

# Overview of Sensor and Control Needs for Advanced Power Generation Technologies



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Robert R. Romanosky, AR Power Systems Product Manager  
National Energy Technology Laboratory



# National Energy Technology Laboratory



- DOE's Only Fossil Energy National Laboratories
- Extensive extramural R&D with strong industry ties
- Focused on-site science and technology R&D
- Technical support for energy and environmental policy development
- Only Government-owned and -operated National Laboratory



## NETL's Mission

- Resolve the environmental, supply, and reliability constraints of producing and using fossil resources to provide Americans with a stronger economy, healthier environment, and more secure future.

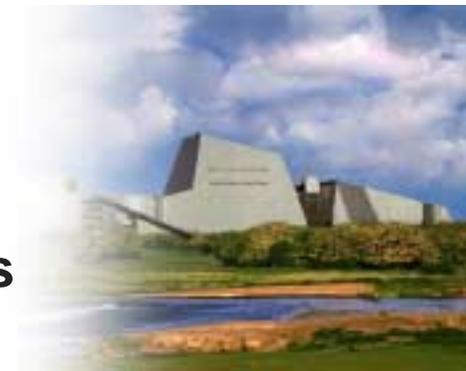


## Power Systems Advanced Research

- Extend state of knowledge in fossil energy technology by supporting development and deployment of innovative systems capable of improving efficiency and environmental performance while reducing costs.
- Ingenuity, innovation and implementation

## Vision 21

- Effectively remove environmental concerns associated with the use of fossil fuels for producing electricity and transportation fuels at competitive costs.



# Office of Coal and Environmental Systems Power Systems Advanced Research

## *Electric Power Using Coal Mining to Light Switch Emissions and Efficiency*

### **Existing Fleet Technologies**

- NO<sub>x</sub>, SO<sub>x</sub>, PM<sub>2.5</sub>, mercury/air toxics
- Clean Coal Demonstrations

### **Mid-Term Markets**

- Re-powering & retrofiting
- Power Plant Improvement Initiative

### **Vision 21**

#### **Carbon Sequestration:**

- An Important Option to Address Climate Change

#### **Mining/Water:**

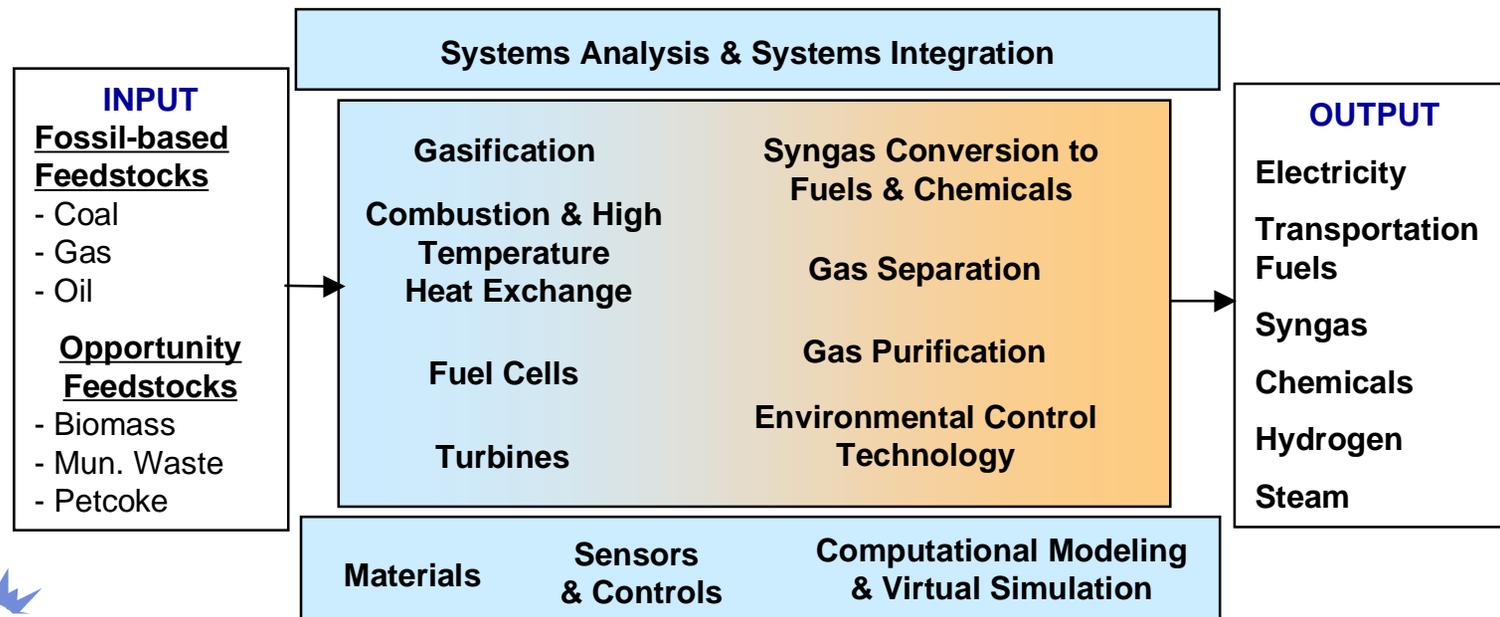
- Addressing Energy Supply Issues



# Vision 21

## *Ultra-Clean Energy Plant of the Future*

- Flexible feedstock
- Electricity and co-products
- Maximum efficiency
- Near-zero emissions



# NETL Power Systems Advanced Research Instrumentation, Sensors, and Control System Program



# What Is Meant by “Sensors and Controls”?

**S**mart

**E**lectronic

**N**ovel

**S**pecific

**O**perate reliably

**R**obust

**S**mall



and



**C**omputerized

**O**ptimizing

**N**eural nets & models

**T**racking & trending

**R**eporting

**O**pen communication

**L**ogic

**S**tandard data transmission



# NETL's Instrumentation, Sensors and Controls Program

- Develop novel or revolutionary technology
- Positioned to screen and accept risk
- Capitalize on technology deployment skills
- Support Vision 21 as a concurrent effort
- Maintain stakeholder relationships (developers and users)
- Take a whole system approach



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# I,S&C Program Structure

- **Basic plan with specific road maps**
- **Internal and external R&D in both fundamental research and engineering development**
- **Collaboration with national labs, research centers, universities, small business and industry**
- **Defined metrics for AR projects**
- **Technology transfer through line organizations and industry**
- **Time-phased, results driven program to keep pace with Vision 21 program and industry**
- **Funding for a defined timeline**



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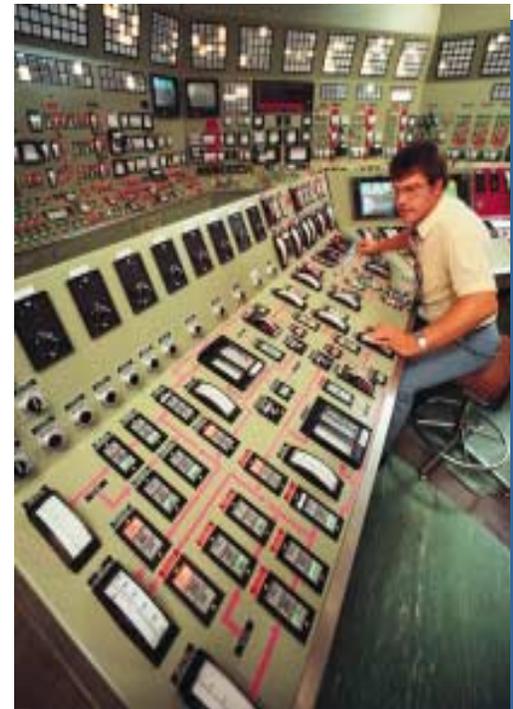
## Why Sensors and Controls?

- **Fossil energy is critical to U.S. economy:**
  - 85% of energy use in the U.S. is supplied by fossil fuels
  - 53% of electric power is generated by coal
- **Demands associated with deregulation**
- **Increasing concerns on global climate change**
- **Higher reductions in pollutant emissions**
- **System access, protection and security**
- **Improved grid connectivity**
- **Infrastructure protection**

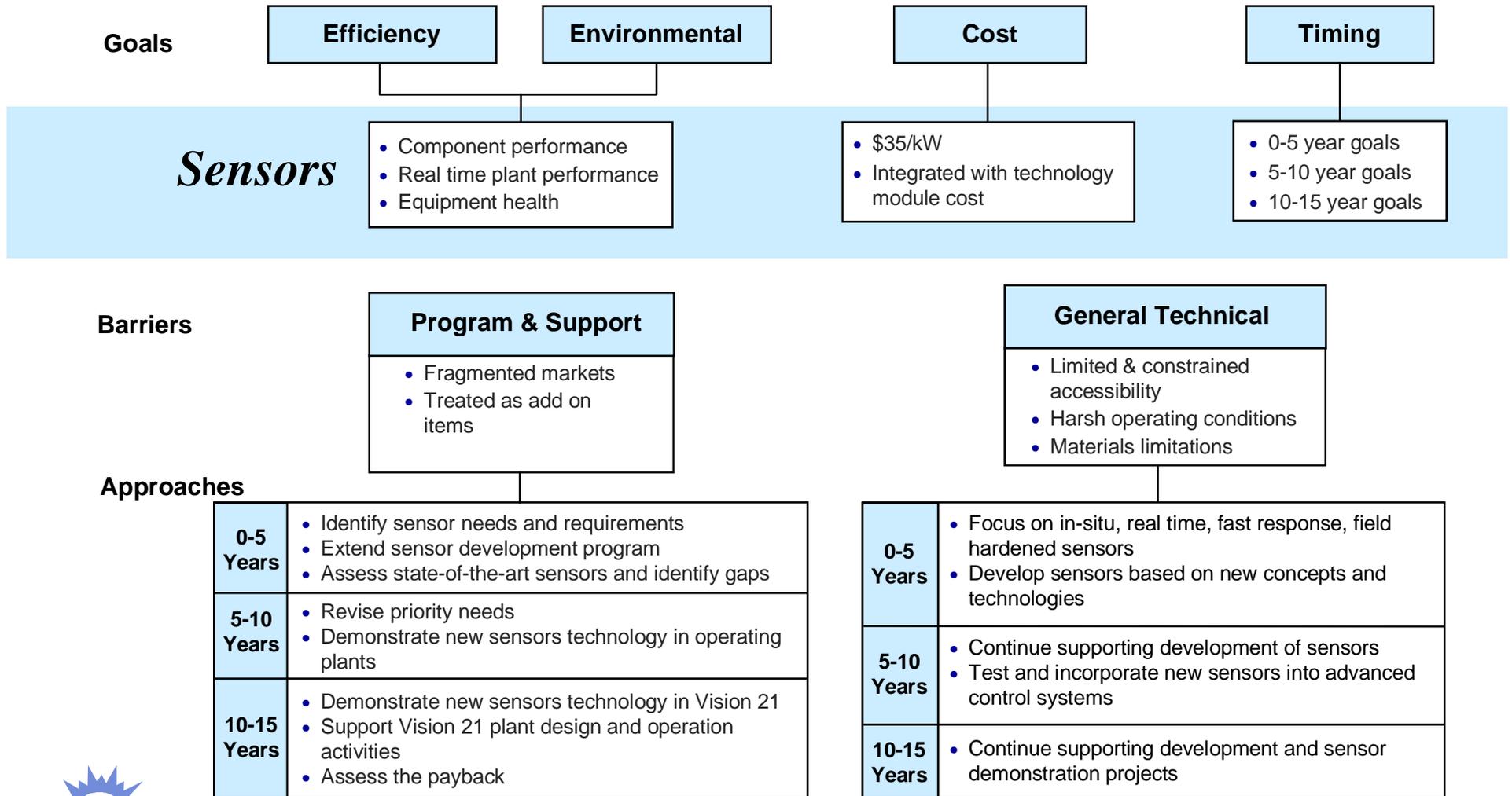


# NETL's Interest - Driving Advancements in Instrumentation, Sensors, and Control Technology

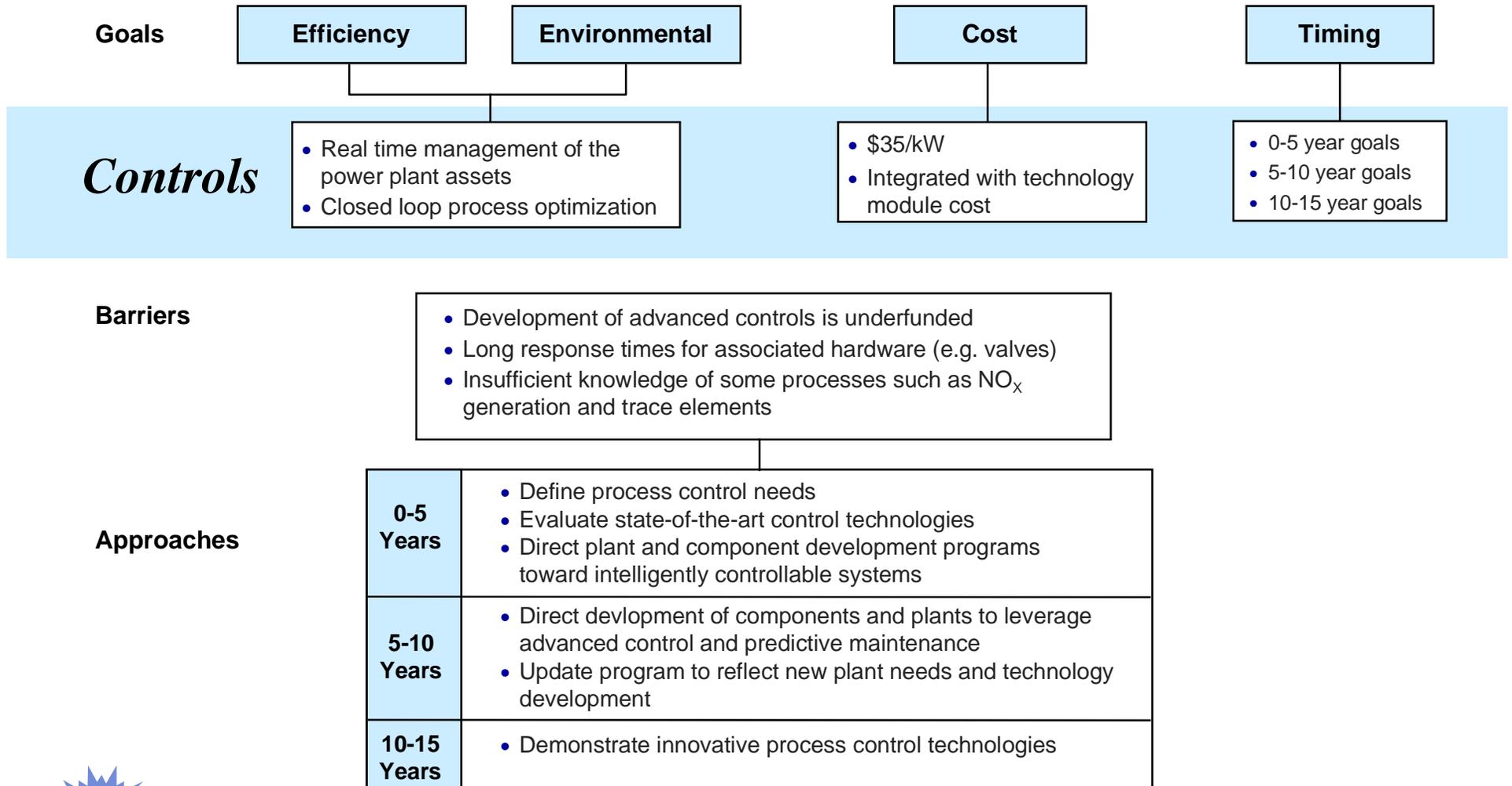
- **Lost cost / high benefit technology**
  - Comparatively small capital investment
  - Lower operating and maintenance costs
  - Enhance efficiency and reduce emissions
  - Increase reliability
- **Opportunity for existing facilities**
  - Dated systems
  - Deregulation
  - Regulatory emissions monitoring and control
  - Installation and operation of SCR systems
- **A must for new facilities**
  - High performance and reliability expectations
  - Protect capital investment
  - Minimize operational and maintenance cost



# Vision 21 Technology Roadmap



# Vision 21 Technology Roadmap



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# **Reassessing the Needs**

**NETL Sponsored Workshop on  
Sensors and Controls  
April, 2001**

**Stakeholder input**

**46 experts (29 organizations)**

**Private Industry, Research Laboratories,  
Academia, and Government Agencies**



# Sensors and Controls Needs - Workshop Results

## Controls

- Supervisory control
- Integrated control
- Neural nets
- Predictive, adaptive control
- Modeling



## System Integration

## Advanced Materials

- High temperature sensing materials

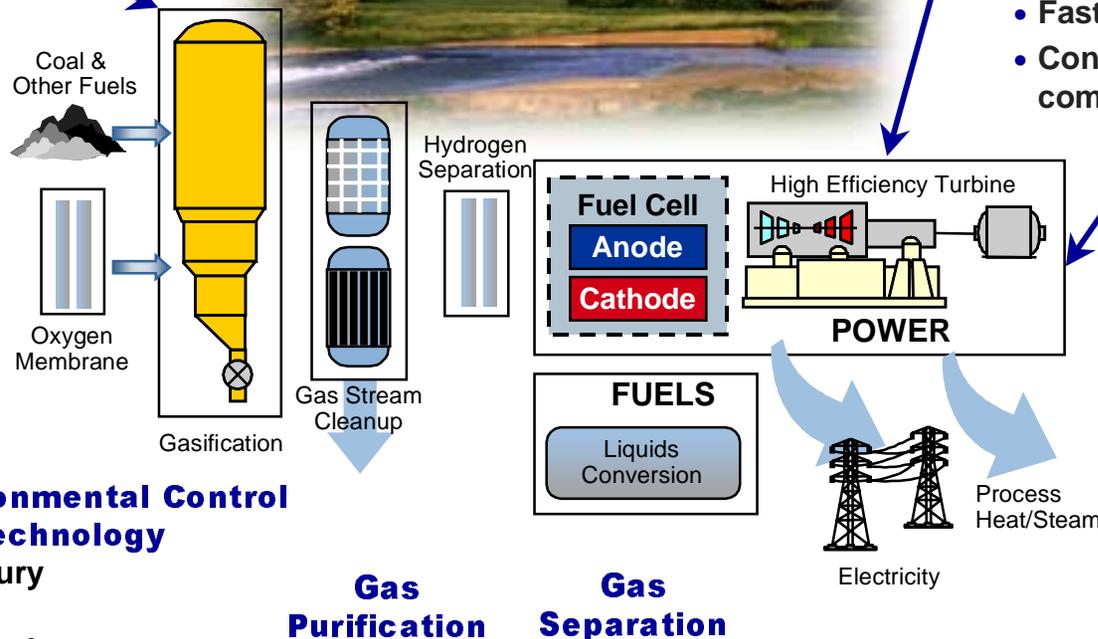
## Computational Modeling and Simulation/Virtual Simulation

### Turbines

- Temperature
- Particulate
- Fuel ratio / burner balancing
- Pressure pulsation
- Thermal barrier coating
- Fast sensors and actuators
- Control algorithms for combustion instability

### Gasification and Advanced Combustion

- Temperature
- Fuel / air ratio control
- Robust sensors
- Feed flow and analysis
- Particle sensing
- Mercury
- Standardized signaling
- Alkali monitor
- O<sub>2</sub> control



### Environmental Control Technology

- Mercury
- NO<sub>x</sub>
- Particulate

### Gas Purification

### Gas Separation



# Sensors for Physical Measurements: Objectives and Barriers

## Temperature

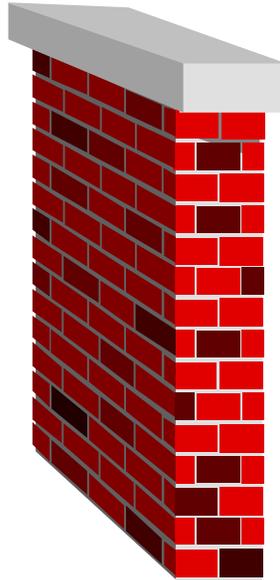
- 3000-4500 °F, 100-400 psi
- 500 hrs, 1 year
- Contact, optical, acoustic

## Solid flow

- 200-350 °F, 0-400 psi
- 5% accuracy
- Microwave, static charge, acoustic, beam deflection

## Flame quality

- Flame ionization, acoustic, chemiluminescence, CCD, IR, UV camera



## Temperature - Barriers

- Contact - materials
- Optical - optical windows
- Acoustic - meaningful data

## Solid flow - Barriers

- Data validity
- Calibration
- Non-uniform particles

## Flame quality - Barriers

- Lack of on-line experience
- Signaling to the control system



# Chemical and Emission Sensors

## ⇒ Mercury

⇒ Total mercury followed by mercury speciation

## • NO<sub>x</sub>

- Replace analyzers with sensors
- Near flame NO<sub>x</sub> measurement
- Tie into control system

## • Particulate

- Size concentration and distribution

## • Ammonia

- Optimize SCR and SNCR systems

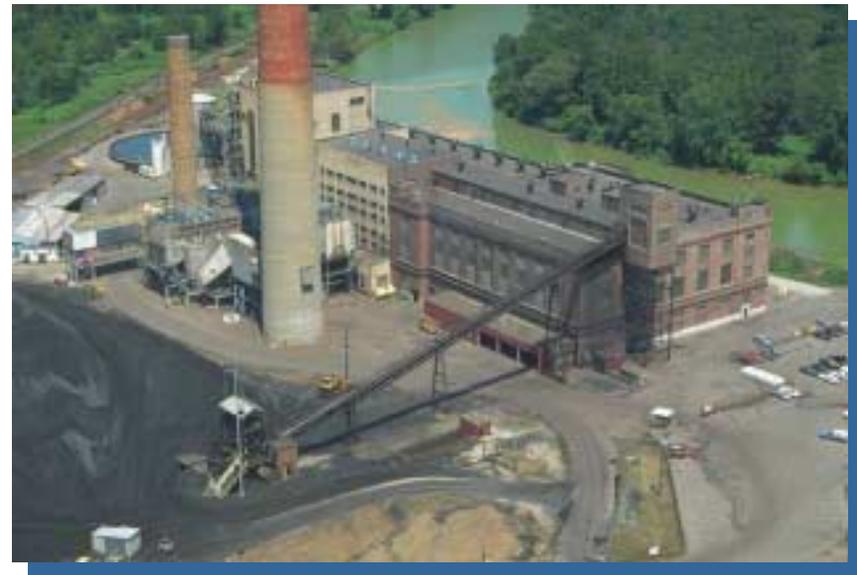
## • Feedstock

- Characterize fuel content and contaminants - Vision 21



# Control Systems

- **Whole system approach**
  - Device, unit, process, system, plant, and facility
- **Simulation of units and entire facilities**
  - Evaluate approaches and options
- **Develop and validate model and algorithms**
  - Dynamic systems
- **Existing facilities**
  - Commercially available systems can offer significant improvement as a retrofit or overhaul



# Instrumentation, Sensors and Control Active Projects

## Controls

- Neural Network-based Intelligent Soot blowing (PPII)
- Distributed Power Sources - Control Requirements

## System Integration

- Identify combinations of technology modules (V21)

## Computational Modeling and Simulation/Virtual Simulation

- V21 technology module modeling and flow sheet simulation (V21)

## Turbines

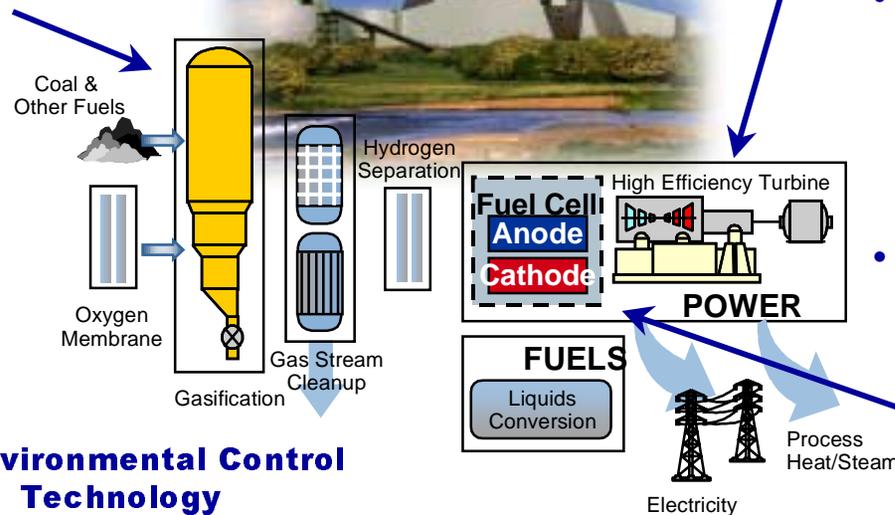
- **Temperature and Pressure**
  - Embedded thermographic phosphors for temperature and pressure indication
- **Fuel ratio / burner balancing**
- **Thermal barrier coating**
  - Infrared sensor for coating diagnostics
- **Condition Monitoring**
  - Flashback sensor
  - Eddy current sensors and parameter analysis
  - RAM monitoring and control algorithms
- **Smart Power Turbine**
  - NETL, GE, Sandia sensor and control development and integration

## Gasification and Advanced Combustion

- Temperature sensors for slagging gasifiers
- Solids Velocity Probe for circulating fluidized beds
- On-line carbon content monitor
- Coal content/Ore grade sensor
- On-line rapid corrosion indicator
- Refractory laser-based contouring technique (PPII)

## Advanced Materials

- Silicon carbide-based sensors for high temperature



## Environmental Control Technology

- Elemental mercury spectrometer
- Micro gas sensors for  $\text{NO}_x$ ,  $\text{SO}_x$ ,  $\text{NH}_3$ ,  $\text{H}_2\text{S}$  using metal oxides

## Gas Separation

- Non-destructive technique to determine candle filter integrity

## Fuel Cells

- Micro-valve design for flow control
- Identification of diagnostic tools for fuel cell plate manufacturing



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# NETL ISCS Research

- **Gasification (high temperature)**
  - high temperature measurement using pyrometry and optical / contact techniques
- **Combustion**
  - Carbon characterization via microwave-excited photoacoustic effects
  - On-line corrosion monitor
  - High temperature solids velocity measurement
- **Environmental Control Technology**
  - Advanced metal oxide film sensor array with neural network (H<sub>2</sub>S, NH<sub>3</sub>, NO<sub>x</sub> and SO<sub>x</sub>)
  - Silicon carbide-based gas sensors
  - Mercury via cavity ringdown spectroscopy



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# NETL ISCS Research

- **Turbines**
  - Combustion control
  - Flame ionization / flashback sensor
  - IR sensor for blade diagnostics
  - Eddy current probe and algorithm to monitor component degradation
  - Thermographic phosphors for embedded monitoring
- **Fuel Cell**
  - Microelectrical mechanical devices (MEMs) for flow control
  - Fuel cell plate manufacturing diagnostic tools
- **Virtual simulation**
- **Evaluation of distributed power control requirements**



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## Future Activities

- **Collaboration and Communication**
  - ISA, EPRI, PIWG
  - National Laboratories, Government Agencies
  - Users and vendors
- **Solicitations**
  - SBIR /STTR
  - Broad-based Federal announcement (BBFA)
  - Others ([www.netl.doe.gov](http://www.netl.doe.gov))
- **Innovation and Implementation**
  - Seek out new or novel adaptations
  - Strive towards implementation



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## Conclusion

- **Opportunities for improvement and development**
  - Instrumentation improvement,
  - Sensor development, and
  - New control methodologies
  - Whole system approach
- **Technology to overcome barriers**
  - Materials, interferences, sampling
- **Research and development programs are**
  - Focused, industry driven, and time-phased
  - Internal and external research efforts



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## **Additional Program Information**

- **Susan Maley**  
IS&C Project Manager  
NETL  
304-285-1321
- **Robert Romanosky**  
Advanced Research Product Manager  
NETL  
304-285-4721

