SOFC Program Mission

To enable the generation of efficient, low-cost electricity with intrinsic carbon capture capabilities for:

• Near term: Natural gas-based distributed generation

• Long term: Coal and natural gas utility-scale applications with Carbon Capture and Sequestration (CCS)
SOFC Program Structure

Key Technologies

SOLID OXIDE FUEL CELLS

- Cell Development
- Core Technology
- Systems Development

Figure courtesy FuelCell Energy
Figure courtesy LG Fuel Cell Systems
Figure courtesy NETL
SOFC Program

R&D Approach

• **Applied Research**
  • Cell and Core Technologies
  • TRL 2 – 5
  • Collaboration with an SOFC developer (industry) encouraged

• **Development**
  • State-of-the-Art systems development
  • Innovative Concepts
  • TRL 5 – 6
SOFC Program

Funding History

Annual Appropriation, $M

SOFC Program Project Portfolio

FY19 Participants
<table>
<thead>
<tr>
<th>Metric</th>
<th>Current</th>
<th>2020 Target</th>
<th>2025/2030 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Cost (100 kW-1MW)</td>
<td>&gt;$12,000/kWe</td>
<td>$6,000/kWe</td>
<td>$900/kWe</td>
</tr>
<tr>
<td>Single Cell Degradation</td>
<td>0.2 - 0.5% per 1,000 hrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell Manufacturing Approach</td>
<td>Batch</td>
<td>Semi- Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>System Degradation</td>
<td>1 - 1.5% per 1,000 hrs</td>
<td>0.5 - 1.0% per 1,000 hrs</td>
<td>&lt;0.2% per 1,000 hrs</td>
</tr>
<tr>
<td>Fuel Reformation</td>
<td>Primarily external natural gas conditioning/reforming</td>
<td>100% integrated natural gas reform inside cell stack</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>&lt;2,000 hrs</td>
<td>5,000 hrs</td>
<td>5 years</td>
</tr>
<tr>
<td>Platform</td>
<td>Proof-of-Concept</td>
<td>Prototype/Pilot</td>
<td>DG: Commercial Utility-scale: Pilot</td>
</tr>
<tr>
<td>Configuration</td>
<td>Breadboard/Integrated systems</td>
<td>Fully packaged</td>
<td>Fully packaged</td>
</tr>
<tr>
<td>Fuel</td>
<td>Natural gas</td>
<td>Natural gas</td>
<td>Natural gas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simulated syngas</td>
<td>Coal-derived syngas</td>
</tr>
<tr>
<td>Demonstration Scale</td>
<td>50 kWe - 200 kWe</td>
<td>200 kWe - 1 MWe</td>
<td>DG: MWe-class Utility-scale: 10 - 50 MWe</td>
</tr>
</tbody>
</table>

Single-cell performance and degradation are acceptable; stack and system performance, reliability and endurance need to be demonstrated.
SOFC Program

R&D Gaps

- **CELLS**
- **STACKS**
- **SYSTEMS**

** Topics **
- Manufacturing/QC
- Chemical Instability
- Contacs
- Seals
- Degradation
- Reliability
- System Integration
- Balance of Plant Operations
SOFC R&D at NETL

**Cell and Stack Degradation Modeling**
- Development of comprehensive predictive modeling tool
- Atoms to system scale bridging
- Validated through experiment

**Electrode Engineering**
- Mitigation of prominent degradation modes
- Successful transfer of technology to industry

**Systems Engineering and Analysis**
- Public dissemination of SOFC market potential, performance, and cost advantages
- Hybrid configuration assessment
- Tie to R&D goals and objectives

**High Temp Optical Sensors**
- Multi-application technology under development for high temperature sensing
- Demonstrated in SOFC
- In-situ sensing of temperature distribution and gas composition
SOFC R&D at PNNL

Materials
- Quantitative understanding of Cr poisoning
- Validation of Cr capture materials
- Enhanced reliability of cathode/contact material interfaces
- Cobalt-free protective coatings for metallic interconnects

Modeling
- Advanced Reduced Order Models (ROM) for accurate simulation of stack performance in system models
- Modeling to mitigate stack degradation and increase reliability

Small-Scale SOFC Test Platform
- Designed and fabricated SOFC test platform (1-10 kW)
- Used for evaluation of performance and reliability of emerging stack technologies
- First technology to be tested: Ceres Power stack module (~4 kW)
SOFC Power System
FuelCell Energy 200 kW Prototype Field-Test

- 200 kWe integrated SOFC Power System
- Test site: Clearway Energy Center, Pittsburgh, PA
- Natural gas fuel
- Grid Connected
- Operating Time: ~2,500 hours

Photo courtesy FuelCell Energy
SOFC Program

Outreach Activities

• NETL “Roadshow”
  • NETL facilitated one-on-one interaction between National Labs and Industry

• SOFC Program Roundtable
  • NETL facilitated annual meeting with select program participants (10-15 on rotating basis) to identify crosscutting issues

• SOFC Program Workshop
  • Annual meeting for SOFC Program participants and the fuel cell community
  • Held jointly with EE&RE

• Monthly teleconferences with all DOE offices working on fuel cells
At the request of Congress, DOE Office of Fossil Energy has written a Report on the Status of the Fuel Cells Program. Changes in Timeline and activities are recommended.

### SOFC Program

#### Report to Congress

At the request of Congress, DOE Office of Fossil Energy has written a Report on the Status of the Fuel Cells Program. Changes in Timeline and activities are recommended.

<table>
<thead>
<tr>
<th>Activity</th>
<th>2018-2020</th>
<th>2021-2024</th>
<th>2025-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Engagement</td>
<td></td>
<td></td>
<td>Data sharing and scaling of commercial systems</td>
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<tr>
<td>2025 Validation and FEED Studies (Ongoing)</td>
<td></td>
<td>200 kWe Long-Term Testing 5,000 and up to 8,000 hours</td>
<td>FEED Study for 1MWE SOFC System</td>
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<tr>
<td>Early-Stage Applied and Basic SOFC R&amp;D on Coal Syngas for Electricity and Hydrogen Generation</td>
<td></td>
<td>Effects of High-Temperature Operations on Materials Degradation</td>
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For Additional Information

NETL Website:  www.netl.doe.gov/

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