ELECTRIC POWER RESEARCH INSTITUTE

CO_2 Testing Program

An Industry/EPRI Initiative to Develop CO_2 Capture and Storage Test Capabilities

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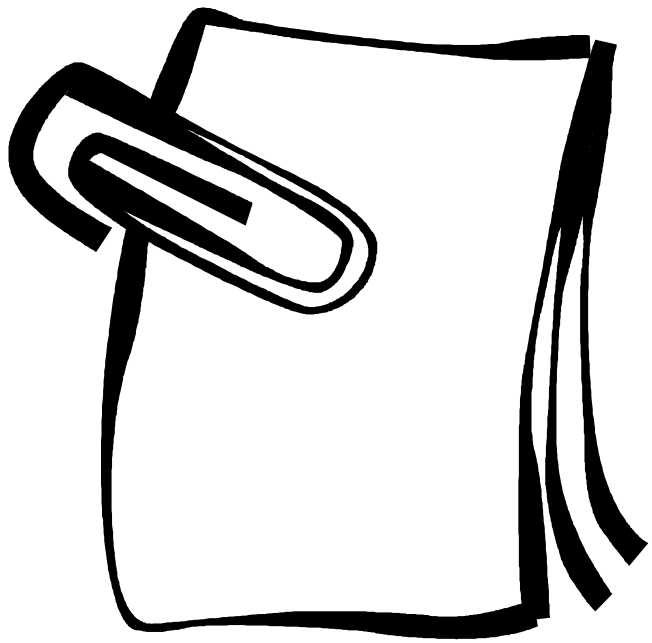
Presentation Outline

- Background
- Current proposal – 5-MW transportable pilot
- Chilled Ammonia process highlights



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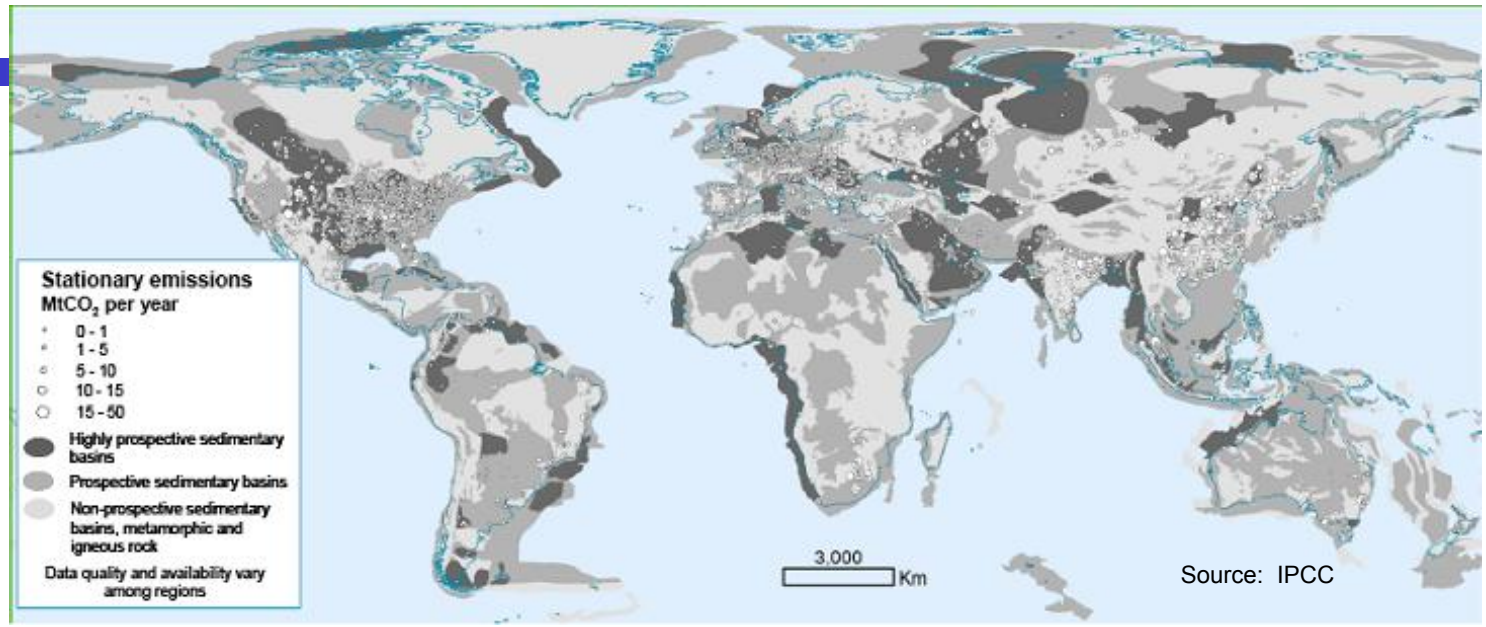
The Need for CO_2 Capture and Storage R&D for PC Power Plants



- **Fossil-fueled power plants are high profile regulatory targets**
- **Cost and energy penalty for carbon capture and storage (CCS) are high**
- **Keeping the coal option is strategically important**
- **IGCC may be future option, but PC/CFB (new and existing) will be significant near- and mid-term**
- **R&D at a credible scale needed but lacking for PC/CFB**

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Rationale for CO_2 Test Centers (the original size of ~10-MW)

- Integrated Test Center crucial step to commercialize CCS technologies
  - Actual coal-fired power plant flue gas CO_2 and operating environment
  - Forces study of integration issues
  - Gain credibility if we show safe storage of as-captured, real power plant CO_2
- Fills hole between lab- and full-scale efforts not currently addressed
  - Existing pilots are small (NETL) or only amine (high cost) scrubbing
- Whether CO_2 capture or storage is required or not, industry needs to know the costs, options and alternatives

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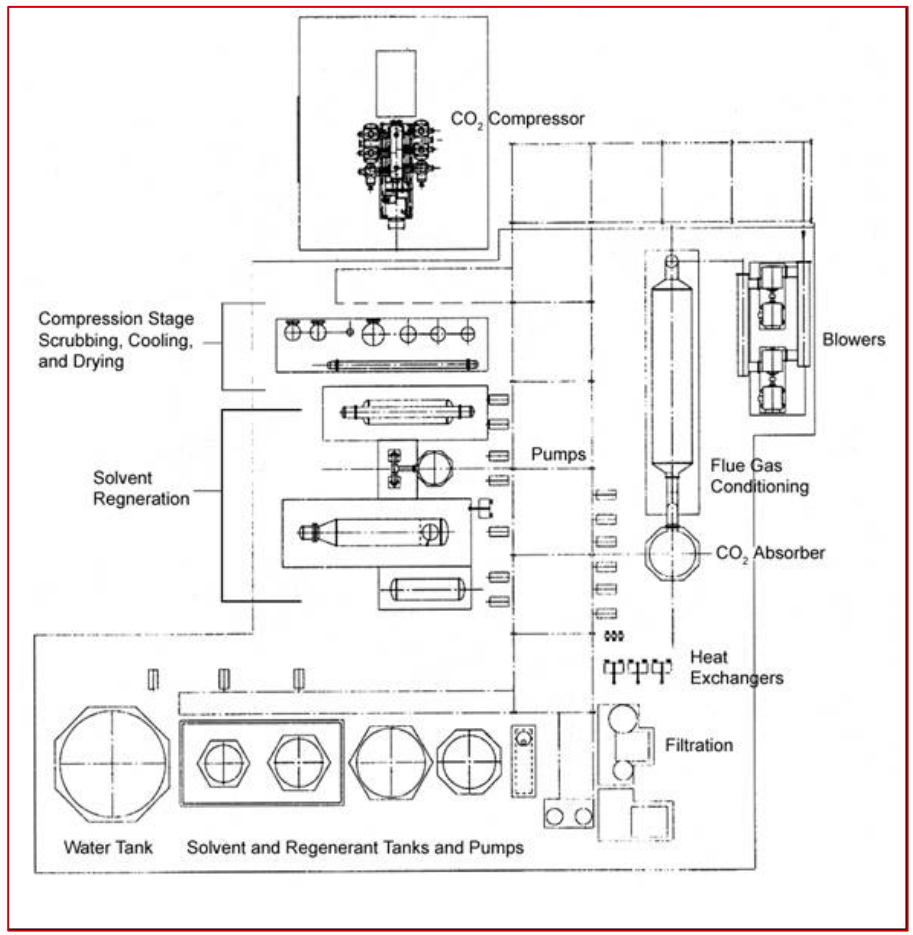
CO_2 Capture and Storage Test Center– Preliminary Engineering, Cost, and Site Selection (10-MW)

- TC project with six members to develop preliminary engineering and costs for a test center
- Evaluated suitability of up to six sites for each member
  - Capture and geologic storage
- Developed test center site-specific designs at best sites for four member locations
  - All PC plants with saline reservoirs
- Plans include space for:
  - Two large pilots (10-MW)
  - One smaller-scale pilot (1-MW)
  - Lab-scale unit with real flue-gas as source



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Guidance from Advisors

Ad Hoc Working Group and select BoD members said:

- Developing CO_2 capture, transport and storage from PC power plants is important
- While storage is important, EPRI should concentrate first on the development of cost-effective CO_2 capture processes
- Current processes are not cost-effective or ready for a large pilot
- The high cost of such a large facility is a significant obstacle

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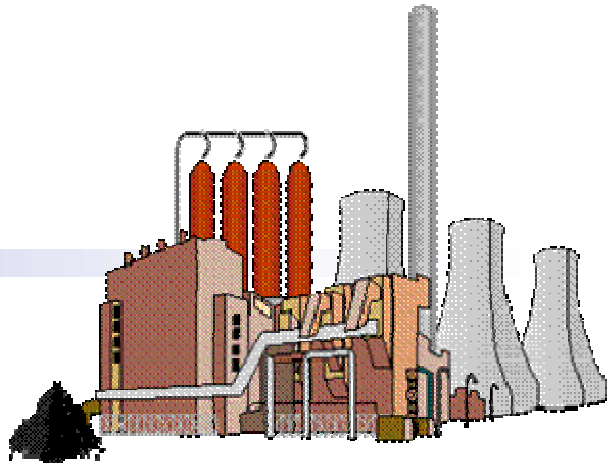
CO_2 Test Centers Current Plan



A multi-phase testing program to develop cost-effective and practical capture technologies

Phase 1

- **1-MW pilot plants**
- **Test solvent, solid and membrane capture technologies**
- **Test materials to be used for compression, transport and injection of flue-gas CO_2**

Phase 2

- **10-MW CO_2 Test Center (150 Tonnes/day)**
- **Capture and store CO_2 at substantial scale and real operating environments**
- **Future phases – larger demos to scale-up to full plant**

Determine the viability of combustion-based coal plants in a carbon constrained future

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CO_2 Capture Pilot Project Launch

- PON released and participation solicitation initiated in early February
- Initial calls made to potential anchor tenant members
- Two companies signed executed agreements
- 13 additional members have agreed in principle to participate
- Funding from these members represents over 2/3 of the project funding

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Chilled Ammonia Process

- Post-combustion, solvent-based, CO_2 capture process
- Ammonia based and designed to improve on current concept
- Being developed by EPRI, Alstom and Statoil
- Data from Technology Innovation bench-scale work looks good
- Economics are very preliminary and supplier derived
- Appropriate for scale-up

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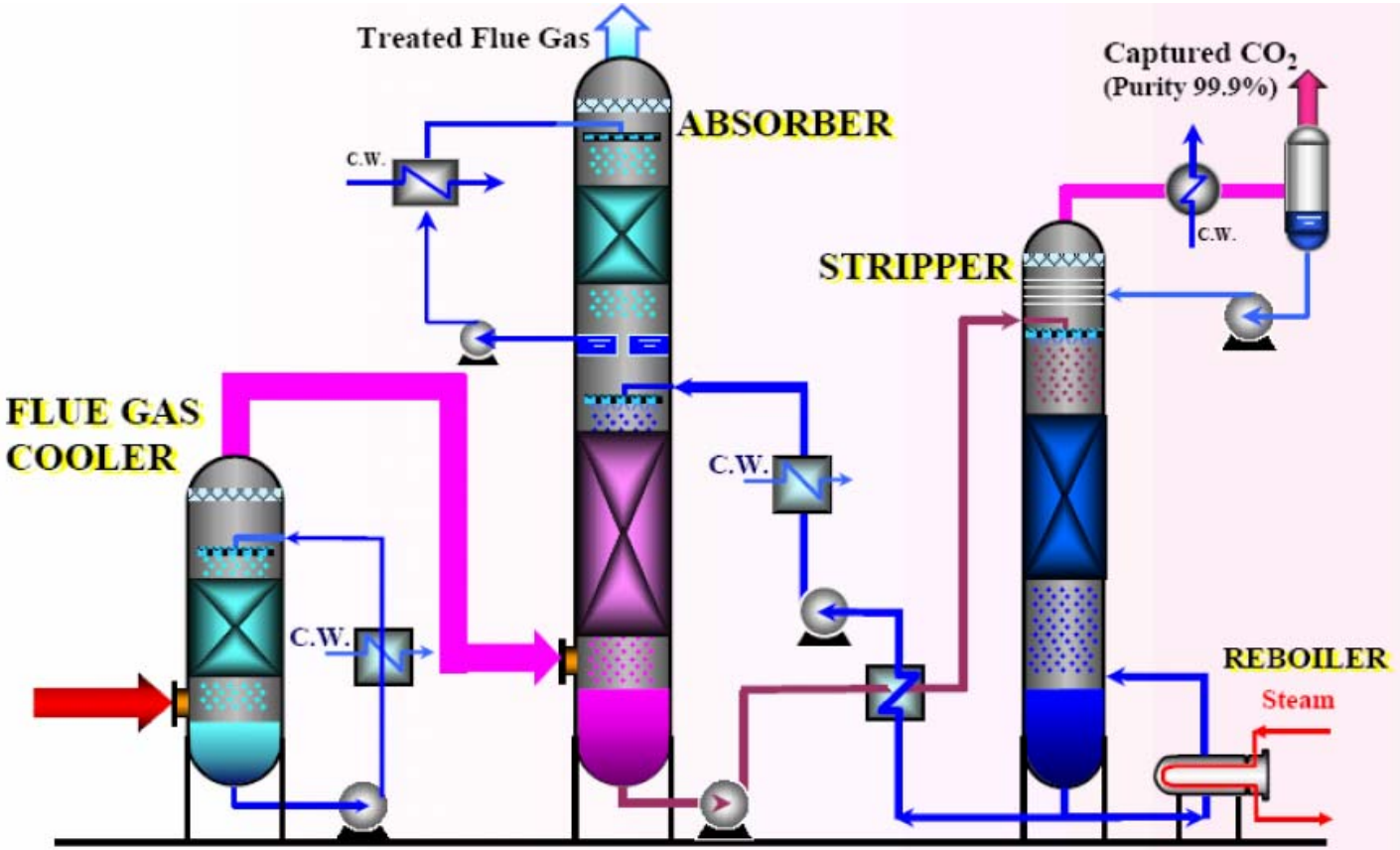
Amine Process Flow



CAP similar, but with pressure/temperature mods

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Reactions Involved in CAP System

- Absorption (35 to 60F, atmospheric pressure):

$$(NH_4)_2CO_3 + CO_2 + H2O \qquad 2NH_4HCO_3$$

- Regeneration (200 to 260F, 300 to 600 psi):

$$2NH_4HCO_3 \qquad (NH_4)_2CO_3 + CO_2 + H_2O$$

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Chilled Ammonia Process: Key Design Features

- Low temperature CO_2 absorption
  - Absorber operation at optimal temperature of 2-16°C (35-60°F)
- High concentration of ammonium carbonate/ammonium bicarbonate (AC/ABC)
  - High CO_2 loading per recycled slurry
- High pressure regeneration saves energy

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CAP/MEA Comparison, Key Operating Components

	MEA	CAP	CAP Superior?
CO_2 Loading, kg/kg solution	0.04-0.06	0.1-0.15	✓
Heat of Reaction, Btu/lb	820	260	✓
Absorption Temp, F	120-140	35-60	✗
Regeneration Temp, F	240-260F	200-260F	even
Regeneration P, psia	15-30	300-600	✓/ ✗
Makeup Cost, $/ton	800-1200	100-200	✓
Makeup, kg/ton CO_2	2	0.2	✓
H_2O/CO_2 in Regen. O/H	0.8-1.5	0.01-0.05	✓

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Bench Scale Unit at SRI

Cold water scrubber

Primary scrubber

Sorbent tank

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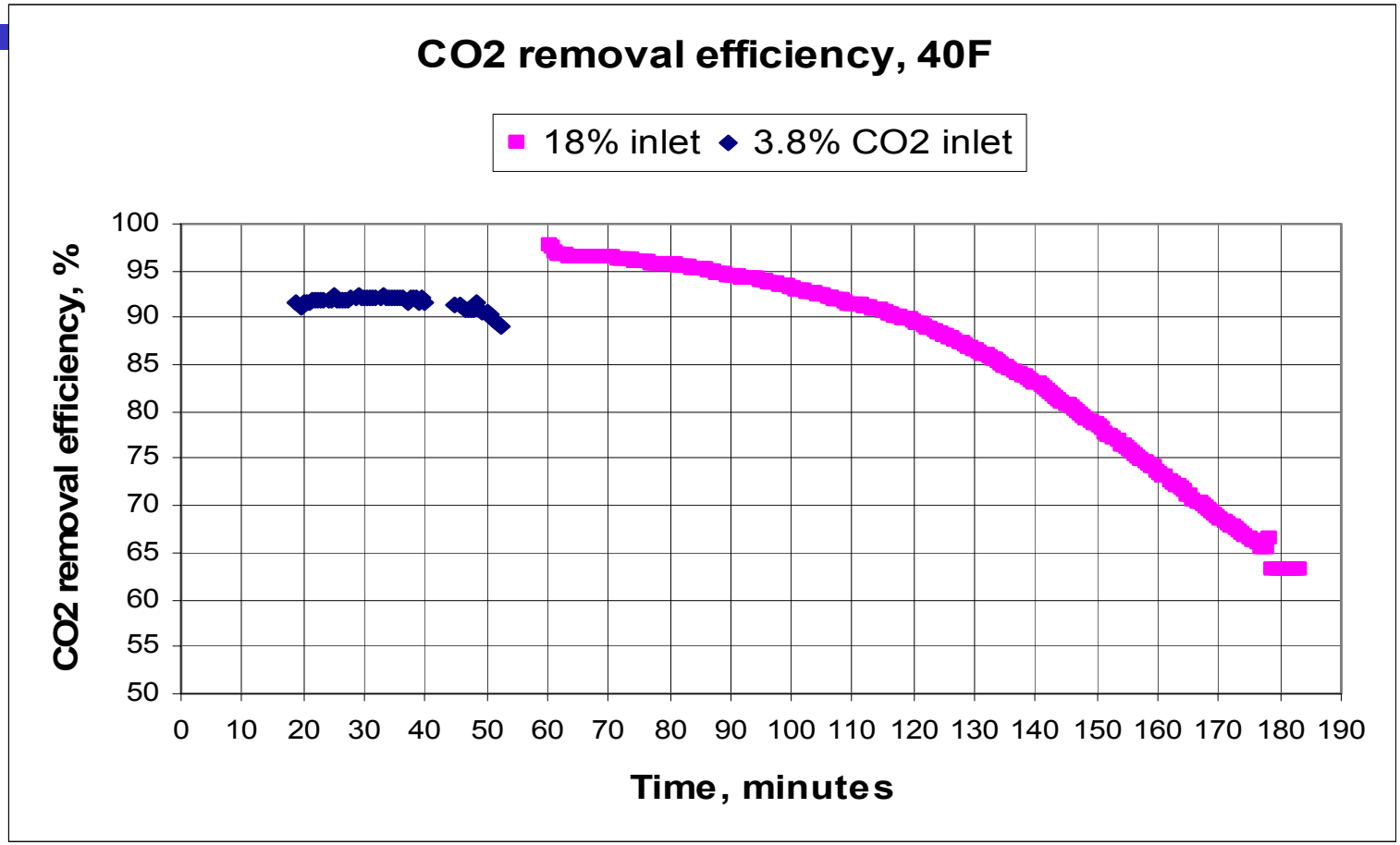
Bench Scale Batch Test, Absorption



+90% efficiency possible for both coal and NG flue gases

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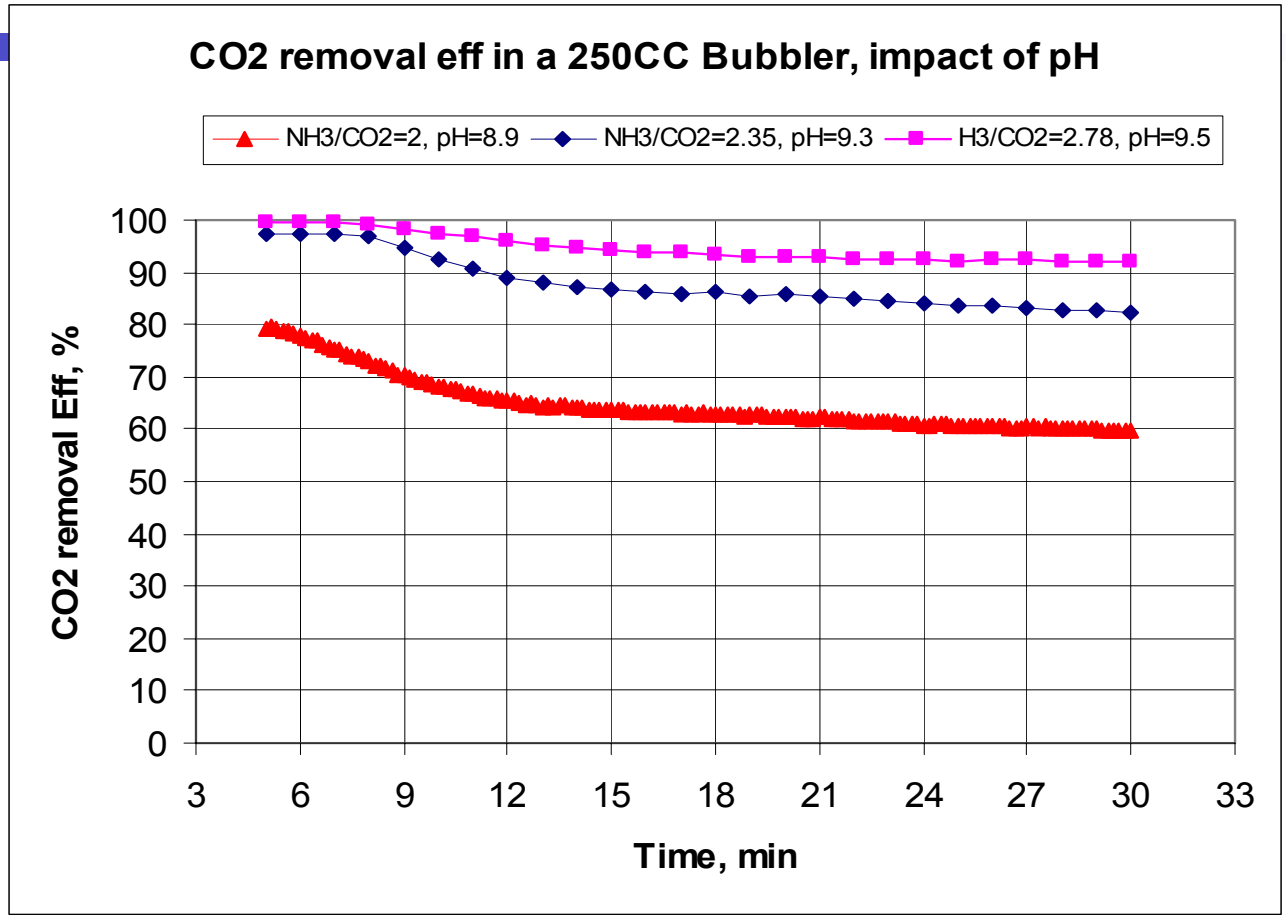
Optimization Efforts, NH_3/CO_2 Ratio



Higher ratio improves efficiency, but diminishes >2

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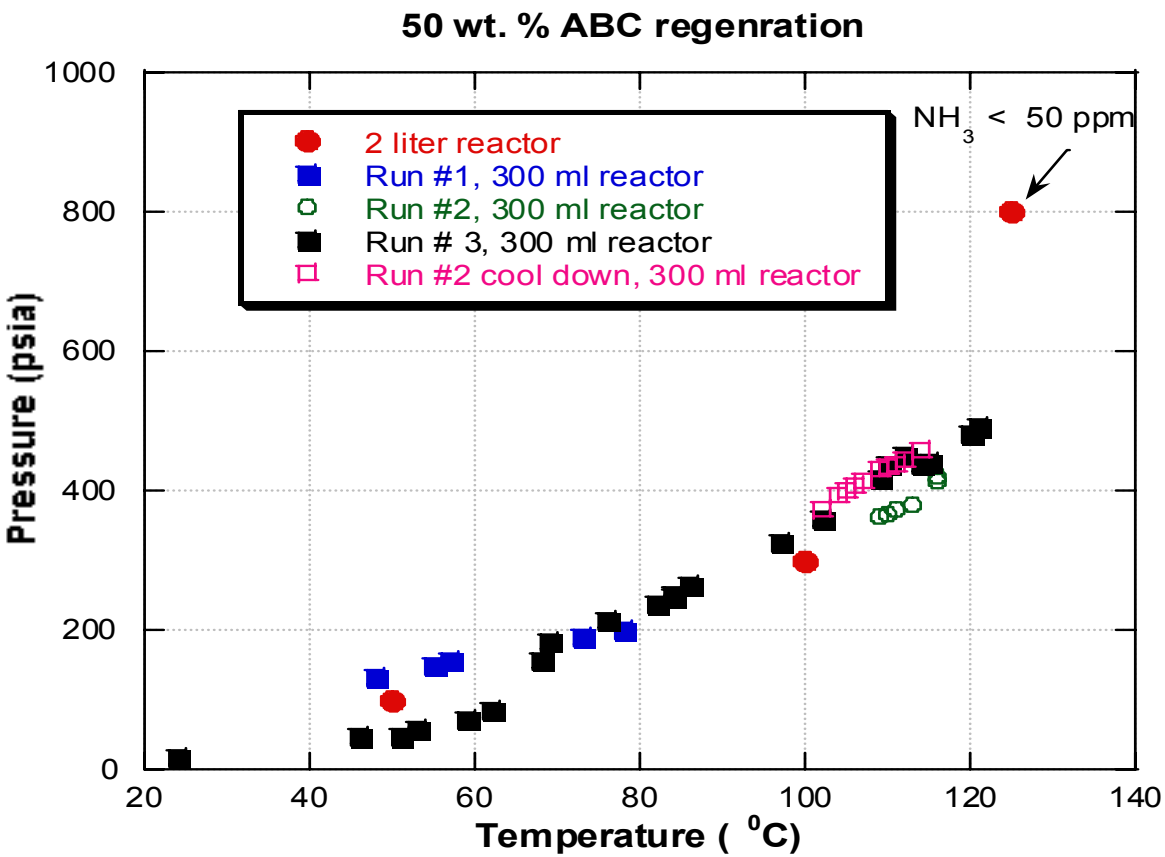
High Pressure Regeneration T/P Tradeoff



Determining best combination for process optimization

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Chilled Ammonia Process Performance Prediction (Early Data Only)

Used Parsons Study for Basis	Supercritical PC Without CO_2 Removal	Supercritical PC With MEA CO_2 Removal	Supercritical PC With NH_3 CO_2 Removal
LP Steam extraction, lb/hr	0	1,220,000	**270,000**
Power Loss, KWe	0	90,000	**20,000**
GROSS POWER, KWE	491,000	402,000	**471,300**
AUXILIARY LOAD, KWE			
Induced Draft Fan	5,000	19,900	**10,000**
Pumping CO_2 system,	0	1,900	**5,000**
Chillers	0	0	**8,900**
CO_2 compressor	0	30,000	**9,500**
NET POWER OUTPUT	462,000	330,000	**415,000**
% POWER REDUCTION		29	**10**

Source: Nexant

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Chilled Ammonia Process Cost Prediction (Early Data Only)

Used Parsons Study for basis	Supercritical PC without CO_2 Removal	Supercritical PC with MEA CO_2 Removal	Supercritical PC with NH_3 CO_2 removal
Levelized cost of Power, c/KWh	5.15	8.56	6.50
% increase		66	26
Avoided Cost, $/ton CO_2	Base	51	20

Source: Nexant

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EPRI / Alstom Discussions

- Based on
  - Common interests (e.g., we jointly bid the chilled ammonia project to DOE but were not successful)
  - Alstom's desire to push scale-up and commercialize the chilled ammonia process
- Organizations agreed to collaborate on the construction and testing of a 5-MW pilot CO_2 test unit of this process

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Collaboration Benefits

- Enables us to leverage our funder's investment even more
- Allows us to accelerate both the development and commercialization path
  - A 5-MW pilot is big enough to use commercial components (e.g., slurry pumps) designed for such an application
  - Teaming with the company that views this technology as their offering of choice will accelerate its commercialization
  - Can move into a size which allows CO_2 storage testing at least 2-3 years faster

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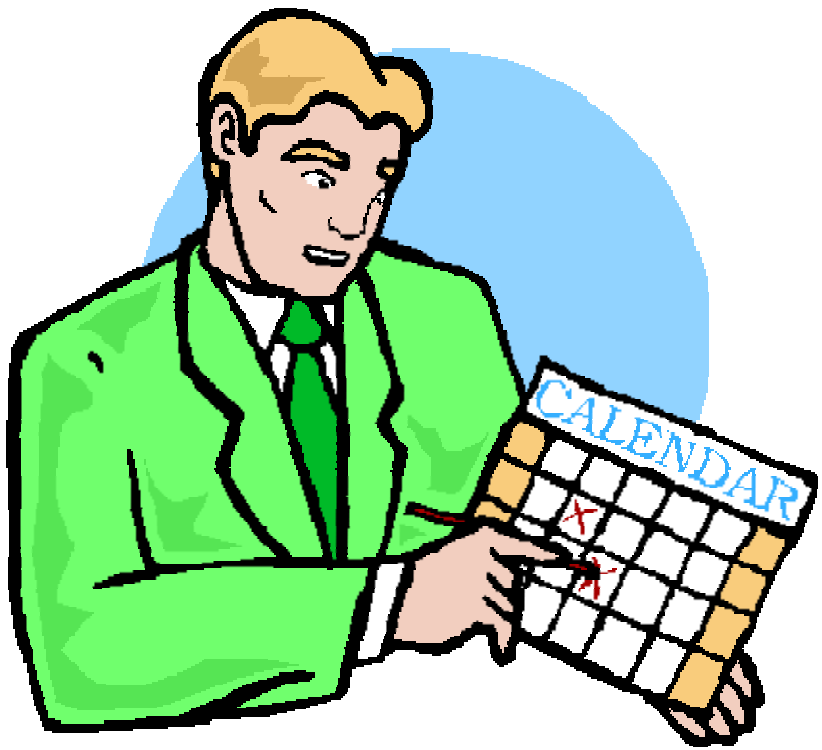
Project Schedule

- Assembling funding in early 2006
- Start on engineering/ procurement in 2006
- Operation of pilot starting in 2007



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