Accelerating Sensor Technology Development through FE-Sponsored Programs

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Sensor Technologies for Fossil Energy Session
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OUTLINE

Introduction

Overviews
  Advanced Energy and Hydrogen Systems
  Crosscutting Research - Sensors, Controls and Novel Concepts Program
  Sensor Activities within Transformative Power Generation

Summary

Key Points of Contact
INTRODUCTION

Advanced Energy and Hydrogen Systems (AEHS) integrates carbon neutral or net-negative greenhouse gas (GHG) emissions technologies with carbon capture and storage (CCS) capabilities and improved fuel conversion efficiency. Focus is on improving efficiency, increasing plant availability, reducing water consumption, and achieving ultra-low emissions of traditional pollutants. Much of AEHS research is targeted at improving overall system efficiency, reducing capital and operating costs, and enabling affordable carbon capture.

While the primary focus is on fossil-based power systems, improvements to these technologies are also applicable to other fossil energy systems.
KEY ADMINISTRATION GUIDANCE

• Executive Order 14008 – “Tackling the Climate Crisis at Home and Abroad”

• White House Coal Power Plant Task Force

• Executive Order 13985 – “Advancing Racial Equity and Support for Underserved Communities Through the Federal Government”
Functional R&D Responsibilities

- Blue hydrogen power production fuel
- Secure, stable, and reliable zero carbon hydrogen power plants
- Adaptive load-following net-zero or negative emissions power plants
- Reduced water consumption/Improve quality
- Overcoming carbon ore quality regionality and associated technology challenges
- Grid integration into utility-scale power plant concepts
- Plant modularity

Six Subprogram Activities

- Advanced Turbines
- Advanced Combustion/Gasification Systems
- Solid Oxide Fuel Cells
- Sensors and Controls and Novel Concepts
- Water Management for Improved Efficiency
- Advanced Energy Materials
ADVANCED COAL & CARBON TECHNOLOGY R&D THRUSTS

Carbon Capture
- Negative Emissions Technologies
- Direct Air Capture
- Natural Gas Sources
- Industrial Sources

Carbon Utilization
- Working Fluid
- Algae Systems
- Conversion to Fuels & Chemicals
- Mineralization into Inorganic Materials

Carbon Storage
- Monitoring, Verification, Accounting & Assessment of Long-Term Storage
- Storage Infrastructure Demonstration
- Regional Carbon Sequestration Partnerships
- CarbonSAFE

Advanced Energy Systems
- Hydrogen Fuel
- Advanced Coal Processing
- Gasification
- Solid Oxide Fuel Cells & Gas Turbines
- Transformative Power Generation

Crosscutting Research
- Sensors & Controls
- High-Performance Materials
- Rare Earth Elements & Critical Minerals
- Energy Storage
- Water Management
- Simulation-Based Engineering
- University Training & Research

STEP (Supercritical CO₂)
- STEP Pilot Plant
- Turbomachinery & Recuperators
- Advanced Concepts in Direct-Fired Cycles
- Systems Integration & Operation

Carbon Utilization Photo Courtesy of MicroBio
Crosscutting Technologies

- Applicable to a broad range of fossil and non-fossil applications.
- Improve operational efficiency, flexibility, and reliability
- Enabling a broad range of assets to be more environmentally sound.
Mission: Test and mature novel sensor and control systems operable in fossil-fueled power plants for real-time measurement capability, improved overall plant efficiencies, more effective ramp rates, and increased flexibility.
**SENSORS, CONTROLS and NOVEL CONCEPTS**

**ENABLE, OPTIMIZE** and **PROTECT** Evolving Generation Technologies

Enable...
- Real-time measurement in extremely harsh environments using novel technologies
- Operations-based predictive maintenance to maximize life and availability
- Increased flexibility (cycling, ramping) to respond to rapidly changing load demand and bolster grid stability

Optimize...
- Plant efficiency and heat rate with advanced control and diagnostic methods
- Sensor capability, placement, size and manufacturability
- Maintenance planning to reduce unplanned outages

Protect...
- Plant equipment and availability by ensuring sensor data, control system, and supply chain security with cutting-edge cyber technology

Image Courtesy of GE
SENSORS, CONTROLS and NOVEL CONCEPTS

Technologies

**ADVANCED SENSORS**
- High-temperatures & harsh environments
- Real-time measurements and diagnostics
- Optical fiber, wireless, embedded
- Materials development, packaging & prototyping
- Testing in relevant environments

**DISTRIBUTED INTELLIGENT CONTROLS**
- Control strategies for advanced energy systems & hybrids
- PID and MPC controls
- Cyber-physical systems
- Condition-based maintenance
- On-line System Identification
- Critical component failure prediction

**NOVEL CONCEPTS**
- Emerging Technologies
- Cybersecurity (blockchain implementation, visible light communications, etc.)
- Direct Power Extraction
Sensors, Controls, and Novel Concepts
Technology Line – Budget History

FY17 | FY18 | FY19 | FY20 | FY21
---|---|---|---|---
3.65 | 7.5 | 8 | 9 | 8

Millions ($)
Sensors, Controls, and Novel Concepts
Technology Line – Project Summary

16 TOTAL PROJECTS

10 COOPERATIVE AGREEMENTS (REQUIRING COST SHARE)

3 FEDERAL WORK PROPOSALS (FWPs)

3 SMALL BUSINESS INNOVATIVE RESEARCH (SBIRS)

$30.77M TOTAL DOE SHARE (ACTIVE)

- Advanced Sensors, 7
- Cyber Physical Systems, 1
- Data Analytics, 4
- Cybersecurity / Blockchain, 2
- Novel Concepts, 1
- Distributed Intelligent Controls, 1
Projects Funded Under Sensors, Controls, and Novel Concepts Technology Line

16 projects in 12 states
ADVANCED SENSORS

**Rems**
- Radically engineered modular systems for gasification
- 1100 - 1500°C
- Meas. Challenges
- Multipoint temp
- Species
- NDE of adv. manuf. components
- Multiphase flow

**Hybrid systems**
- 800°C in fuel cell
- 1500°C in GT
- Meas. Challenges
- T and H₂ dist in SOFC
- Transient control

**Coal-fired Boilers**
- Steam 1110°F (600°C), 4000 psig
- Fire side 2500°F (1370°C) +
- Ash / slag / SOx
- Meas. Challenges
- Tube temperatures / flow (cycling)
- Corrosion/erosion/exfoliation
- Steam chemistry
- Coal particle size
- Temperature / species dist. Inside boiler

**Subterranean chemistry monitoring**
- High pressure brine
- Meas. Challenges
- Salts in water
- Wellhead measurement
- Downhole measurement

**Chemical Looping**
- > 1000°C
- Pressurized
- Erosive
- Meas. Challenges
- Solids circulation
- Oxidation state
- Multipoint temp
ADVANCED SENSORS

OPERATIONS-BASED ASSESSMENT

OPTICAL FIBER SENSING

ADVANCED MANUFACTURING

DIAGNOSTICS & INSPECTION

EMBEDDED SENSORS
Transformative Power Generation
Sensors Projects & Plant Test Sites

Technologies in Development
• Advanced Sensors (incl. temperature, corrosion, wireless, real-time, combustible gases, ash deposition)
• Online Coal Analyzer
• Dynamic Plant Control Systems for Improved Transient Operation
• Condition-based Monitoring Systems

Plant Size
- >500 MW
- 300-500 MW
- 100-300 MW

Coal Type
- Bituminous
- Sub-bituminous
- Lignite
- Non-coal

7 Projects with a total budget of $10.1M
Technology Development Pathway

An Active Portfolio from Concept to Market Readiness

**COMMERCIALIZATION**
Technology available for wide-scale market use

**DEMONSTRATION**
System demonstrated in operational environment

**SYSTEM TESTING**
System performance confirmed at pilot-scale

**DEVELOPMENT**
Technology component validated/integrated

**DISCOVERY**
Concept identified/proven at laboratory-scale

**Technology Maturation**

**Fundamental Studies**

- Systems Engineering and Integration
  - Engineering analysis
  - Pre-FEED/FEED studies
  - NEPA
- Decision Science and Analysis
  - Screening studies
  - Techno-economic analysis
  - Technology Readiness Assessments

**Scale**
**Technology Confidence**
**Investment**
**Private Sector Cost Share**
Technology Development Pathway

An Active Portfolio from Concept to Market Readiness

**COMMERCIALIZATION**
Technology available for wide-scale market use
TRL 9

**DEMONSTRATION**
System demonstrated in operational environment
TRL 8

**SYSTEM TESTING**
System performance confirmed at pilot-scale
TRL 6-7

**DEVELOPMENT**
Technology component validated/integrated
TRL 4-5

**DISCOVERY**
Concept identified/proven at laboratory-scale
TRL 1-3

**Transformative Power Generation**

**Crosscutting Research**
Sensors & Controls

**Fundamental Studies**

- Technology Readiness Assessments
- Techno-economic analysis
- Screening studies
- NEPA
- Pre-FEED/FEED studies
- Engineering analysis
- Systems Engineering and Integration

**KNOWLEDGE-BASED DECISION MAKING**

- Decision Science and Analysis
- Systems Engineering and Integration
- Technology Confidence
- Investment
- Private Sector Cost Share
SUCCESSFUL DEPLOYMENT OF UNIVERSITY OF MAINE WIRELESS SENSOR AT LONGVIEW POWER PLANT (2020)

- Tested a robust, hardened prototype of a novel, wireless surface acoustic wave (SAW) sensing technology
- Real-time temperature measurements were conducted for boiler tube monitoring (36 sensor units + antenna units)
- Testing confirmed correlation between steam temperature and measured temperature
- This demonstration, funded by TPG, represents a successful technology transition and maturation of predecessor R&D efforts supported by Sensors & Controls program.

Future Development Efforts:

• Advanced sensors for new technologies (H₂, SOFC, etc.) addressing unique performance, environmental, material compatibility and manufacturing issues
• Control and optimization strategies for new hybrid systems (SOFC with H₂ turbine, generation with energy storage, etc.)
• Operations-based predictive maintenance of emerging advanced generation and hybrid technologies to improve availability and economics
• Development and testing of plant cybersecurity mechanisms as the threat landscape evolves
In Conclusion

These (Your) Efforts Are Helping to Meet DOE Strategic Goals

- Advance Technology Readiness Levels
- Explore Emerging Concepts
- Driving Innovation & Delivering Solutions

Encourage Interactions with Others Throughout the Meeting

- Helps Grow a Robust Program
- Allows Us to Amplify Your Work and Successes
- Builds New Collaborative Relationships
KEY POINTS OF CONTACT

Sensors, Controls and Novel Concepts

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