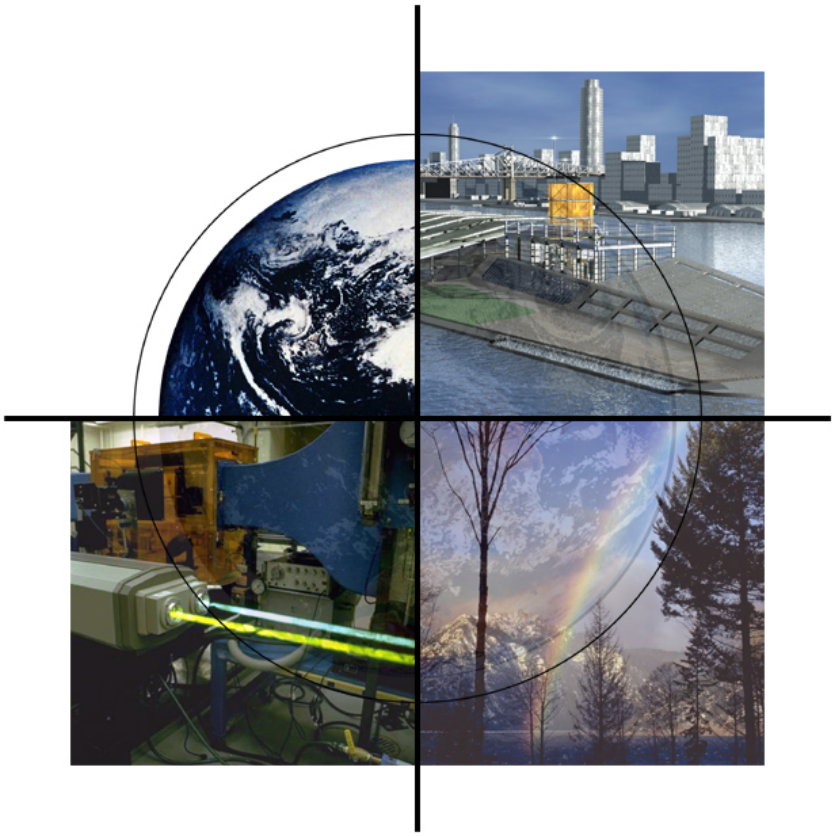
Fossil Energy Advanced Materials Program



22nd Annual Fossil Energy Materials Conference meeting

Pittsburgh, PA
July 8-10, 2008

Robert Romanosky, Technology Manager
National Energy Technology Laboratory

Roddie Judkins

A Typical Day for Rod Judkins

… And He Loved It!!!!

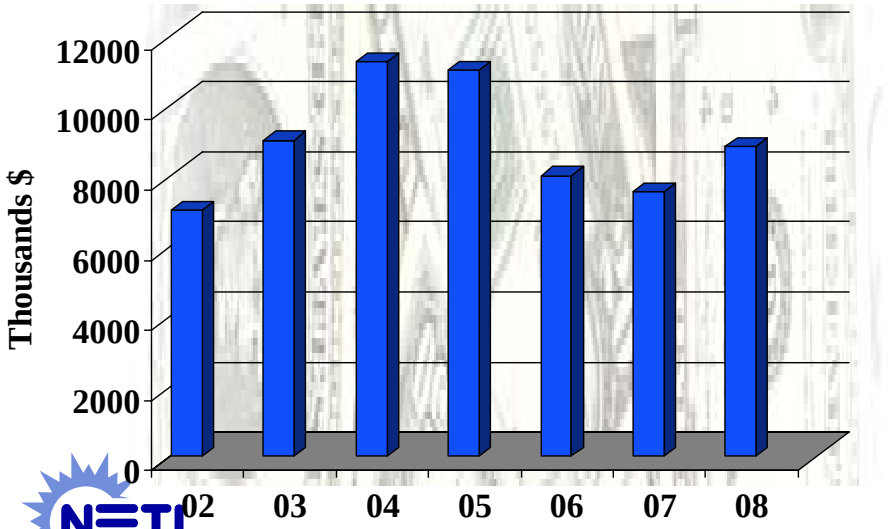
Real Men Don't Ask For Directions

Advanced Research Materials Program

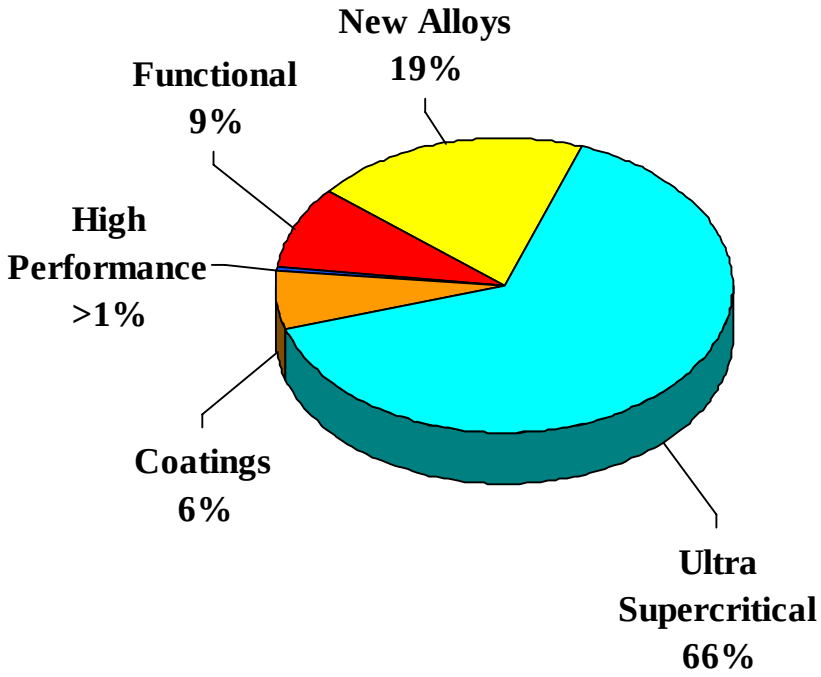
Projects by Organization

• Industry	12
• National Laboratories	9
(AMES 2; ANL 1; INEEL 1; LANL 1; ORNL 3; PNNL 1)	
Total	21

Annual Material Budget



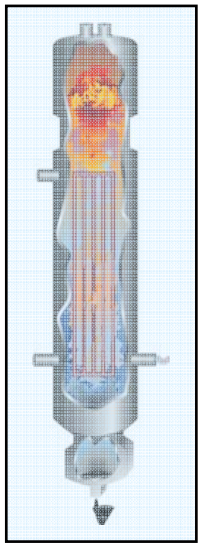
FY08 Budget Allocation

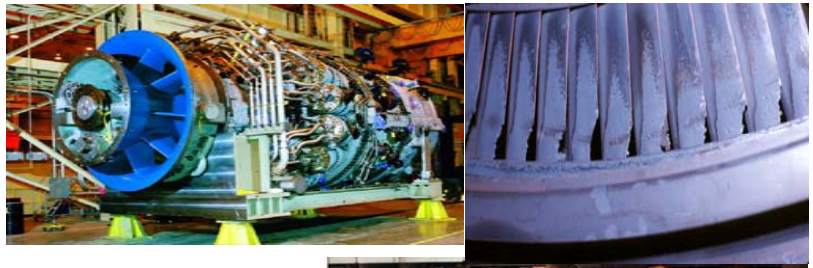


Fossil Energy Key Material Research Areas

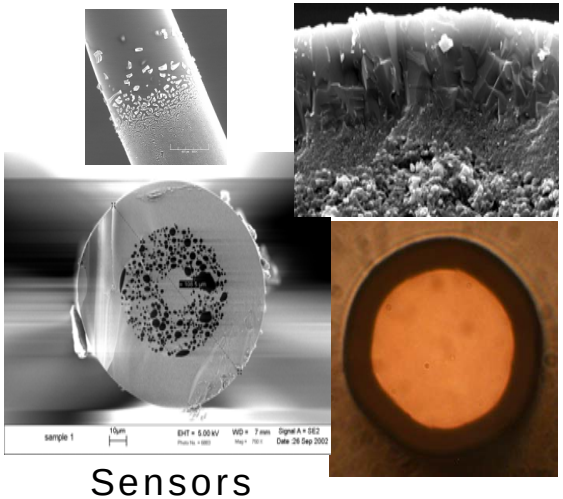
USC Boilers/Turbines

Gasifier

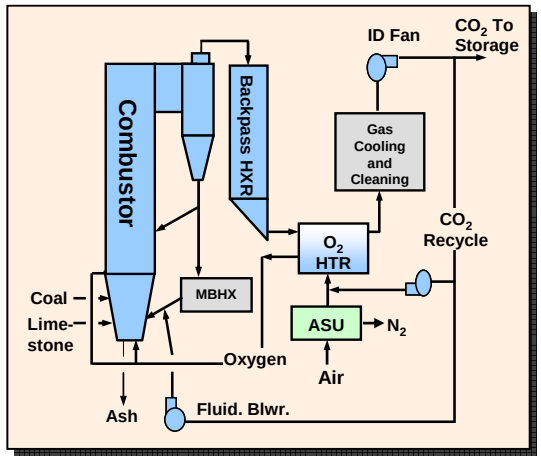




Advanced Turbines



Sensors



Oxy-Firing

Fuel Cells

AR Materials Research Areas

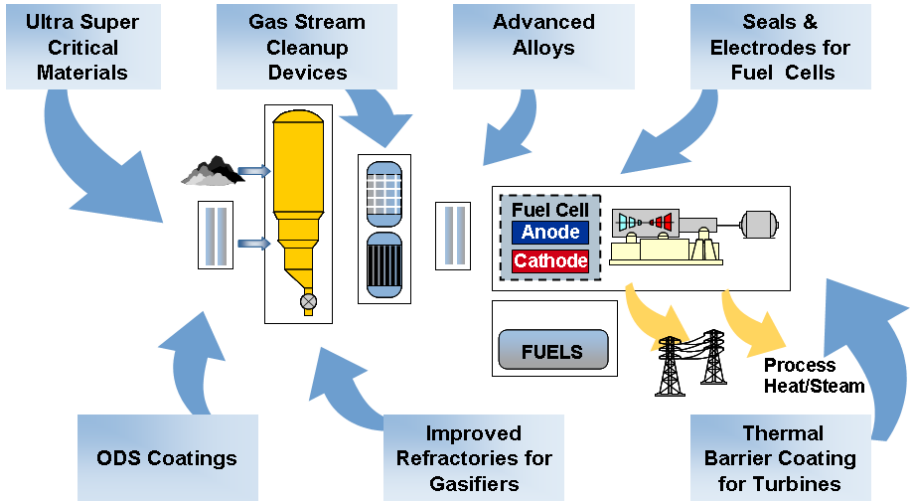
- **New Alloys** - To increase the temperature capability of alloys for use in specific components required for advanced power plants by understanding the relationships among composition, microstructure, and properties.

- **Functional Materials** - To understand the special requirements of materials intended to function in specific conditions such as those encountered in hot gas filtration, gas separation, and fuel cell systems.

- **Breakthrough Materials** - To explore routes for the development of materials with temperature/strength capabilities beyond those currently available.

- **Coatings & Protection of Materials** - To develop the design, application, and performance criteria for coatings intended to protect materials from the high-temperature corrosive environments encountered in advanced fossil energy plants.

- **Ultra Supercritical Materials** – To evaluate and develop materials technologies that allow the use of advanced steam cycles in coal-based power plants to operate at steam conditions of up to 760°C (1400°F) and 5,000 psi .



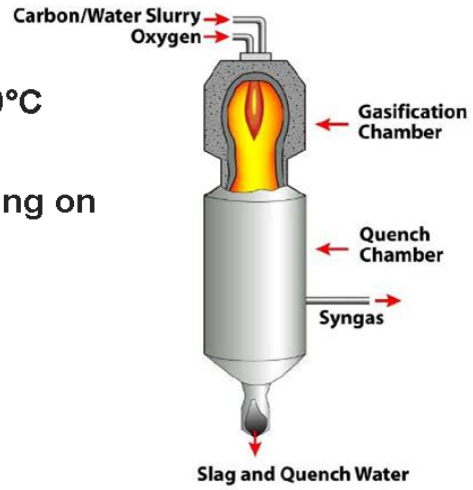
Materials R&D Key to Energy Options

Key Research Projects

- USC Boilers and Turbines
- High Temperature Alloys
- Modeling and Material Performance in Low N_2 Environments
- Refractory Material for Slagging Gasifier
- Computational Capability to Protect Corrosion Wastage of Boiler Tubes

Development of Advanced Refractory Materials for Slagging Gasifiers

- Temperatures of 1325 to 1600°C
- Thermal Cycling
- Variable Environment (oxidizing on start-up; reducing in service)
- Corrosive Slags of Variable Chemistry
- Corrosive Gases
- Pressures ≥ 400 psi



The result is frequent gasifier shutdowns for refractory replacement

What and Why Oxy-fuel Combustion

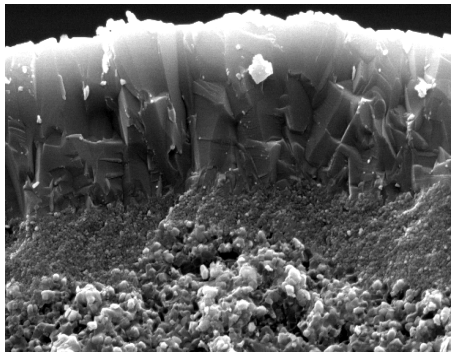
- **Energy production (in particular, electricity) is expected to increase due to population increase and per capita increase in energy consumption**
  - Oxy-fuel combustion is one option for providing increased capacity to satisfy the future energy consumption demand
    - **Can be used for retrofitting or new plants**
- **Global climate change - one of the sources for CO_2 increase in the atmosphere is exhaust from fossil fuel combustion plants**
  - Oxy-fuel combustion readily supports the capture and sequestration of CO_2 from power plants

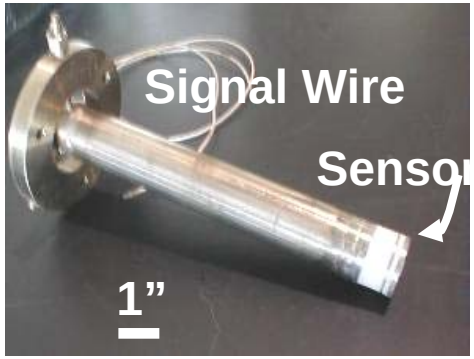
Technological Barriers – Materials Needs

- **Better understanding of material performance in oxyfuel environments**
  - Evaluate ash assisted hot-corrosion of boiler alloys
  - Develop computational models to predict fireside corrosion will aid in the development of all advanced combustion systems
  - Evaluate other plant components
    e.g., coal pulverizers (wear-corrosion interactions)
- **Future Capability: Combine Oxyfuel with USC.**
  - Potential cleaner coal combustion technology
    - Oxyfuel: ease of flue gas clean-up and CO_2 sequestration
    - USC: maximize efficiency
  - Need cost effective advanced alloys that can withstand the oxyfuel/USC environment
    - higher temperatures and higher pressures than current systems

Advanced Sensor Materials

- Harsh Environmental Conditions
- Sensor Material Development
- Rugged Sensor Designs





Driver for New Sensing Technology

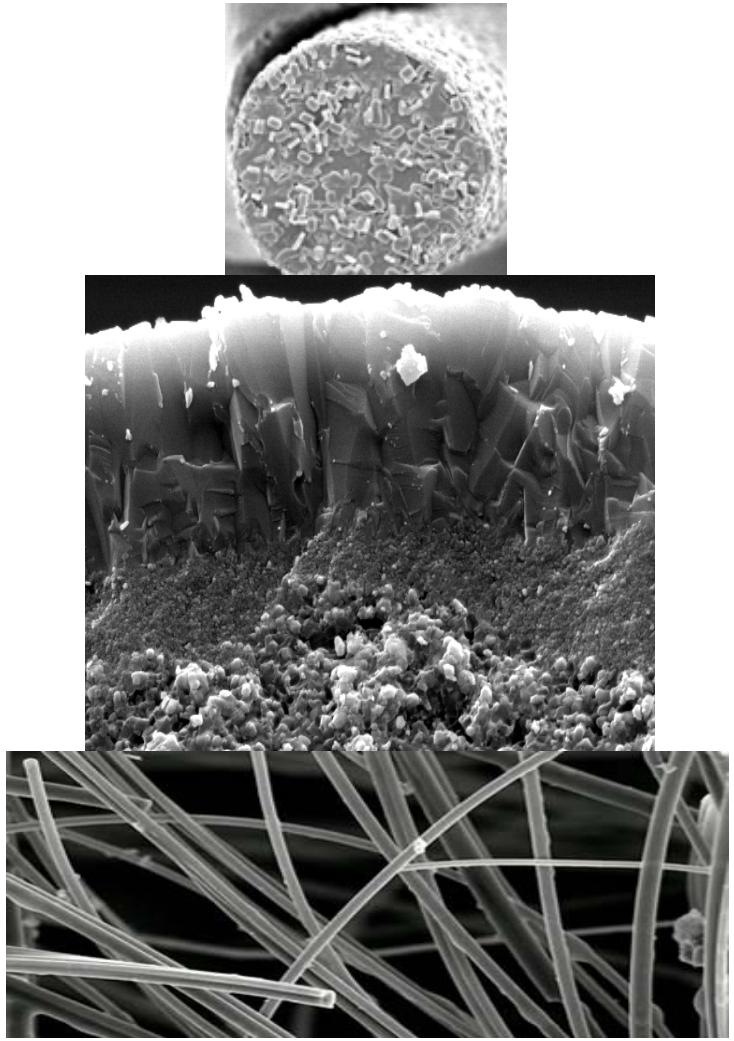
- **Advanced Power Generation:**
  - Harsh sensing conditions throughout plant
  - Monitoring needed with advanced instrumentation and sensor technology.
  - Existing instrumentation and sensing technology are inadequate

- **Coal Gasifiers and Combustions Turbines:**
  - have the most extreme conditions
    - Gasifier temperatures may extend to 1600 °C and pressures above 800 psi. Slagging coal gasifiers are highly reducing, highly erosive and corrosive.
    - Combustion turbines have a highly oxidizing combustion atmosphere.

- **Targeting development of critical on line measurements**
  - Sensor materials and designs are aimed at up to 1600 °C for temperature measurement and near 500 °C for micro gas sensors.
  - Goal is to enable the coordinated control of advanced power plants followed by improvement of a system's reliability and availability and on line optimization of plant performance.

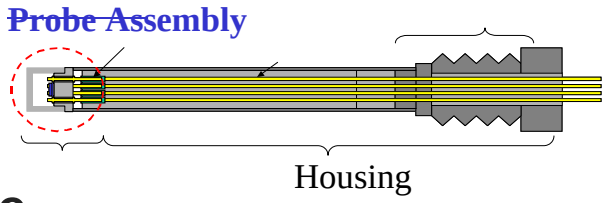
Materials for Sensing in Harsh Environments (Optical and Micro Sensors)

- **Sapphire**
- **Alumina**
- **Silicon Carbide**
- **Doped Silicon Carbide Nitride**
- **Yttria stabilized zirconia**
- **Fused/doped silica for certain conditions**
- **Interest in**
  - Active / doped coatings
  - 3D porous or “mesh” nano-derived ceramics / metal oxides



Sensor Packaging
(Design, Materials, Technology Transfer)

- **Package sensor to enable exposure to environment but protect for adequate performance**
  - Chemical exposure, electrical lead failure, mechanical thermal expansion considerations
- **Ease in handling, installation, replacement**
- **Barrier for technology transfer**



What Does the Future Look Like?

- **The USA and the world will face great energy challenges with ever increasing environmental constraints**
- **Advanced fossil energy power systems will be needed**
- **The Advanced Research Materials Program is poised to have even greater impacts on future energy systems**
  - Novel materials for gas separation
  - Fuel cell materials
  - Next generation stainless steels with higher strength and better oxidation resistance
  - Advanced coatings
  - Prescriptive materials design and lifetime prediction for extreme environments

Program Roadmap