue gas
> Proprietary inhibitor prevents corrosion and reduces degradation by oxygen
> Reports of improved economics recently



Source: Fluor Corporation

Fluor Econamine FG Flowsheet



Source: Fluor Corporation

Selexol Process

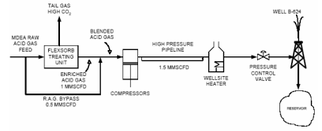
> Preferred solvent in IGCC
> 50+ plants worldwide
> Physical solvent process
> Selexol=dimethyl ether of polyethylene glycol

Photo: Selexol in Sarlux 550 MW IGCC Plant
Source: UOP

CO_2 for EOR or Reinjection

> 25% of all U.S. natural gas needs to be (and is) processed for CO_2 removal to meet pipeline specifications
> This CO_2 is potentially available for capture at a low marginal cost
> Several plants are operating currently capturing the gas for EOR or reinjection

Tom Brown Acid Gas Injection



> In Moab, UT, Tom Brown Inc., operates the Lisbon Gas Plant
> Injecting ½ MMscfd of CO_2 (21 million pounds per year) along with about that much H_2S, without subsidies
> Economically justifiable on it's own

Duke Energy Gas Transmission—Kwoen Sour Gas Upgrader, British Columbia

> Already remove "acid gas" (CO_2 and H_2S) to meet specs
> Acid gas may be available at pressure (if physical solvent plant)
> Inject acid gas downhole to avoid S recovery
> Kwoen Plant injected 70K tons of CO_2 derived from 72 BCF of natural gas processed from August 2002 through December 2003

Advanced Technologies

> Many high-tech approaches are at various stages of development
> Enzyme processes, advanced sorbents, new solvents, cryogenics, membranes, advanced contactors
> Most are a decade or more away and most will not ultimately prove feasible or economic

Conclusions

> Capture is an expensive part of the whole process of capture/transportation/storage
> Technologies exist but are not cheap
> Incentives will be required to move capture and sequestration forward
> Technology improvements are needed
> Breakthroughs would be welcome