NETL Modular Framework:
Optimization of existing plants & IGCC with CO₂ capture & water minimization

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Research Program Overview and Goals

- **Large-scale problem**
  - 2 billion tons CO$_2$ from coal by 2020 in US
  - Flue gas: 5 million lb/hr for 550MW plant

- **No existing economical solution**
  - Process synthesis
  - Process integration & optimization

- **National importance**
  - Inexpensive, abundant electricity
  - Water resources growing scarcer

- **Time critical (deployable by 2015/2020)**

- **Comprehensive modeling and optimization framework**
  - Integrated research program
  - Multiple significant research activities
  - Contribute to solving larger problem
U.S. CO₂ Emissions from Coal Plants

Previous study indicated that in 2030 80% of emissions will be from plants existing in 2010.

Post- and Oxy-combustion CO$_2$ Capture
Increase in COE

References:
Expected Cooling Water Shortage in 2025

Freshwater Use in Thermoelectric Power Plant

Approximately 3% of U.S. freshwater consumption used for thermoelectric power generation

Approximately 39% of U.S. freshwater withdrawal used for thermoelectric power generation

Steam

Condensate

Heat Exchanger

Cooling water (cooled)

Evaporation

Makeup

Non-traditional water sources

Cooling Tower

Blowdown
Power Plant Water Withdrawal Requirements
with and without CO₂ capture

Integrated Gasification Combined Cycle
Pulverized Coal
Natural Gas Combined Cycle

Water Withdrawal, gpm/MW net

Source: Water Requirements for Existing and Emerging Thermoelectric Plant Technologies; NETL, August 2008
Modular Framework for Analysis and Optimization Of Existing Plants & IGCC: CO2 Capture & Water Minimization

Generalized Plantwide Optimization Framework

Carbon Capture Modules

- Absorption systems
  - Rate-based simulation
  - Aqueous amine systems
  - Advanced amine systems
  - Ionic liquids
  - Oligomers
- Solid sorbents
  - Capture
  - Regeneration
  - Fluidized bed
- Compression systems
- Oxidation looping combustion
  - Oxidation reactor
  - Reduction reactor
  - Direct chemical looping
  - Indirect chemical looping
- Post-combustion membranes
  - Polymeric membranes
  - Ceramic membranes
  - Hybrid membrane/solvent

IGCC Modules

- Adsorption
  - Pressure Swing Adsorption (PSA)
  - Temperature Swing Adsorption (TSA)
  - Hybrid PSA/TSA

Existing Plants Modules

- Combustion system
- Feed water heater
- Boiler
- Economizer
- Superheater
- Steam turbines
- Condensers
- FGD

Plantwide Water Simulator

Potential modules for cooling water/process water & treatment systems

- Cooling system models
  - Heat exchangers
  - Recirculation/floowdown
  - Dissolved solids
- Water recovery
  - Cooling tower
  - Flue gas
  - FGD
  - Wet coal
- High fidelity cooling tower models
  - Welded
  - Natural/mechanical
  - Hybrid
- Nontraditional water sources
  - Treated waste water
  - Produced water
  - Mine water
- Water treatment processes
  - Impaired sources
  - Mineral removal
- Fouling & corrosion models
  - Cycles of concentration
  - Treatment requirements

Cooling alternatives
- Air-to-Air
- Geothermal
- Organic Rankine cycle

Process water model
- Steam
- FGD unit
Generalized Plantwide Optimization Framework

Excel

Aspen

Excel

Aspen

Excel

Aspen

Excel

Aspen
Generalized Plantwide Optimization Framework

- GAMs/BARON
- Library of Derived Algebraic Models
- "Black Box" Derivative-Free Optimization Algorithms (simulation-based)
- Superstructure Development
  - Process Synthesis
    - HEN
- Algorithms to Develop Surrogate Models from Simulations
Project Team

- **Dr. David Miller (NETL)**
  - John Eslick (postdoc) – modular framework
  - Andrew Lee (postdoc) – modular framework (joining April 2010)
  - Juan Morinelly (postgrad) – modular framework (joining April 2010)
  - TBD

- **Prof. Nick Sahinidis (CMU)**
  - Alison Cozad (PhD student) – Blackbox optimization of Advanced CCS Systems

- **Prof. Ignacio Grossmann (CMU)**
  - Linlin Yang (PhD student) – Simultaneous superstructure-based water/energy/heat optimization of conventional power plants
  - Ravi Kamath† (PhD student) – IGCC synthesis and integration

- **Prof. Larry Biegler † (CMU)**
  - Anshul Agarwal (PhD student) – PSA for CC from PC plants
  - Sree Rama Vetukuri (PhD student) – PSA for CC from IGCC

- **Prof. Wade Huebsch (WVU)**
  - Dr. Egemen Ogretim (postdoc) – Predictive cooling tower model

- **Prof. Dave Dzombak (CMU)**
  - Ming-Kai Hsieh (postdoc) – treated municipal waste water as cooling water

- **Profs. Javad Abbasian and Hamid Arastoopour (IIT)**
  - Michael Walker & Iman Safari (PhD students) – Treating nontraditional water sources

- **Ms Cathy Summers* and Dr. Danny Oryshchyn* (NETL)**
  - Sivaram (Hari) Harendra* (postdoc) – Water recovery from oxycombustion/IPR

- **Dr. John van Osdol* (NETL) – Modeling carbon capture processes
- **Dr. Eric Liese* (NETL) – Predictive turbine models