Office of Fossil Energy’s Solid Oxide Fuel Cell Program Overview

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15th Annual SECA Workshop
Pittsburgh, PA
July 22 -23, 2014
FE Solid Oxide Fuel cells (SOFC) Program

FE Clean Coal R&D Program

CCS and Power Systems

Advanced Energy Systems

Carbon Storage

Solid Oxide Fuel Cells

Carbon Capture

CCS Demonstrations

Coal & CBTL

Advanced Turbines

Crosscutting Research

Advanced Combustion Systems

Gasification Systems

CCS: Carbon Capture and Storage
SOFC Power Systems – Cost of Electricity (COE)

SOTA: State of the Art
IGCC: Integrated Gasification Combined Cycle
PC: Pulverized Coal
IGFC: Integrated Gasification Fuel Cell
NGCC: Natural Gas Combined Cycle
NGFC: Natural Gas Fuel Cell

* Advanced IGCC system includes: coal feed pump, warm gas cleanup, H₂ membrane, advanced H₂ turbine, and ITM
** Advanced IGFC system includes catalytic gasifier, 0.2% degradation rate, and internal reforming
*** Advanced NGCC system features a J-class turbine with a state-of-the-art carbon capture system

Advanced SOFC systems are cost-competitive with IGCC and NGCC Systems

Source: NETL Systems Analysis
SOFC Power Systems - Efficiency

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SOFC system performance is superior to all other systems
SOFC: Meets DG Market Need

- **SOFC Natural Gas DG all-electric power application**
  - Provides > 20 percentage point gain in efficiency
  - Substantially reduces CO₂ emissions (lb/kWh)
- **Cost-competitive SOFC DG product by circa 2020**
- **Projected learning curve to achieve competitive cost is consistent with similar technology commercialization experience**

SOFC Natural Gas DG applications will provide pathway to utility scale coal and natural gas-fueled power plants with >97% carbon capture
SOFC Program

• **Focus:**
  - Near Term: Natural gas distributed generation (DG)
  - Long Term: Coal and natural gas central station applications with CCS

• **Targets:**
  - System Performance Degradation: 0.2%/1,000 hours
  - Stack Cost: $225/kWe*
  - Power Block Cost: $900/kWe*

• **Development Timeline**
  - FY2016: 125 kWe-class Module Test
  - FY2018: FOAK** 250 kWe Power System Field Test
  - FY2020: FOAK** 1 MWe-class Power System at customer site
  - Post-FY2020: Utility-scale IGFC/NGFC Central Station

Based on progressively larger natural gas-fueled validation tests, MWe-class DG SOFC Power Systems that are *cost-competitive* with existing DG technologies are envisioned circa 2020

* N°—of-a-kind at specified volume, 2011$s
** FOAK – First-of-a-Kind
SOFC Program - Structure

R &D Needs
Research Topics

Industry Teams

Core Technology Program
(Universities, NLs)

Technology Transfer
SOFC Program – FY 14 Projects

The SOFC program supports a diversified portfolio of ~20 R&D projects
## SOFC Program - Project Portfolio

### Atmosphere Pressure Systems
- FuelCell Energy
- Delphi

### Pressurized Systems
- LG Fuel Cell Systems

### Anode Electrolyte Cathode (AEC) Development

<table>
<thead>
<tr>
<th>Boston U</th>
<th>Georgia Tech</th>
<th>NETL/RUA</th>
<th>ORNL</th>
<th>PNNL</th>
<th>U. Connecticut</th>
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<td>WVU</td>
<td>WVU-EPSCoR</td>
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### Small Business Innovative Research
- Innosense LLC
- Mo-Sci
- MSRI
- NexTech
- Sonata LLC

### Congressionally Directed Projects
- Penn State U.
- U. Akron
Since its inception as the Solid State Energy Conversion Alliance (SECA), the U.S. Department of Energy has invested nearly $600M in SOFC technology.
SOFC Program - Challenges

• **Improved Cell Performance**
  – Today: Overpotential = 140 mV at normal operating conditions
  – Target: Overpotential = 70 mV at normal operating conditions

• **Improved Durability and Reliability**
  – Today: Lab-scale stack tests
  – Target: Fully-integrated SOFC power systems

• **Reduced System Performance Degradation**
  – Today: 1 – 1.5% per 1,000 hours
  – Target: 0.2% per 1,000 hours

• **Fuel Reformation**
  – Today: Primarily external fuel (natural gas) conditioning/reformation
  – Target: 100% integrated fuel reformation inside fuel cell stack

• **Manufacturing**
  – Today: Batch processing
  – Target: Advanced manufacturing techniques

*Single-cell performance and degradation are acceptable; stack and system performance, reliability and endurance needs to be demonstrated*
FY14 SOFC Program Update

- Two competitive solicitations
  - 11 projects selected
  - 2 Industry Teams, 9 Core Technology

- Increased emphasis on system level testing

- Increased emphasis on Industry Team – Core Technology collaboration

- Peer Review of 7 Projects

- Updated NETL and SOFC Program website

- Web-based SOFC Program Portfolio

- Three new SBIR projects
Natural gas fueled DG systems will establish the manufacturing and operational experience necessary to validate and advance the technology for both natural gas and gasified coal-based central power generation.
SOFC Program ... Key Takeaways

- Focus on cost reduction and increased reliability
- Demonstrations at system-level are critical
- Industry Team - Core Technology collaboration is essential
- Look out for and take advantage of revolutionary advances in materials and manufacturing processes

A technically and economically viable SOFC system will create market-pull
15th Annual SECA Workshop - Overview

**Tuesday**
- **Plenary Session:** ARPA-E, Booz Allen Hamilton
- **Industry Team Presentations**
- **National Laboratories**

**Tuesday Evening Poster Session and Reception**

**Wednesday**
- **Plenary Session:** Synopsis of Interconnection Development
- **Core Technology Teams:** Cathodes
- **Core Technology Teams:** Modeling
- **Core Technology Teams:** Protective Coatings
15th Annual SECA Workshop Participants
Web-sites and Contact Information

NETL Website:  www.netl.doe.gov/
SOFC Program website:  www.netl.doe.gov/research/coal/energy-systems/fuel-cells
Reference Shelf:
- SOFC Program FY14 Project Portfolio
- SOFC Technology Program Plan
- Technology Readiness Assessment
- Past SECA Workshop Proceedings
- Systems Analysis
- Fuel Cell Handbook

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www.netl.doe.gov/research/coal/energy-systems/fuel-cells
# SOFC Program – FY14 Selections

<table>
<thead>
<tr>
<th>Recipient</th>
<th>Title</th>
<th>DOE Share</th>
<th>Recipient Cost Share</th>
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<td>Acumentrics</td>
<td>Advanced SOFC Quality Control and the Role of Manufacturing Defects on Stack Reliability</td>
<td>$788,267</td>
<td>$197,067</td>
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<td>Boston University</td>
<td>Mitigation of Chromium Impurity Effects and Degradation in SOFCs: Understanding Transport and Thermodynamics</td>
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<td>Case Western Reserve University</td>
<td>Long Term Degradation of LSM-Based SOFC Cathodes: Use of a Proven Accelerated Test Regimen</td>
<td>$798,175</td>
<td>$326,759</td>
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<td>University of Connecticut</td>
<td>Materials and Approached for the Mitigation of SOFC Cathode Degradation in SOFC Power Systems</td>
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<td>Michigan State University</td>
<td>Durable, Impermeable Brazes for Solid Oxide Fuel Cells</td>
<td>$694,026</td>
<td>$173,506</td>
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<td>University of Pennsylvania</td>
<td>Cost-Effective Manufacturing and Morphological Stabilization of Nanostructured Cathodes for Commercial SOFCs</td>
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<td>University of South Carolina</td>
<td>University-Industry Driven Partnership to Develop Reliable, Robust and Active SOFC Cells and Stacks</td>
<td>$500,000</td>
<td>$283,170</td>
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<td>West Virginia University Research Corporation</td>
<td>Novel Nanostructured-Tailored Highly Active and Stable Electro-Catalytic Architecture on Surface of Cathode of SOFCs</td>
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<td>West Virginia University Research Corporation</td>
<td>Scalable and Cost-Effective Barrier Layer Coating to Improve Performance and Stability of SOFC Cathode</td>
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<td>FuelCell Energy Inc.</td>
<td>Reliable SOFC Systems</td>
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<tr>
<td>LG Fuel Cell Systems</td>
<td>Improved Reliability of Solid Oxide Fuel Cell Systems</td>
<td>$7,500,000</td>
<td>$1,875,000</td>
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