U.S. DOE Office of Fossil Energy
Solid Oxide Fuel Cell (SOFC) Program

Shailesh Vora

Technology Manager, Fuel Cells
National Energy Technology Laboratory

Fuel Cell Seminar
November 6, 2019

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

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

Figure courtesy NETL

Figure courtesy LG Fuel Cell Syster

Figure courtesy FuelCell Energy

SOFC Program

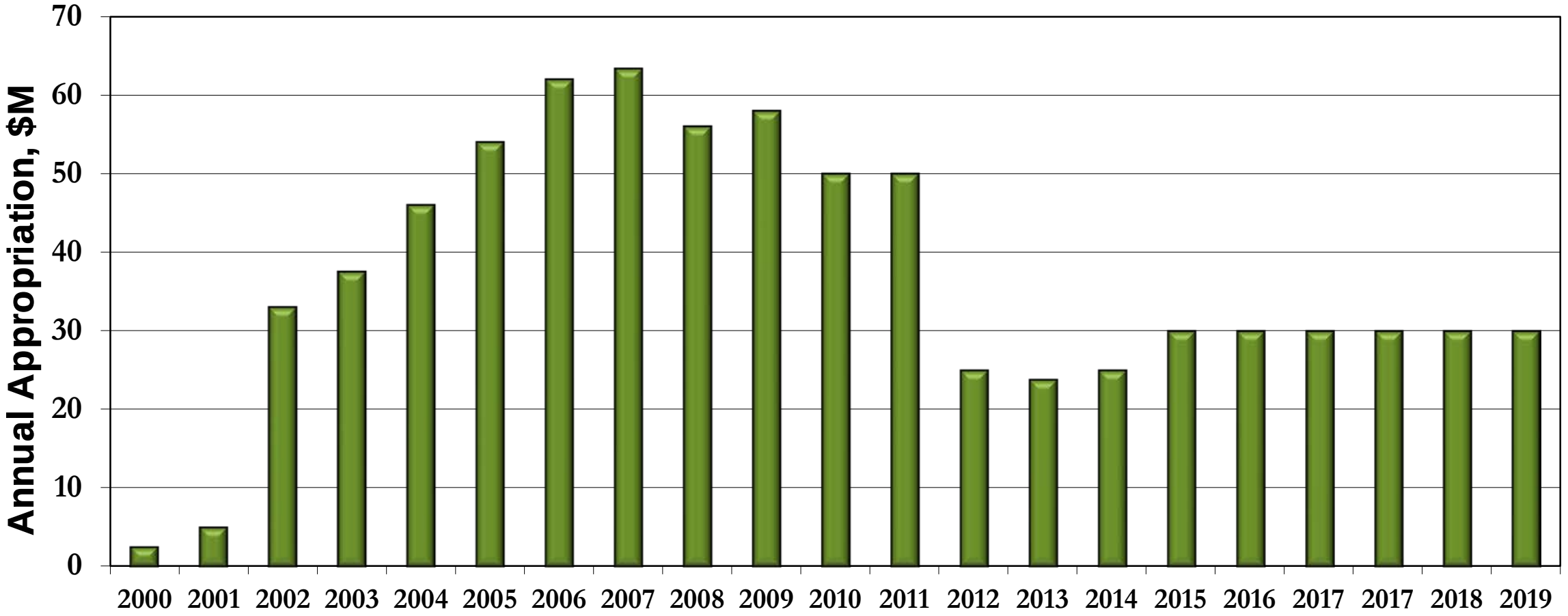
R&D Approach

- **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

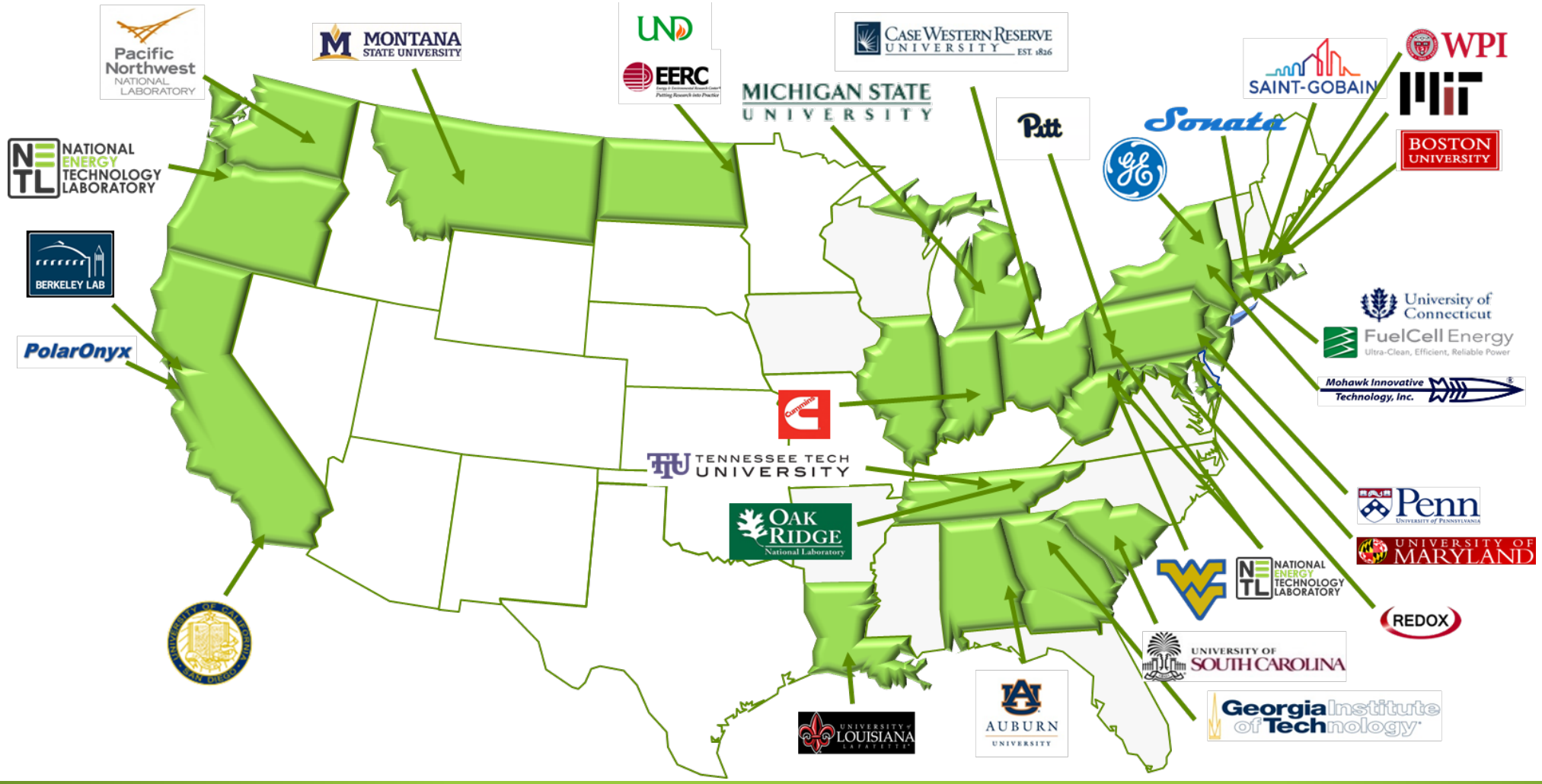
SOFC Program

Funding History



SOFC Program Project Portfolio

FY19 Participants



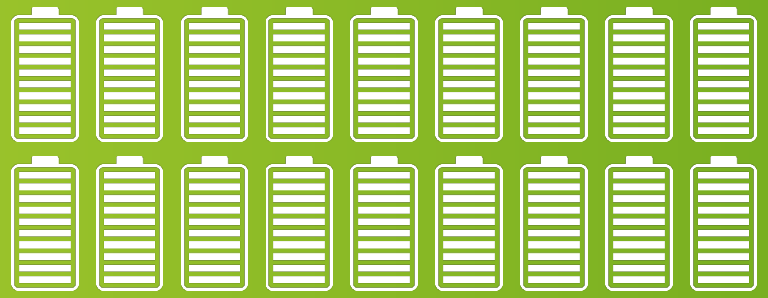
SOFC Program Metrics

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

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

SOFC Program

R&D Gaps

TECHNOLOGY	TOPIC
CELLS	MANUFACTURING/QC
	CHEMICAL INSTABILITY
STACKS 	MANUFACTURING/QC
	CONTACTS
	SEALS
SYSTEMS 	DEGRADATION
	RELIABILITY
	SYSTEM INTEGRATION
	BALANCE-OF-PLANT
	OPERATIONS

SOFC R&D at NETL

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

SOFC R&D at PNNL

NATIONAL ENERGY TECHNOLOGY LABORATORY

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

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.

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

For Additional Information

Office of Fossil Energy: www.energy.gov/fe/office-fossil-energy
NETL Website: www.netl.doe.gov/

Dr. Shailesh D. Vora
Technology Manager, Fuel Cells
National Energy Technology Laboratory
U. S. Department of Energy
412-386-7515
Shailesh.Vora@netl.doe.gov