Overview of SOFC Program at DOE NETL

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Preface

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 Structure

TECHNOLOGY AREA	KEY TECHNOLOGIES
SOLID OXIDE FUEL CELLS	Cell Development
	Core Technology
	Systems Development

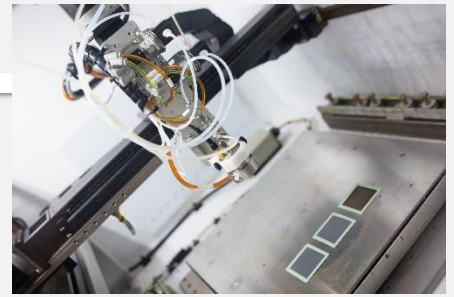


Figure courtesy NETL

Figure courtesy LG Fuel Cell Systems

Figure courtesy FuelCell Energy

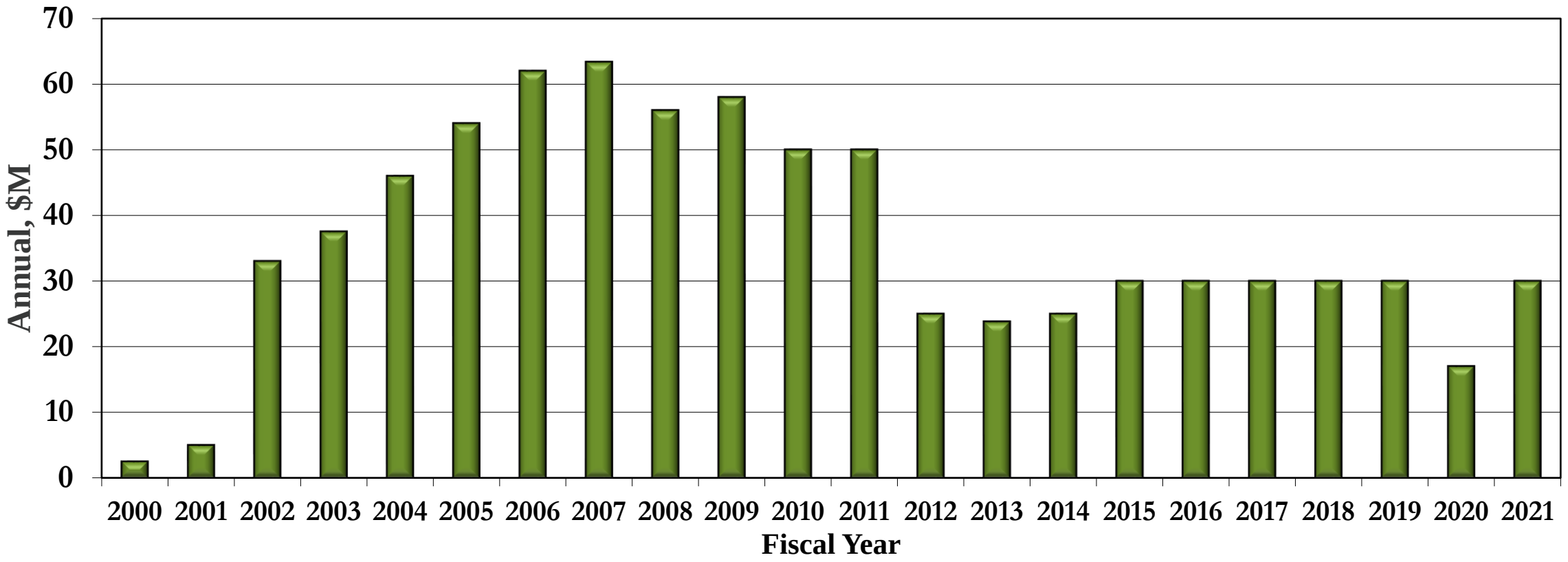
SOFC Program Metrics

Metric	Current	2025/2030 Target
System Cost (100 kW- 1MW)	>$12,000/kWe	$900/kWe
System Degradation	1 – 1.5% per 1,000 hrs	<0.2% per 1,000 hrs
Demonstration Scale	5 kWe – 200 kWe	DG: MWe-class Utility-scale: 10 – 50 MWe

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

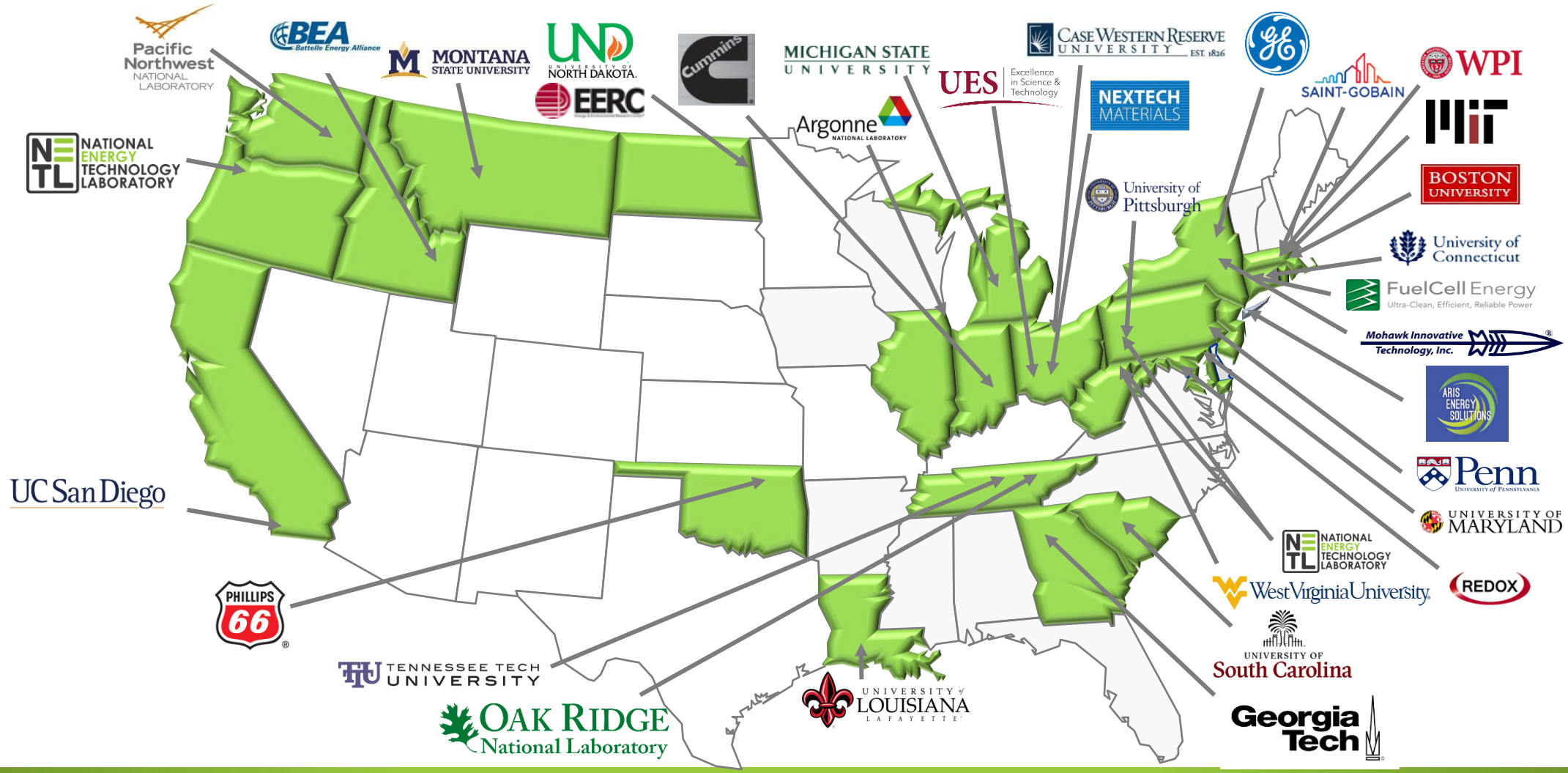
SOFC Program

Funding History



SOFC Program Project Portfolio

FY21 Participants



SOFC R&D at NETL Research and Inovation Center (RIC)

NATIONAL ENERGY TECHNOLOGY LABORATORY

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

NETL RIC - Accomplishments

NATIONAL ENERGY TECHNOLOGY LABORATORY

Cell and Stack Degradation Modeling

- **Formalized partnership with developer to integrate high temperature fiber optic sensors into SOFC stack**
- **Demonstrated ability to predict SOFC performance degradation from multiple modes**
  - Progress toward public release of predictive toolsets in 2021
- **Added to simulations:**
  - Infiltrated materials
  - Reversible SOFC operation
  - Delamination

Electrode Engineering

- **Tested commercial SOFC in reversible mode for 2400 h, cycling between fuel cell and electrolysis mode every 100 h**
  - Infiltrated commercial SOFC showed significant reduction in degradation when operating under electrolysis mode
- **Novel materials discovery and fabrication**

Systems Engineering and Analysis

- **Robust cell and stack production cost model completed**
  - Intended for public release March 2021
- **IGFC and NGFC techno-economic analyses under final NETL review**
  - Intended for public release March 2021
- **Scoping study completed on hybrid carbon conversion technologies with SOFC component**
  - Collaboration with INL

SOFC Program
The Role of other National Laboratories

- **Pacific Northwest National Laboratory**
  - Modeling & Simulation
  - Materials Development
  - SOFC Component Development
- **Argonne National Laboratory**
  - Cell Materials characterization and statistical analysis to improve batch-to-batch variability
  - Develop low-cost high-throughput diagnostic techniques
- **Oak Ridge National Laboratory**
  - Materials characterization
  - Mechanical testing of cell and stack materials
- **Idaho National Laboratory**
  - Partnership on hybrid fuel cell systems.

SOFC Prototype System Field Tests

FuelCell Energy

- 200 kWe integrated SOFC Power System
- Fabrication of ~2,000 full-scale cells
- ~5,800 hours operation - Full power for one of the two modules
- System power degradation < 1.5% per 1,000 hrs

20’ X 8’ X 8.5’

Cummins-Ceres Power

- 10 kWe integrated SOFC Power System
- ~1,000 hours operation
- System power degradation < 0.5% per 1,000 hrs

3.8’ X 1.8’ X 5.8’

Photo courtesy Ceres Power

FY 2020 FOA (DE-FOA-002300)

Small-Scale Solid Oxide Fuel Cell Systems and Hybrid Electrolyzer Technology Development

- Issue date: 5/28/2020
- $34M DOE, 20% cost share
- **AOI 1** – Small-scale distributed power generation SOFC systems.
- **AOI 2** – Hybrid systems using solid oxide systems for hydrogen and electricity production including the validation and development of materials and systems required for improving the cost, performance and reliability.
- **AOI 3** – Cleaning of coal-derived syngas for use as SOFC fuel and testing of single and multiple cells on syngas.

"Per the FY 2020 Energy and Water Appropriations Act Report (H.R. 1865 / Public Law 116–94) , "The Department is directed to issue a funding opportunity announcement for $30,000,000 for Solid Oxide Fuel Cells that includes all topic areas as outlined in the recommendations of the Department's August 2019 Report on the Status of the Solid Oxide Fuel Cell Program"

FOA-002300 Awards

AOI	Awardee (Prime)	Title
1	Cummins Inc.	Improving Cost and Efficiency of the Scalable SOFC Power System
1	Redox Power Systems, LLC	Small-Scale Solid Oxide Fuel Cell Systems and Hybrid Electrolyzer Technology Development
1	Aris Energy Solutions LLC	Modular Fuel Cells Providing Resiliency to Data Centers and Other Critical Power Users
2	The Regents of the Univ. of Calif., U.C. San Diego.	Efficient, Reliable and Cost-Effective Reversible Solid Oxide Cell Technology for Hydrogen and Electricity Production
2	Cummins Inc.	Cummins R-SOFC System Development
2	Phillips 66	A Highly Efficient and Affordable Hybrid System for Hydrogen and Electricity Production
2	FuelCell Energy, Inc.	Performance Improvements for Reversible Solid Oxide Fuel Cell Systems
2	Pacific Northwest National Laboratory	Low Cost, Large Area SOEC Stack for H2 & Chemicals
2	NexTech Materials, Ltd. dba Nexceris, LLC	Reversible Solid Oxide Fuel Cell System
2	Saint-Gobain Ceramics and Plastics	Reversible SOFC-SOEC Stacks Based on Stable Rare-Earth Nickelate Oxygen Electrodes
2	Battelle Energy Alliance, LLC (Idaho National Laboratory)	Performance Validation of a Thermally Integrated 50 kW High Temperature Electrolyzer System
3	University of North Dakota	Solid Oxide Fuel Cell Technology Development

FY 2021 FOA (DE-FOA-002400)

FOSSIL ENERGY BASED PRODUCTION, STORAGE, TRANSPORT AND UTILIZATION OF HYDROGEN APPROACHING NET-ZERO OR NET-NEGATIVE CARBON EMISSIONS

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

FOA-002400 Awards

Awardee	Title
Georgia Institute of Technology	Durable and High-Performance SOECs Based on Proton Conductors for Hydrogen Production
Massachusetts Institute of Technology	Improving Durability and Performance of Solid Oxide Electrolyzers by Controlling Surface Composition on Oxygen Electrodes
OxEon Energy LLC	Development of Stable Solid Oxide Electrolysis Cell for Low-Cost Hydrogen Production
The Regents of the Univ. of Calif., U.C. San Diego.	Development of Novel 3D Cell Structure and Manufacturing Processes for Highly Efficient, Durable and Redox Resistant Solid Oxide Electrolysis Cells
University of Louisiana at Lafayette	Development of High-Performance Metal-Supported SOECs and Innovative Diagnostic Methodologies
University of South Carolina	Developing Stable Critical Materials and Microstructure for High-Flux and Efficient H_2 production through Reversible Solid Oxide Cells
West Virginia University Research Corporation	Designing Internal Surfaces of Porous Electrodes in Solid Oxide Electrolysis Cells for Highly Efficient and Durable Hydrogen Production
Worcester Polytechnic Institute	Heterostructured Cr Resistant Oxygen Electrode for SOECs

SOFC Program: Takeaways

- Conducting additional basic R&D to address critical needs and mature technology – SOFC and SOEC
- Acquiring fabricating and operational experience on integrated, prototype field tests
- Potential for hybrid systems to produce hydrogen in SOEC mode and electricity in SOFC mode
- Prior and on-going SOFC R&D supported by FE will provide the technology basis for SOEC development going forward
- SOFC power systems offer a pathway to the highest efficiency and lowest cost electric power generation with CCS

Questions?

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

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REFERENCE SHELF:

- SOFC Program Project Portfolio
- Workshop Proceedings
- Systems Analysis

SOFC
SOLID OXIDE FUEL CELL