# Staged, Pressurized Oxy-Combustion (SPOC)

## McIlvaine Company Hot Topic Hour

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Richard Axelbaum
Jens Professor of Environmental Engineering Science
Department of Energy, Environmental and Chemical Engineering
Director, Consortium for Clean Coal Utilization (CCCU)
Washington University in St. Louis

# Consortium for Clean Coal Utilization

Founded in January of 2009, the Consortium is dedicated to addressing the scientific and technological challenges of ensuring that coal can be used in a clean and sustainable manner.

## Approach

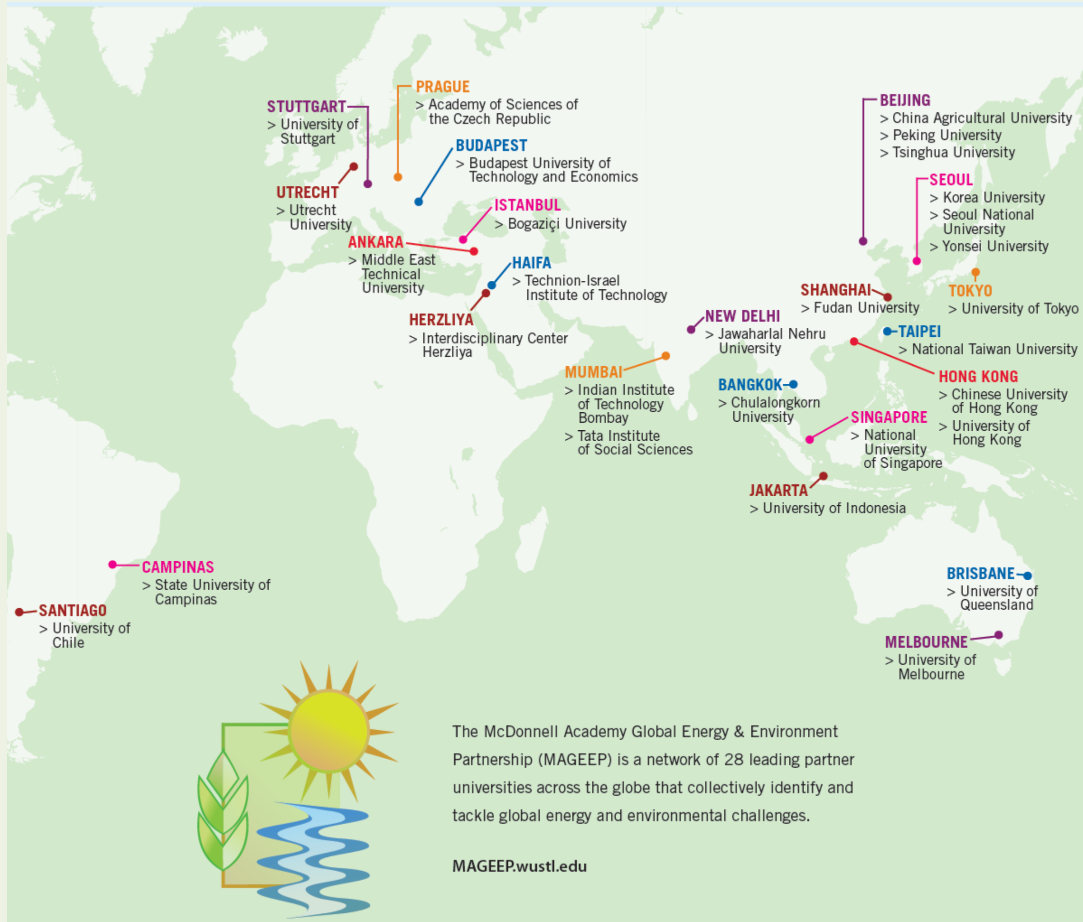
- Research projects are being supported at Washington University in collaboration with Partner Universities around the world.
- State-of-the-art clean coal facilities have been established.
- A motivated work force is being educated to address the challenges associated with clean utilization of coal in the 21st century.

## Sponsors

Peabody Energy | Arch Coal | Ameren

# CCCU Research Portfolio

- Carbon Dioxide Capture
  - Oxy-combustion
  - Post combustion capture
- Carbon Dioxide Utilization
  - Chemical conversion
  - Algae
- Geological Sequestration
  - Injection/storage modeling
  - Chemical interactions
  - $CO_2$ Imaging
- Mercury and HAPS control
- Fly Ash Utilization




International Partner Institutions

# Advanced Coal & Energy Research Facility


ACERF:

- 1 MWth capacity
- Configured for oxy-combustion
- Full suite of emissions monitoring

Additional Facilities:

- 30kW lab-scale test furnace
- Drop tube furnace
- Fuel/ash characterization

# DOE Project Goals

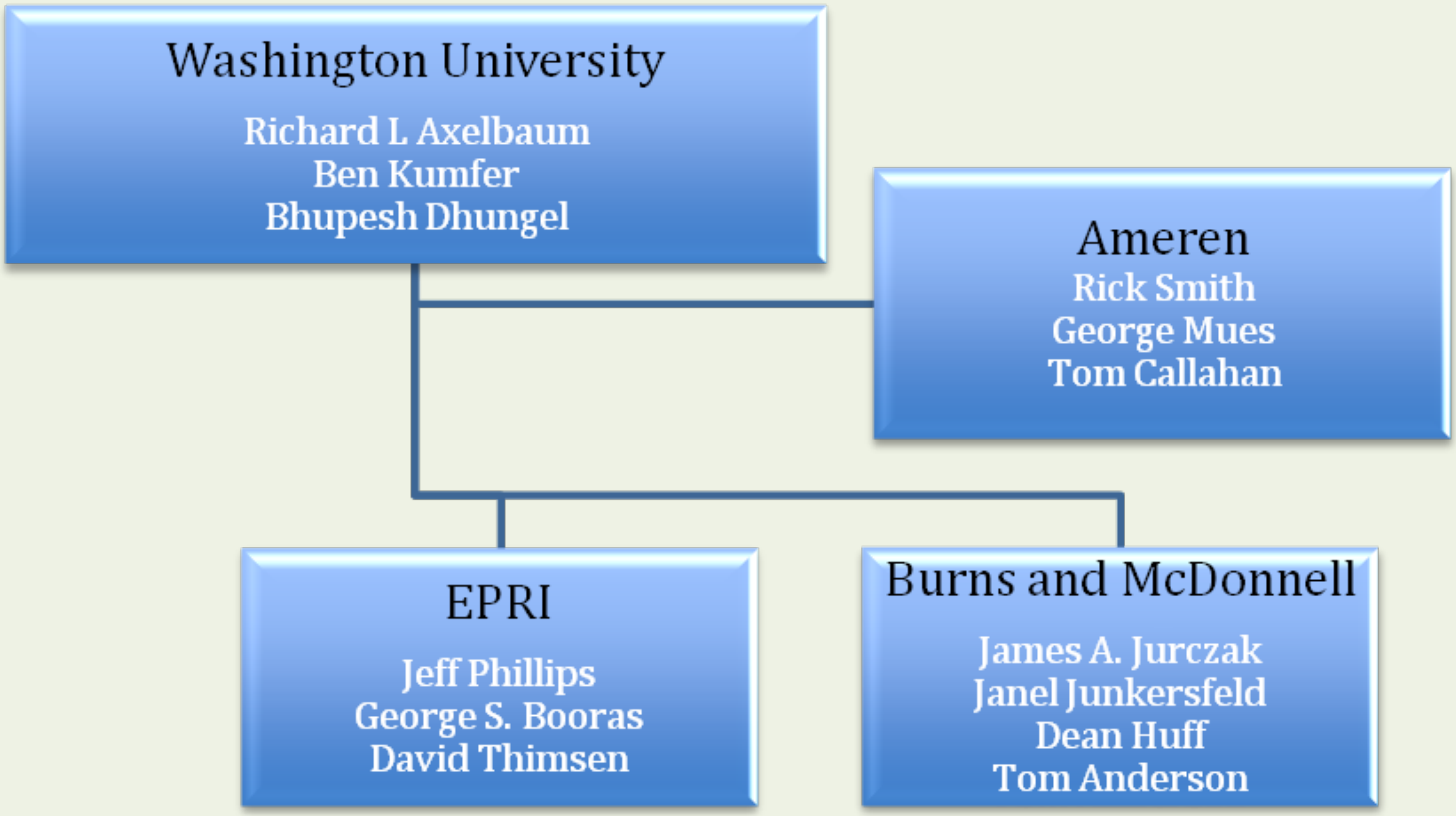
- Develop a novel pressurized oxy-combustion process capable of achieving 90% carbon dioxide capture at no more than a 35% increase in cost of electricity (COE) (<$25/ton $CO_2$ captured)[1]

- Optimize the design through process modeling to minimize COE

- Identify and analyze potential technical barriers and determine possible solutions

1. Research and Development Goals for $CO_2$ Capture Technology DOE/NETL-2009/1366

# Project Team



# Pressurized Oxy-Combustion

- The requirement of high pressure $CO_2$ for sequestration enables pressurized combustion as a tool to increase efficiency and reduce costs

- Combustion occurs at 10-40 bar

- Benefits:
  - Latent heat of flue gas moisture can be utilized
  - Reduces flue gas volume, potentially translating into lower capital costs
  - Avoids air ingress
  - Increases convective heat transfer (for a given velocity)
  - Increases char burning rates

# Advanced Oxy-Combustion Rankine Cycle

*To achieve project goals, capital and operating costs must be reduced over those of 1st generation oxy-combustion or other approaches to pressurized oxy-combustion*

- Capital Costs
  - Minimize heat transfer surface area
  - Minimize auxiliary equipment size (CPU, filters, fans)

- Operating Costs
  - Maximize efficiency
    - Recover latent heat in flue gas
    - Use a high temperature & pressure steam cycle
    - Minimize parasitic loads
  - Minimize excess oxygen requirements

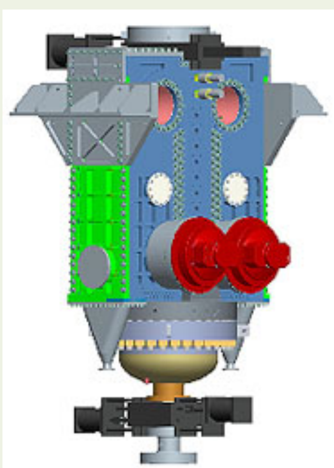
# Coal Slurry vs. Dry Feed

**Case A: coal slurry**

(50wt% dry coal, 50% $H_2O$) + $O_2$, **λ = 1.065** → combustion → 39.3% $CO_2$, 56.8% $H_2O$, **3.0% $O_2$**, 0.6% S, 0.3% N → moisture removal → **90.9% $CO_2$**, **7.1% $O_2$**, 1.3% S, 0.8% N → to CPU

**Case B: pulverized coal**

(as received, 11wt% H2O) + $O_2$, **λ = 1.041** → combustion → 62.2% $CO_2$, 33.3% $H_2O$, **3.0% $O_2$**, 0.9% S, 0.5% N → moisture removal → **93.3% $CO_2$**, **4.5% $O_2$**, 1.4% S, 0.8% N → to CPU

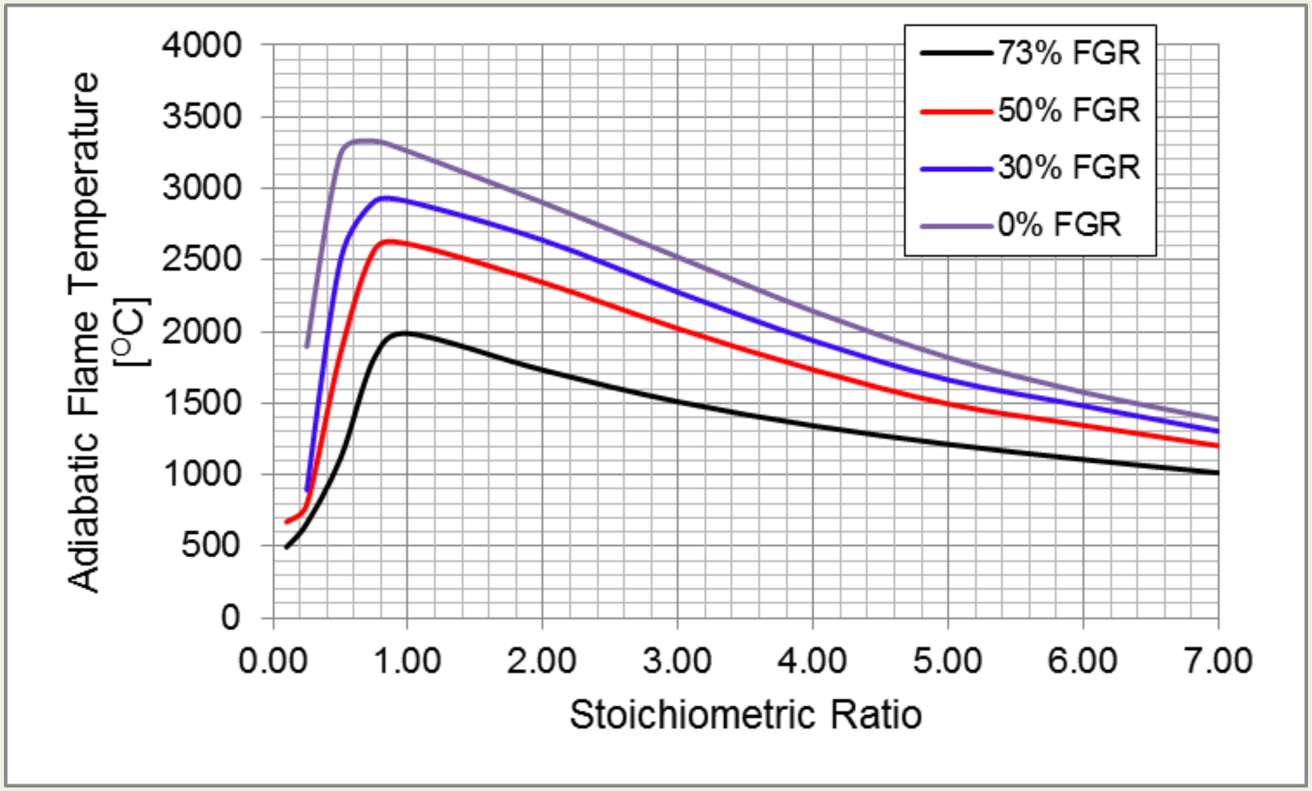


Pratt & Whitney Rocketdyne dry solids feed pump

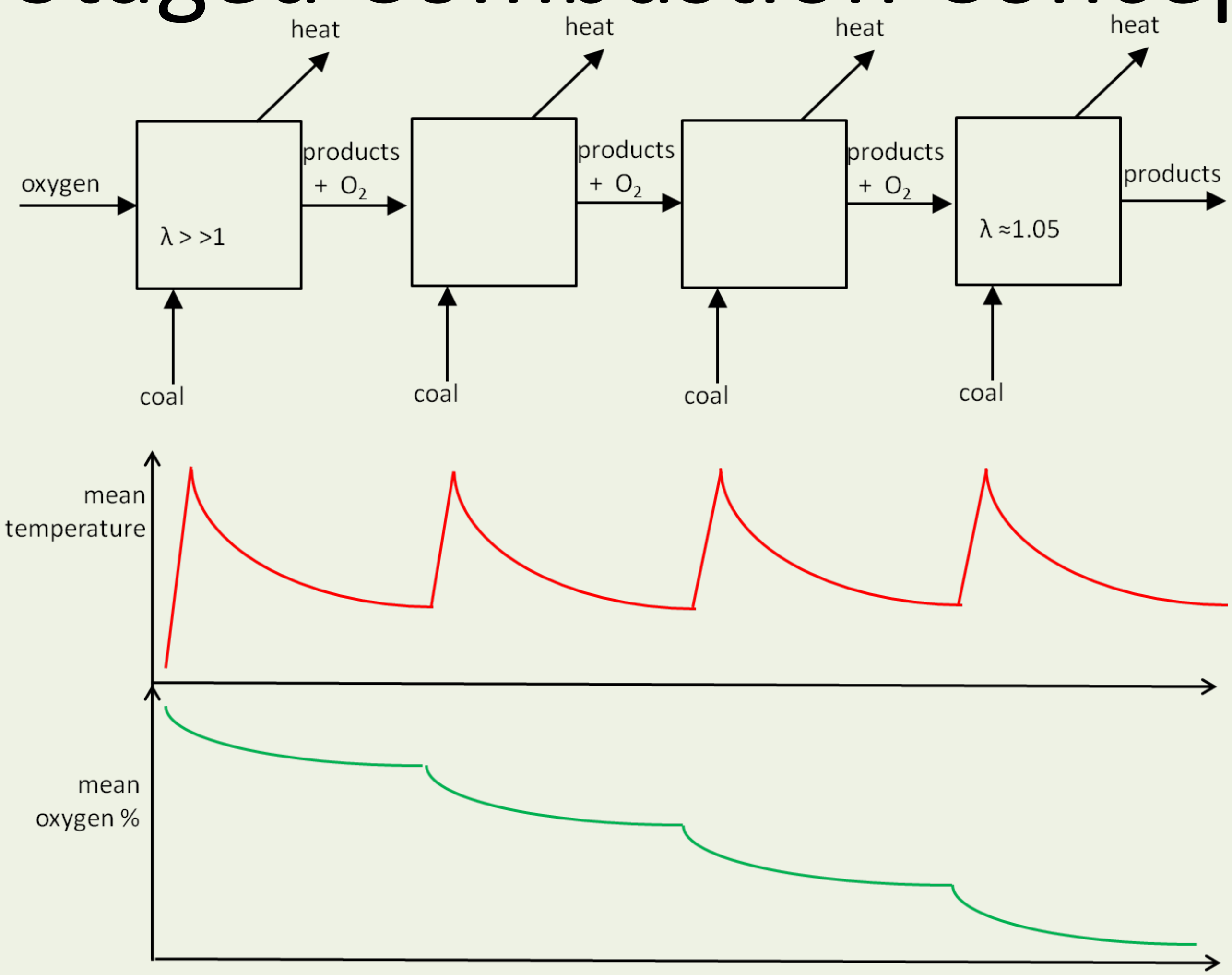
- Less $O_2$ required from ASU
- Less $O_2$ removal in CPU

# First Thoughts on Temperature Control

- Temperature in oxy-combustion is typically controlled by addition of RFG or water (CWS or steam)
- But, global combustion temperature is also a function of stoichiometric ratio

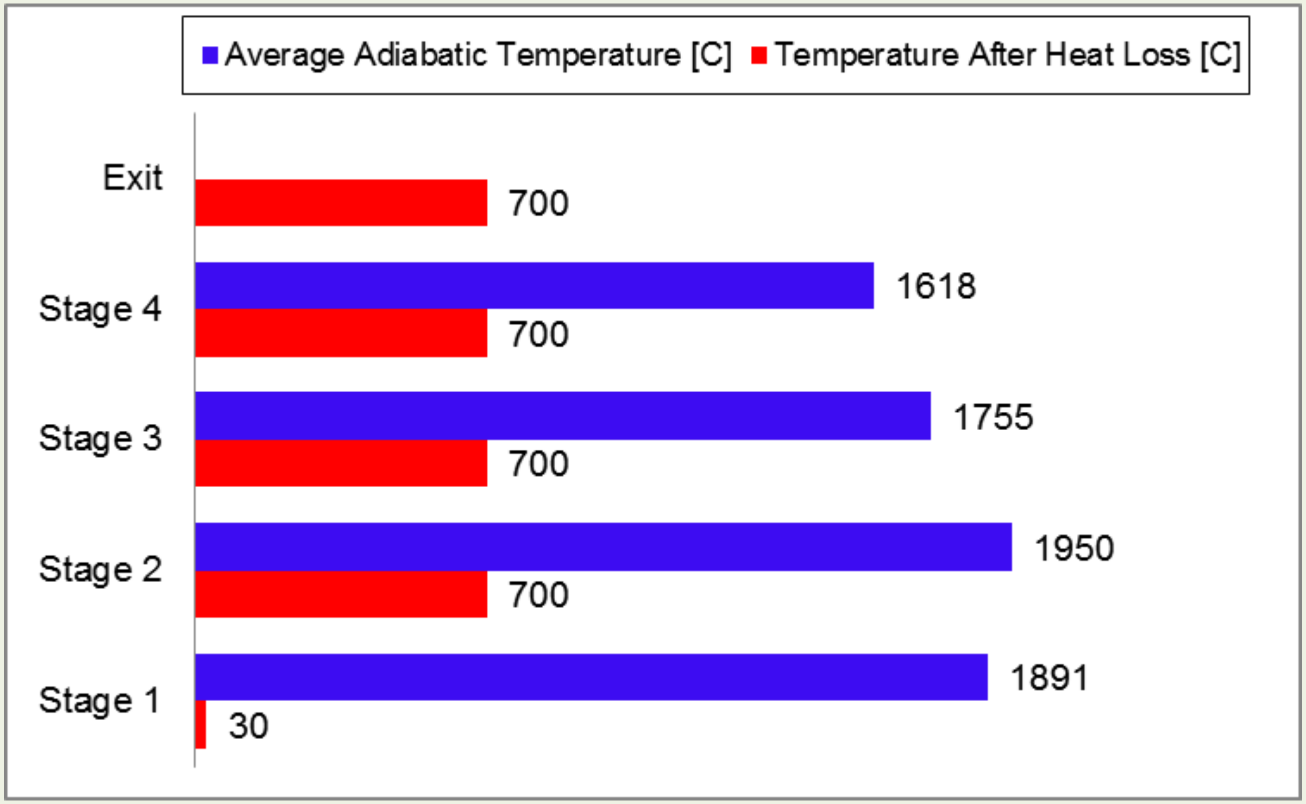


# Staged Combustion Concept




- Employ high stoichiometric ratio in early stages to control mean temperature
- Cooled products from early stages (CO2, H2O) assist in controlling temp downstream

# Progression of T and Gas Composition




| End of Stage | Vol. % wet CO2 | Vol. % wet H2O | Vol. % wet SO2 | Vol. % wet N2 | Vol. % wet O2 |
|---|---|---|---|---|---|
| Stage 1 | 23.4 | 8.8 | 0.2 | 5.1 | 62.5 |
| Stage 2 | 41.4 | 15.6 | 0.4 | 4.6 | 38.0 |
| Stage 3 | 55.6 | 20.9 | 0.6 | 4.2 | 18.7 |
| Stage 4 | 67.1 | 25.2 | 0.7 | 3.9 | 3.0 |

# Benefits of Staged Combustion

- Near-zero flue gas recycle
  - Minimizes flue gas volume
  - Minimizes equipment size
  - Minimizes parasitic loads and pumping costs associated with RFG
  - Minimizes oxygen requirements
- Higher peak temperature
  - Increased radiation heat transfer
  - With proper design, can ensure maximum and uniform heat flux to the boiler tubes