National Carbon Capture Center: Pre-Combustion Focus Project NT0000749

John Wheeldon, NCCC/EPRI
Tony Wu, NCCC/SCS

2010 NETL CO_2 Capture Technology Meeting
Pittsburgh
September 13 to 17, 2010

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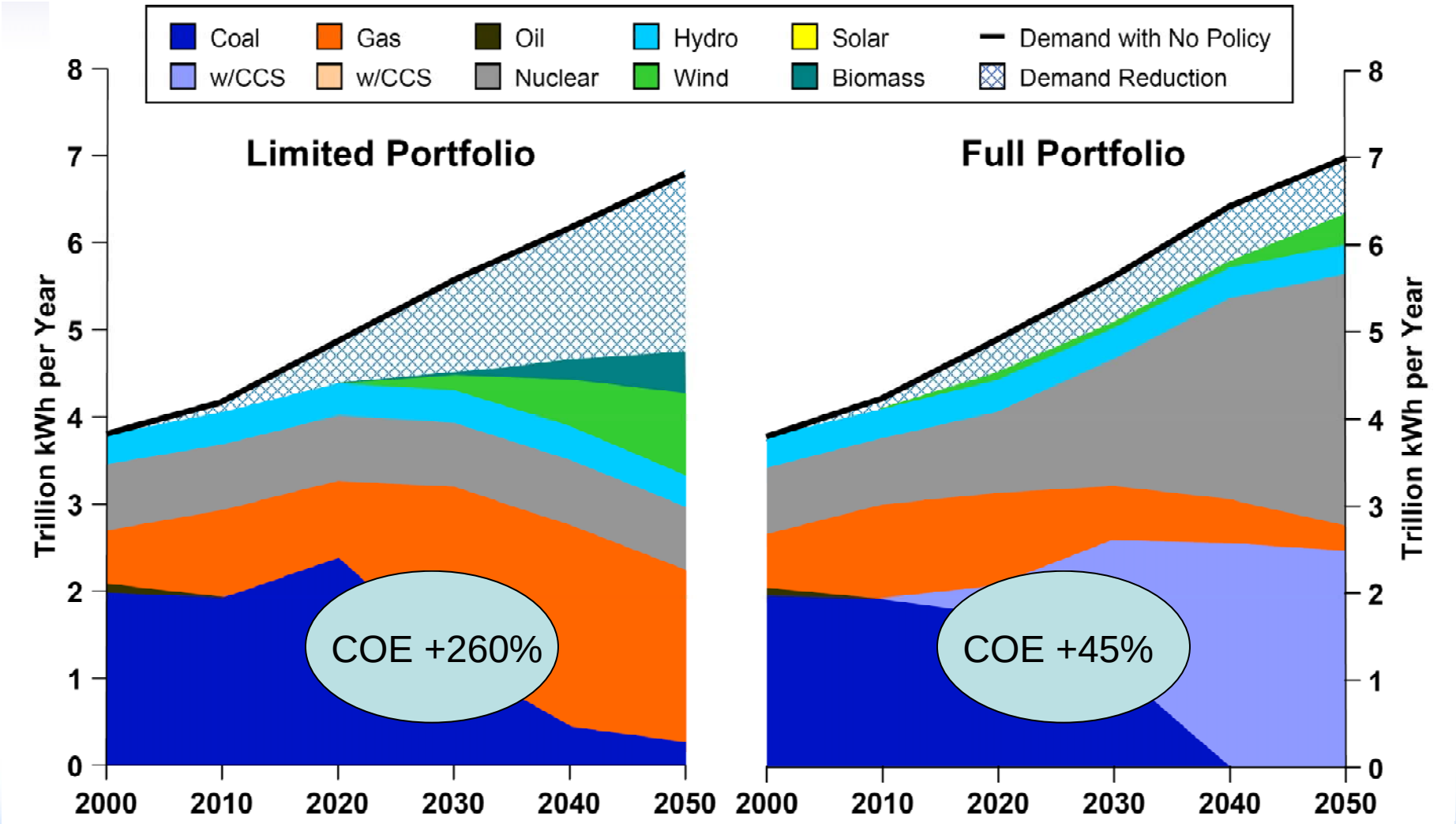
EPRI Merge Analysis 2008: Effect on Levelized COE



http://mydocs.epri.com/docs/public/000000000001019563.pdf

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View Of National Carbon Capture Center

National Carbon Capture Center (NCCC) established at Power Systems Development Facility (PSDF) in Wilsonville, AL

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U.S. Department of Energy

National Carbon Capture Center

at the Power Systems Development Facility

PARTICIPANTS:

Managed by Southern Company Services, Inc.

National Carbon Capture Center

- Cooperative Agreement DE-NT0000749 effective October 1, 2008 for five years through September 31, 2013
- PSDF established by DOE in early '90s to accelerate development of more efficient advanced coal-based power plant technologies
  - Research centered around high-temperature, high-pressure filtration
  - Signed over 100 NDAs with developers to support advancement of their technologies
- Air-blown Transport Gasifier commenced operation in 1999
- Funded by DOE's CCPI-2, a 580-MW Transport Gasifier power plant being built in Mississippi using local lignite to enter service in 2015
- PSDF's accelerated development objective for advanced power plants fulfilled and planned to fulfill same objective at NCCC for carbon capture technologies

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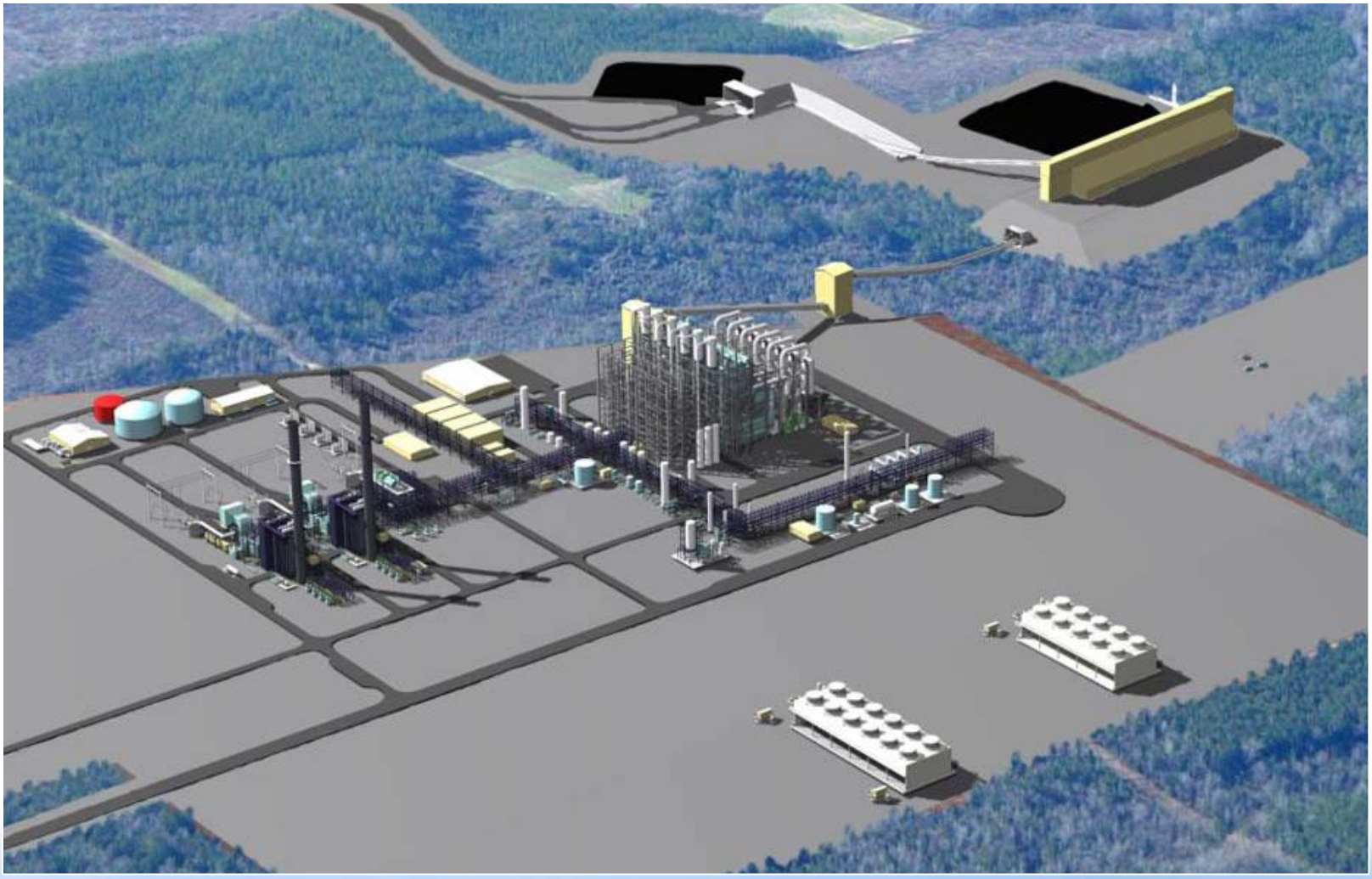
Artist's Impression of 580-MW Kemper County TRIG™ Project Site



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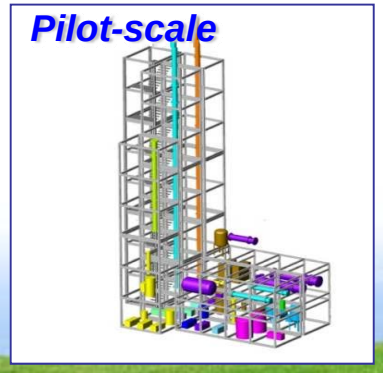
The National Carbon Capture Center

Provides first-class facilities to test developer's technologies for extended periods under commercially representative conditions with coal-derived flue gas and syngas and thereby accelerate development of cost-effective carbon capture technologies

- NCCC provides all necessary infra structure into which developer's technology can be inserted but developer must provide their technology (equipment or solvent) and pay for out-of-the-ordinary analyses
  - Experienced operators and maintenance staff
  - Comprehensive data collection and analysis capability
  - Flexible facilities allow for scale-up from bench- to engineering-scale
  - Post- and pre-combustion facilities currently available



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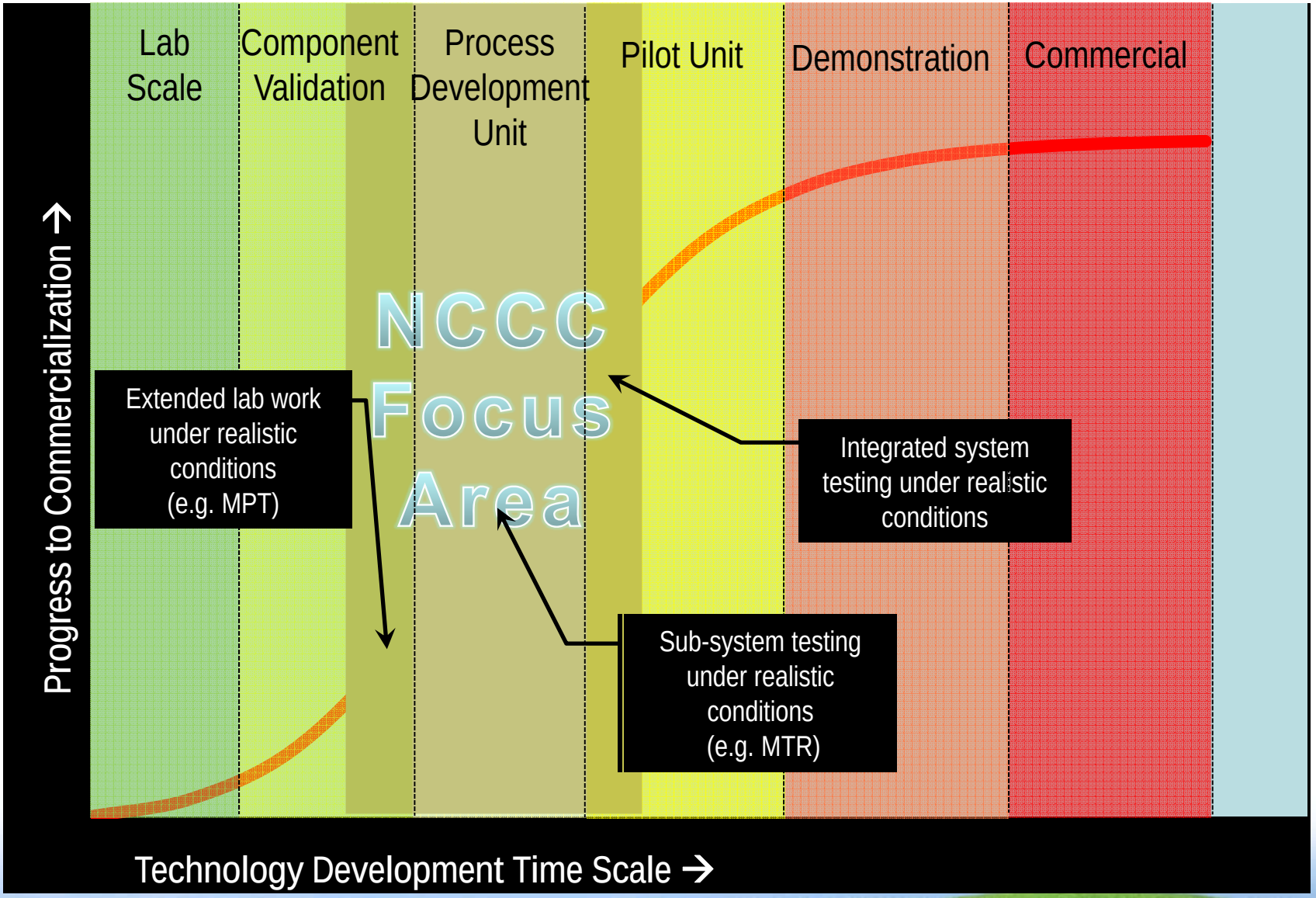
Focus of NCCC Technical Program



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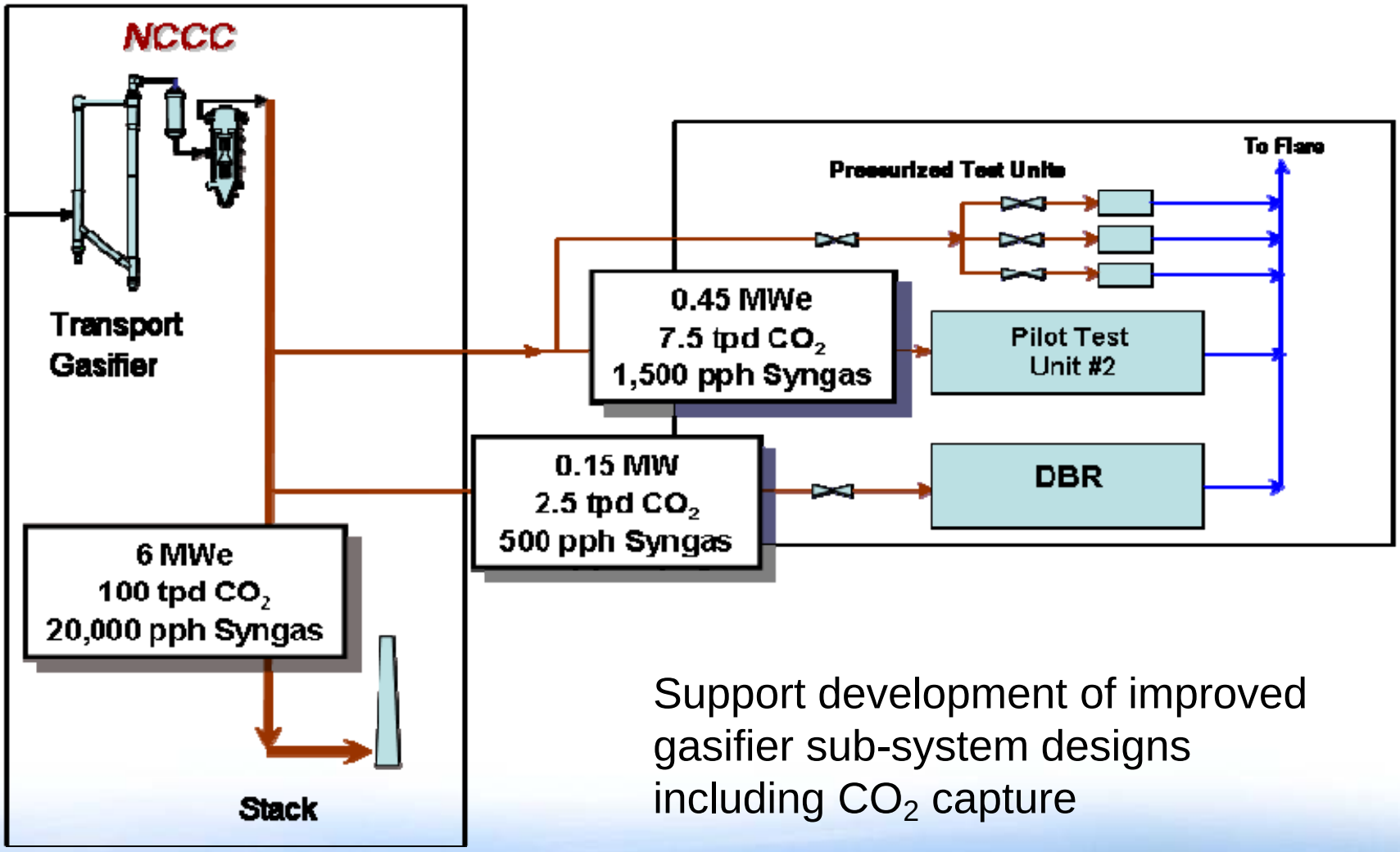
Layout of Syngas Slipstreams



Support development of improved gasifier sub-system designs including CO_2 capture

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Syngas Slipstream Testing

Previous activities

- Warm gas sulfur cleanup
- Fuel cells
- Ammonia & hydrocarbon cracking
- Gas analyzers

Current activities

- Water-gas shift catalyst
- Heavy metal removal
- H_2 & CO_2 membranes
- CO_2 capture solvents

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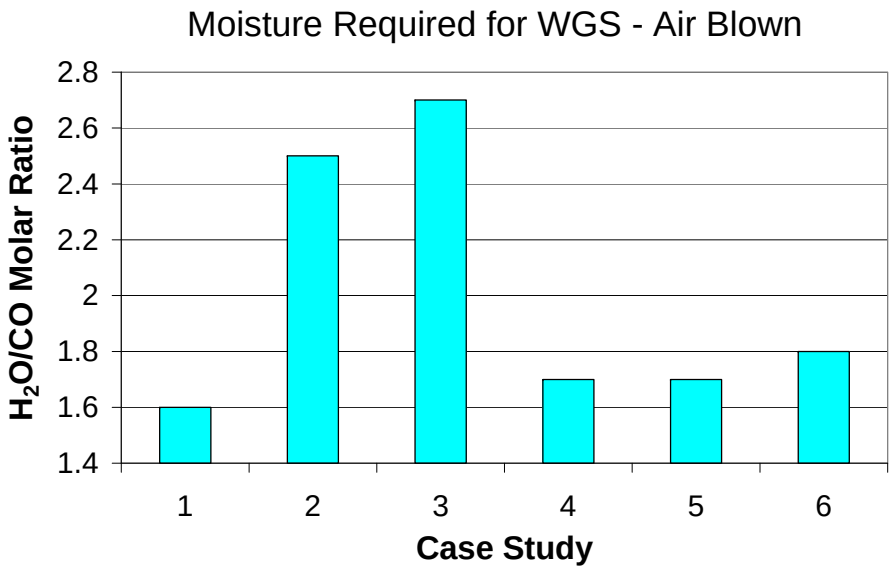
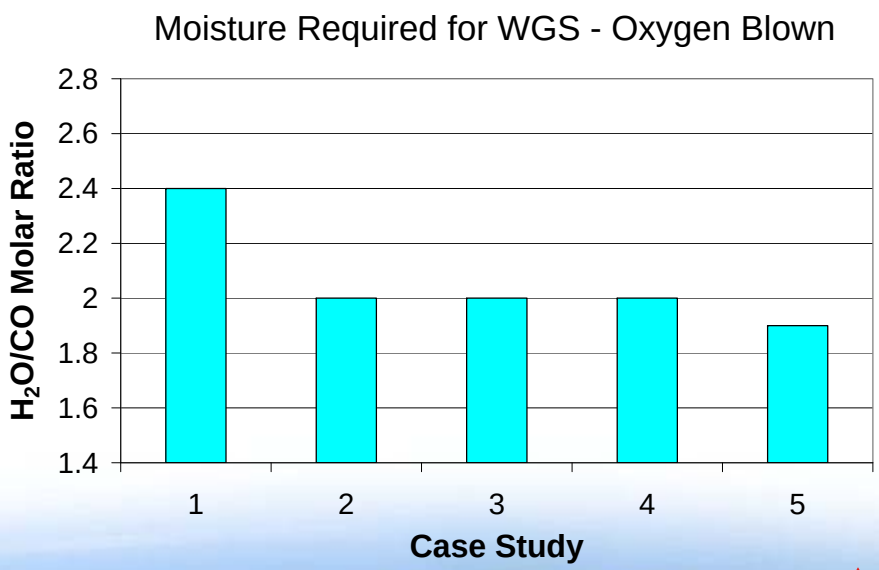
Studies Indicate that WGS Steam-to-CO Ratio for IGCC Not Well Defined



$$CO + H_2O = CO_2 + H_2$$

Discussions held with vendors since 2008 to promote improved catalysts and reactors for use with reduced steam ratios. NCCC facilities provided test data to support their analysis and development.

- Catalysts developed for petro-chemical applications that require almost complete CO conversion with no methane production
  - Power plant requirements less stringent.
- Carbon deposition occurs for gaseous fuels with high hydrocarbon contents
  - Hydrocarbon content of syngas is low.



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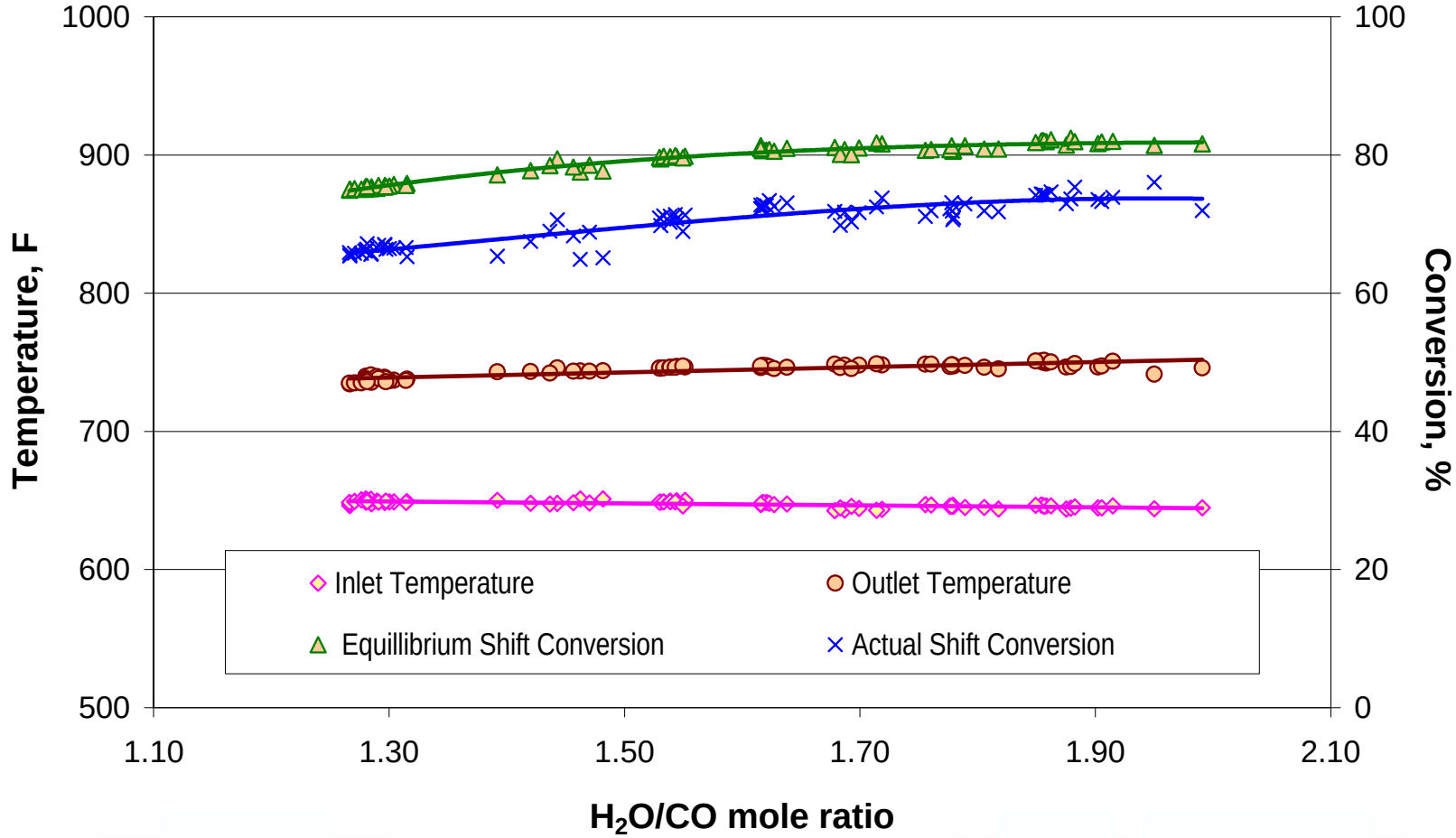
WGS Catalyst Tested with 650ºF Syngas Inlet Temperature



- No methane produced or carbon deposited.

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Media and Process Technology (MPT)

- Single alumina tube 30-inches long, 0.225-inches OD with carbon molecular sieve layer on inner surface.
  - Tube mounted in stainless steel sleeve and syngas enters on outside of tube.
- Syngas augmented with bottled hydrogen to 55 vol. % and membrane operated at 440°F and 215 psia
  - 1-2 lb/hr total flow.
- 30-percent hydrogen yield achieved.

	Feed	Permeate	Reject
Hydrogen, vol. %	55	98	50
CO_2, vol. %	5	0.1	NA
H_2S, ppmv	600	10	670

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Supporting Scale-Up and Evolution of MPT Design

- New arrangement sets 14 tubes in a 2-inch stainless steel tube and designed for 20 lb/hr of hydrogen-augmented syngas.
- Tubes held in position by fused glass in a ceramic collar.
- Membrane material place on outside of tube with syngas entering inside tube
- Testing has resulted in improved performance and increased size of
- membrane assemblies

Media and Process Tech Inc.

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Membrane Technology and Research (MTR)

- MTR designs and manufactures, polymeric membrane systems for industrial gas separations
- $4.4 million DOE-funded project processing 250,000 scfd flue gas at a power plant in Arizona

- NCCC supporting testing of similar membrane exposed to coal-derived syngas and its impurities
- Skid 10 ft x 2.5 ft processing 15,000 scfd syngas
- Over 1,200 hours operation complete with gas analyses for permeate and reject streams
  - Polymeric hydrogen membrane rated for 1 lb/hr of syngas similarly tested

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Parr Stirred Batch Reactor

- Reactor: 17 inches tall x 6 inches ID with volume of 0.28 ft^3
- Maximum operating conditions 1915 psia and 660ºF
- Heating jacket 3.75 kW

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Testing of CO_2 Capture Solvents

- Variety of chemical absorption solvents tested including ammonia, amino acids, and potassium carbonate
- Two physical absorption solvents tested, dimethyl ethers of polyethylene glycol (DEPG) and polydimethylsiloxane (PDMS)
- Industrial chemistry expertise and advanced chemical analytical techniques provided by Southern Research Institute in conjunction with University of Alabama at Birmingham

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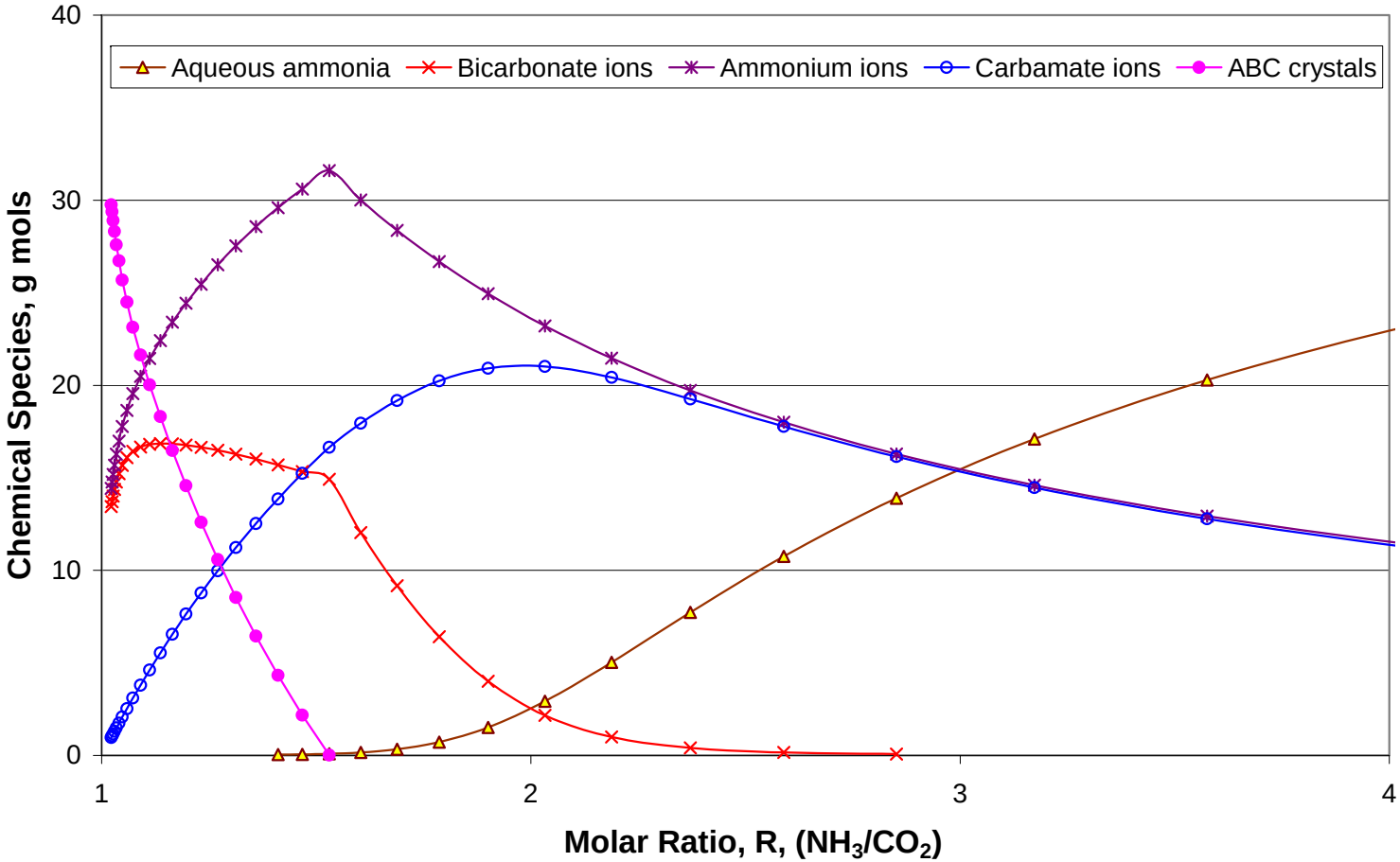
Liquor Composition Predicted by Model



- Ammonia chemistry is complex and model is being used to understand absorption and regeneration processes
  - Test data has been used to validate the model

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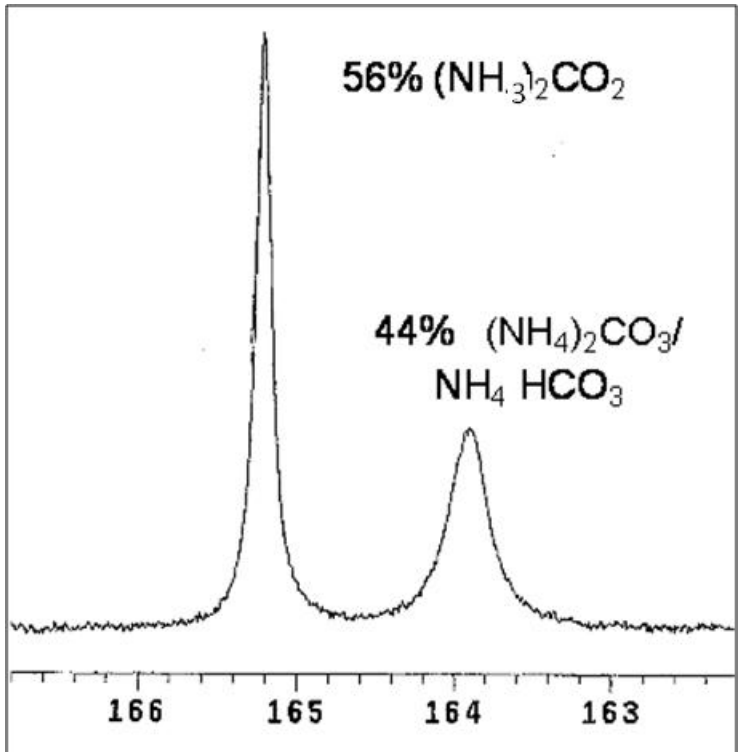
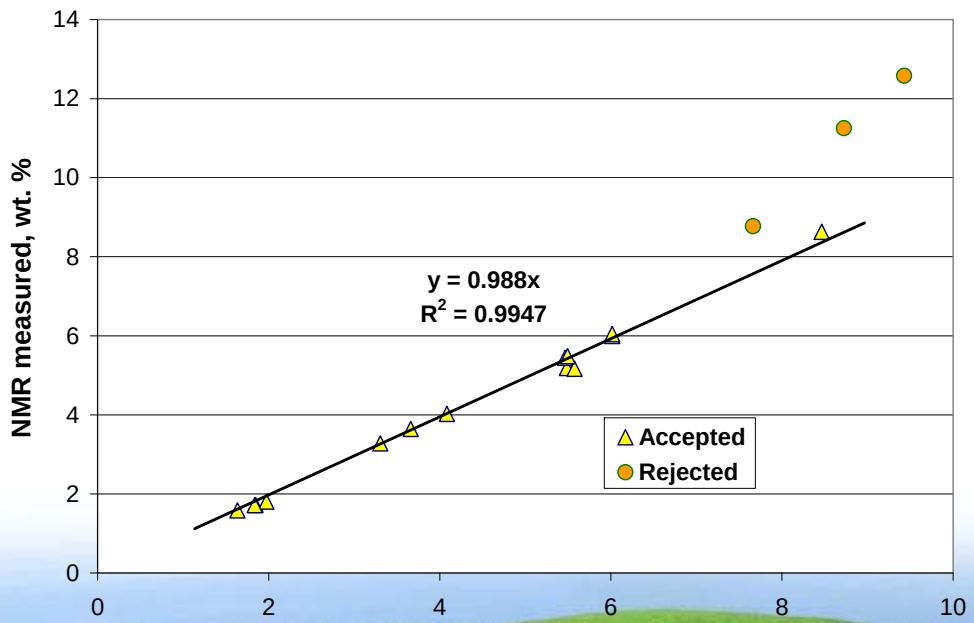
Nuclear Magnetic Resonance Analysis



Frequency shift

- Left-hand peak allows direct determination of ammonium carbamate.
- Right-hand peak determines combination of ammonium carbonate and bicarbonate.
- Greater the horizontal separation of peaks the greater the bicarbonate content.



- Calibration curve developed at University of Florence

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Additional Test Support Provided

- DOE-NETL program testing 12 solid oxide fuel cell “buttons”
  - Each “button” different allowing a wide range of variables to be investigated within the same operating period, thereby accelerating development.
- Johnson Matthey high-temperature palladium-based mercury sorbent
  - Also removed arsenic and selenium at 600°F
- DOE-NETL gas chromatograph-inductively coupled plasma-mass spectrometer (GCICP/MS) to continuously measure trace elements in syngas down to ppb levels
  - EPA Method 29 is a batch method with significant delay before results available

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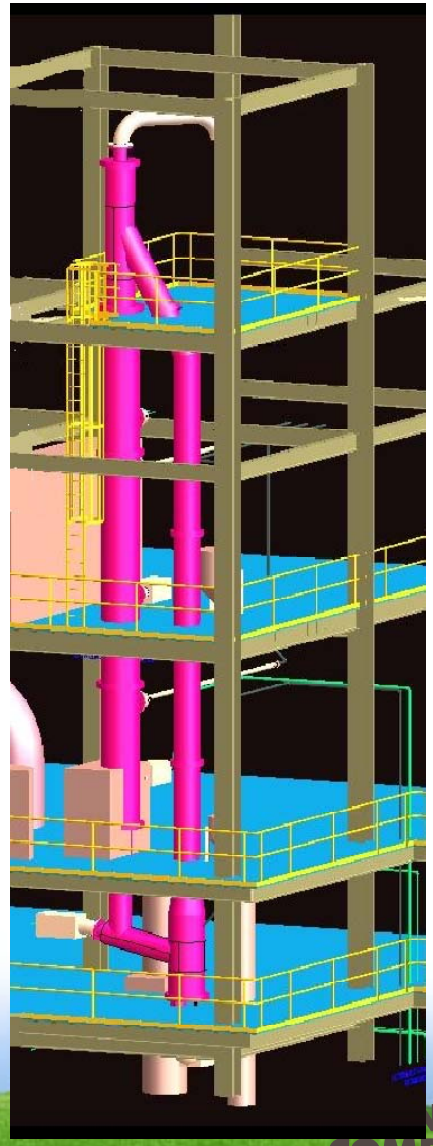
Future Planned Pre-Combustion Testing

- Assessing feasibility of installing Ohio State's Chemical Looping 0.25-MW_t Pilot Plant at NCCC
  - B&W developing design to process 800 lb/hr syngas and will support test program.
- Worcester Polytechnic Institute collaborative to test Pd and Pd alloy hydrogen membrane.
- In discussion with developers to test larger CO_2 and hydrogen membranes and CO_2 sorbents



Closing Comments

- CO_2 capture and storage (CCS) essential to allowing continued use of coal and maintaining electricity prices affordable in a low-carbon economy.
  - Electricity must bear the cost of CCS so improved technology options are required
- The DOE is funding a large number of novel approaches and the NCCC is prepared to work with the developers to improve their technologies and accelerate development

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Questions?

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