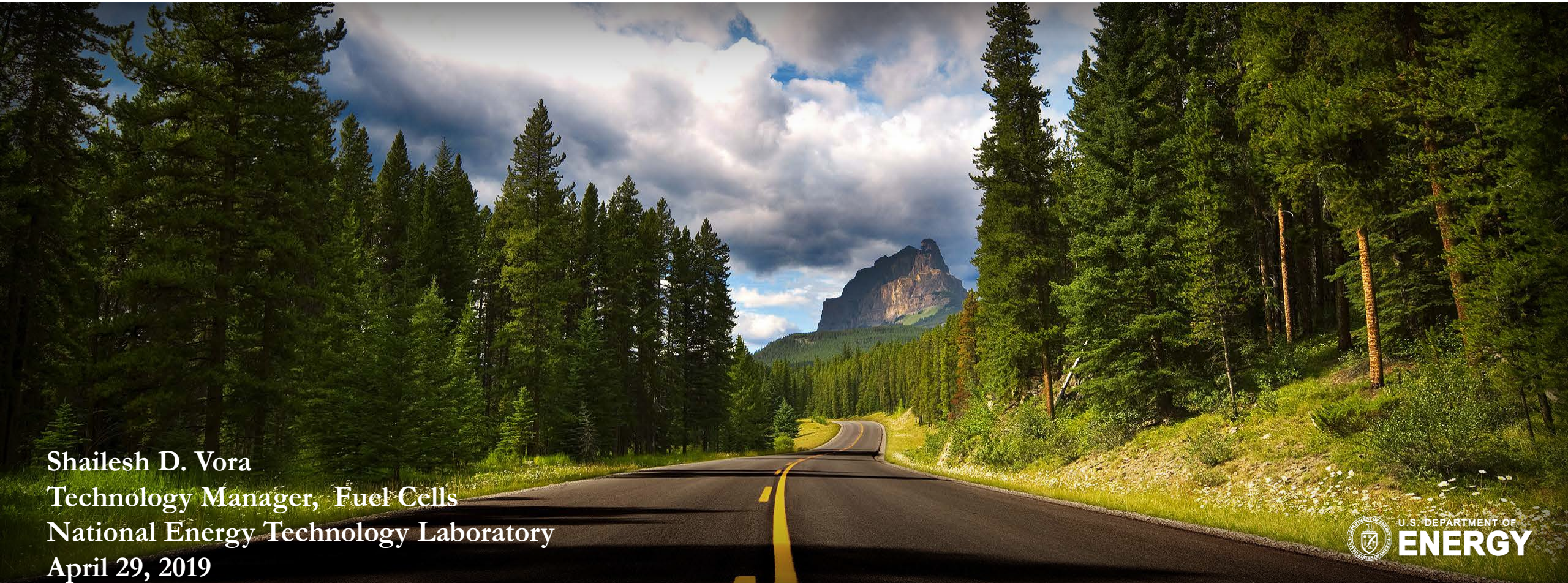
U.S. DOE Office of Fossil Energy Solid Oxide Fuel Cell (SOFC) Program



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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 Systems

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

The SOFC Program is focused on the design, scale-up, and integration of the SOFC technology into modules and systems, and the development and testing of progressively larger stacks/systems.

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**

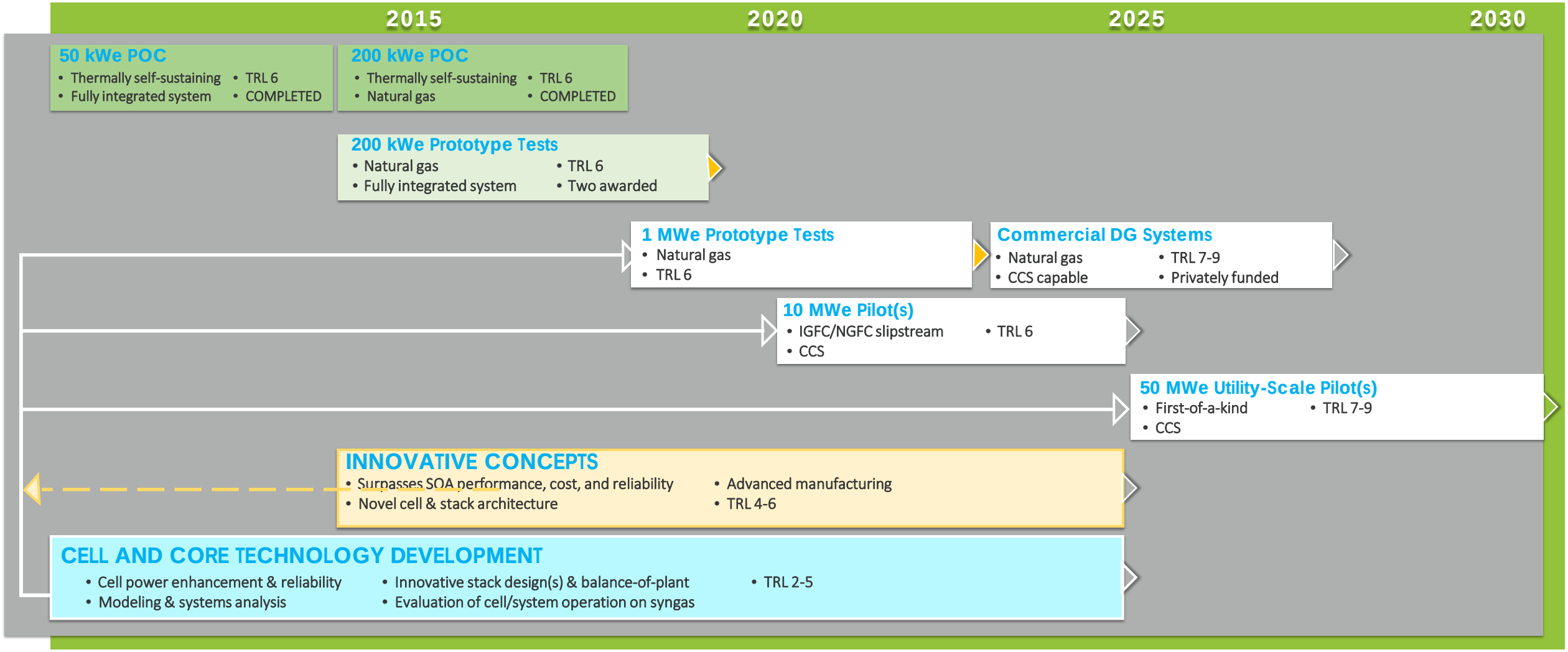
Single-cell performance and degradation are acceptable; stack and system performance, reliability and endurance need to be demonstrated

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 Program Development Timeline



SOFC R&D at NETL

Cell and Stack Degradation Modeling	Electrode Engineering	Systems Engineering and Analysis	High Temp Optical Sensors
• Development of comprehensive predictive modeling tool • Atoms to system scale bridging • Validated through experiment	• Mitigation of prominent degradation modes • Successful transfer of technology to industry	• Public dissemination of SOFC market potential, performance, and cost advantages • Hybrid configuration assessment • Tie to R&D goals and objectives	• 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	Modeling	Small-Scale SOFC Test Platform
• Quantitative understanding of Cr poisoning • Validation of Cr capture materials • Enhanced reliability of cathode/contact material interfaces • Cobalt-free protective coatings for metallic interconnects	• Advanced Reduced Order Models (ROM) for accurate simulation of stack performance in system models • Modeling to mitigate stack degradation and increase reliability	• 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: NRG Energy Center Pittsburgh, PA
- Natural gas fuel, Grid Connected
- Target operating time: 5,000 hrs

Photo courtesy FuelCell Energy

SOFC Power System

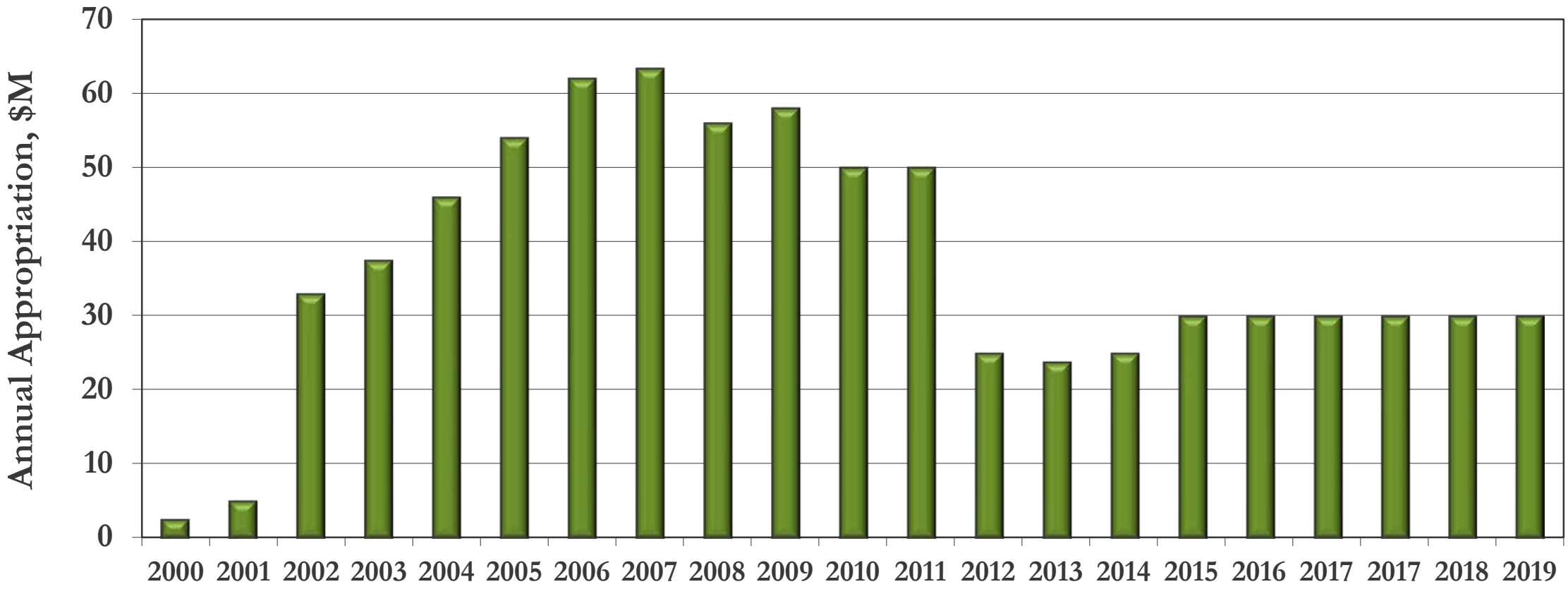
LG Fuel Cell Systems 250 kW Prototype Testing

- 250 kW integrated SOFC Power System
- Test site: Stark State College
  North Canton, OH
- Natural gas fuel, grid connected
- 1,300 hrs on load
- Efficiency: 55% AC
- Power degradation: 0.3% per 1000 hrs

Photo courtesy LG Fuel Cell Systems

SOFC Program

Funding History



SOFC Program

Key Takeaways

- Program now emphasizing the resolution of design, operation, and performance considerations at the system level
- Acquiring fabricating and operational experience on integrated, prototype field tests based on state-of-the-art cell and stack technology
- Cell Development and Core Technology research continues and is well aligned with industry need

For Additional Information

Office of Fossil Energy: www.energy.gov/fe/office-fossil-energy

NETL Website: www.netl.doe.gov/

SOFC Program website: www.netl.doe.gov/coal/research/energy-systems/fuel-cells

Reference Shelf:

- SOFC Program Project Portfolio
- SOFC Technology Program Plan
- Technology Readiness Assessment
- Past Workshop Proceedings
- Systems Analysis
- Fuel Cell Handbook

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