This presentation provides an overview of a Fossil Energy and Carbon Management (FECM) R&D Program that is implemented based on both Administration priorities and Congressional direction. Plans for future technology development reflect expected trajectories of current R&D, but these plans are subject to change. Furthermore, some stages of future technology development, although necessary for commercialization, may not be financially supported by the government.
SOFC Program: Near-Term Objectives

- Validate small-scale SOFC systems for distributed generation applications
- Develop efficient and cost-effective electrolyzers (SOEC) for hydrogen production
- Conduct R&D to mature SOFC and SOEC technologies and make progress towards low cost, high efficiency hydrogen production and power generation
SOFC Program: Funding History

![Bar chart showing funding history from 2000 to 2022.](chart.png)
SOFC Program Project Portfolio
FY22 Participants

*Multiple awards*
<table>
<thead>
<tr>
<th>Cell and Stack Degradation Modeling</th>
<th>Electrode Engineering</th>
<th>Systems Engineering and Analysis</th>
<th>High Temp Optical Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Development of comprehensive predictive modeling tool</td>
<td>• Mitigation of prominent degradation modes</td>
<td>• Public dissemination of SOFC market potential, performance, and cost advantages</td>
<td>• Multi-application technology under development for high temperature sensing</td>
</tr>
<tr>
<td>• Atoms to system scale bridging</td>
<td>• Successful transfer of technology to industry</td>
<td>• Hybrid configuration assessment</td>
<td>• Demonstrated in SOFC</td>
</tr>
<tr>
<td>• Validation through experiment</td>
<td></td>
<td>• Tie to R&amp;D goals and objectives</td>
<td>• In-situ sensing of temperature distribution and gas composition</td>
</tr>
<tr>
<td><strong>Cell and Stack Degradation Modeling</strong></td>
<td><strong>Electrode Engineering</strong></td>
<td><strong>Systems Engineering and Analysis</strong></td>
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</table>
| • Added to degradation modeling framework:  
  • Infiltrated materials  
  • Reversible SOFC operation  
  • Delamination/cracking  
  • Redox/thermal cycling  
  Created microstructural analysis tool for analyzing 3D electrode reconstructions  
  Developed machine learning methods for predicting lifetime performance from microstructural data | • Tested commercial SOFC in reversible mode  
  • Infiltrated commercial SOFC showed significant reduction in degradation when operating under electrolysis mode  
  • Novel materials discovery and fabrication  
  • Used additive manufacturing to produce cathodes with microstructural gradients in three dimensions | • Robust cell and stack production cost model completed  
 • Updated IGFC and NGFC techno-economic analyses  
 • Scoping study completed on hybrid carbon conversion technologies with SOFC component  
  • Collaboration with INL |
SOFC Accomplishments

Mohawk Innovative Technology

- High temperature Anode Exhaust Recycle Blower tested in FuelCell Energy’s 100 kW System for ~2,000 hours.
- 50% lower cost than state-of-the art after production of 100 units
- Potential to further lower cost by additional 20% with the use of Additive manufacturing
- Demonstration of collaboration between two standalone projects
SOFC Accomplishments

Aris Energy Solutions

• 3-year project between Aris Energy, NETL, WVU, and NASA

• SOFC Systems Testing at NETL Morgantown, WV Site

• NETL is testing dynamic operation of 4 X 1.5 kW BlueGEN SOFC systems distributed by Aris, manufactured by SOLIDPower

• 5.6 kW of power exported to NETL MGN grid beginning 12/2021

• Providing technical guidance to WVU/NASA for larger installation in Fairmont, WV
Develop technologies to reinvigorate the use of the United States' vast fossil-fuel resources and power infrastructure for net-zero carbon energy and commodity production through the production, transport, storage, and utilization of fossil-based hydrogen with zero or negative carbon emissions.

- Issue date: 1/15/2021
- Close date: 3/8/2021
- AOI 5: Solid Oxide Electrolysis Cell (SOEC) Technology Development for Hydrogen Production
- Total DOE Funds: $8M
- Number of awards: 8
<table>
<thead>
<tr>
<th>Awardee</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia Institute of Technology</td>
<td>Durable and High-Performance SOECs Based on Proton Conductors for Hydrogen Production</td>
</tr>
<tr>
<td>Massachusetts Institute of Technology</td>
<td>Improving Durability and Performance of Solid Oxide Electrolyzers by Controlling Surface Composition on Oxygen Electrodes</td>
</tr>
<tr>
<td>OxEon Energy LLC</td>
<td>Development of Stable Solid Oxide Electrolysis Cell for Low-Cost Hydrogen Production</td>
</tr>
<tr>
<td>The Regents of the Univ. of Calif., U.C. San Diego.</td>
<td>Development of Novel 3D Cell Structure and Manufacturing Processes for Highly Efficient, Durable and Redox Resistant Solid Oxide Electrolysis Cells</td>
</tr>
<tr>
<td>University of Louisiana at Lafayette</td>
<td>Development of High-Performance Metal-Supported SOECs and Innovative Diagnostic Methodologies</td>
</tr>
<tr>
<td>University of South Carolina</td>
<td>Developing Stable Critical Materials and Microstructure for High-Flux and Efficient H₂ production through Reversible Solid Oxide Cells</td>
</tr>
<tr>
<td>West Virginia University Research Corporation</td>
<td>Designing Internal Surfaces of Porous Electrodes in Solid Oxide Electrolysis Cells for Highly Efficient and Durable Hydrogen Production</td>
</tr>
<tr>
<td>Worcester Polytechnic Institute</td>
<td>Heterostructured Cr Resistant Oxygen Electrode for SOECs</td>
</tr>
</tbody>
</table>
SOEC Accomplishments

FuelCell Energy

Compact Stack Architecture (CSA)

Cell with active area of 81 cm²

Stack size for system demonstration

- 0.87 KW SOFC
- 1.6 KW SOEC
- 2.8 KW SOFC
- 5.4 KW SOEC
- 6.7 KW SOFC
- 12.7 KW SOEC
SOFC Program: Takeaways

- Conducting basic R&D to address critical needs and mature technology – SOFC and SOEC
- Acquiring fabricating and operational experience on integrated, prototype SOFC field tests
- Focusing on hybrid systems to produce hydrogen in SOEC mode and electricity in SOFC mode
- Prior and on-going SOFC R&D supported by FECM will provide the technology basis for SOEC development going forward
Questions?

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https://netl.doe.gov/coal/research/energy-systems/fuel-cells

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Shailesh.Vora@netl.doe.gov
412-386-7515

REFERENCE SHELF:
- SOFC Program Project Portfolio
- Workshop Proceedings
- Systems Analysis