

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



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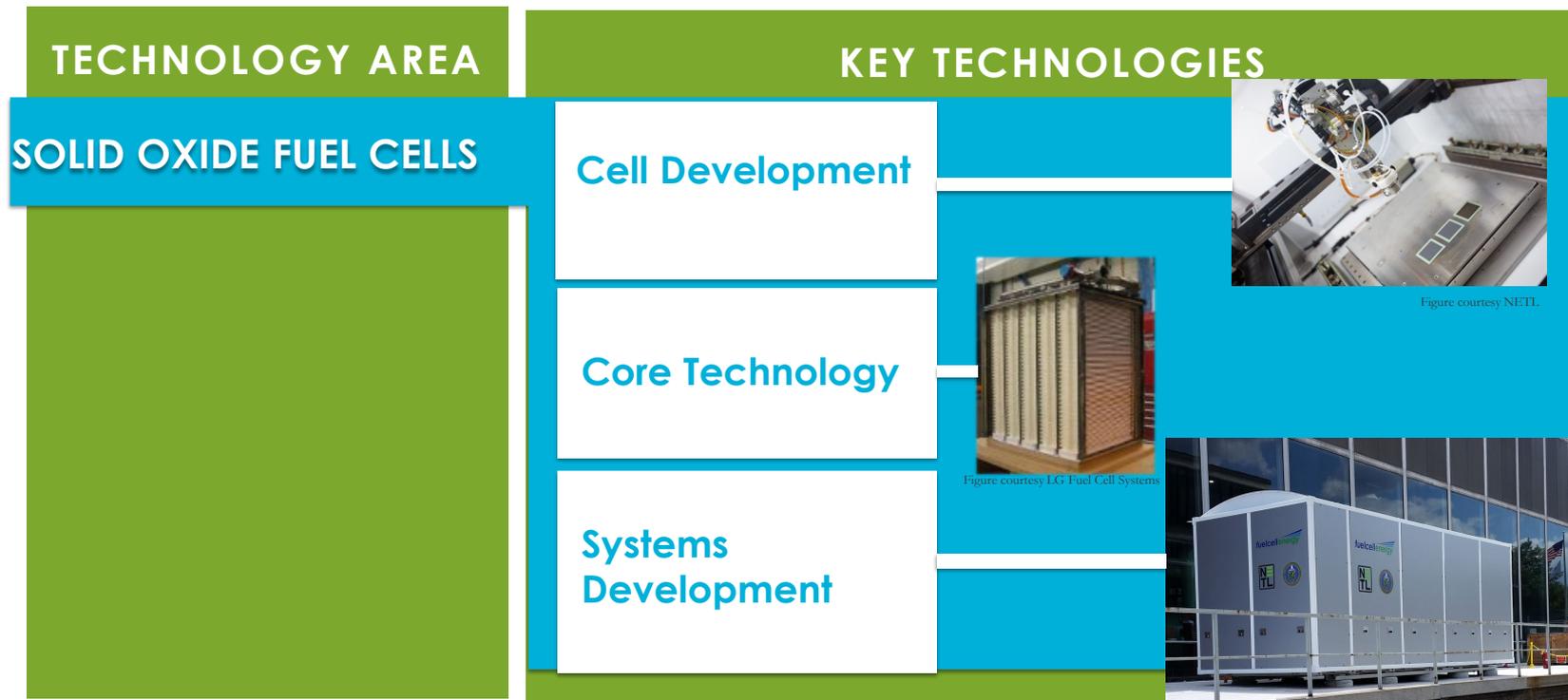
# SOFC Program Mission

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



# 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

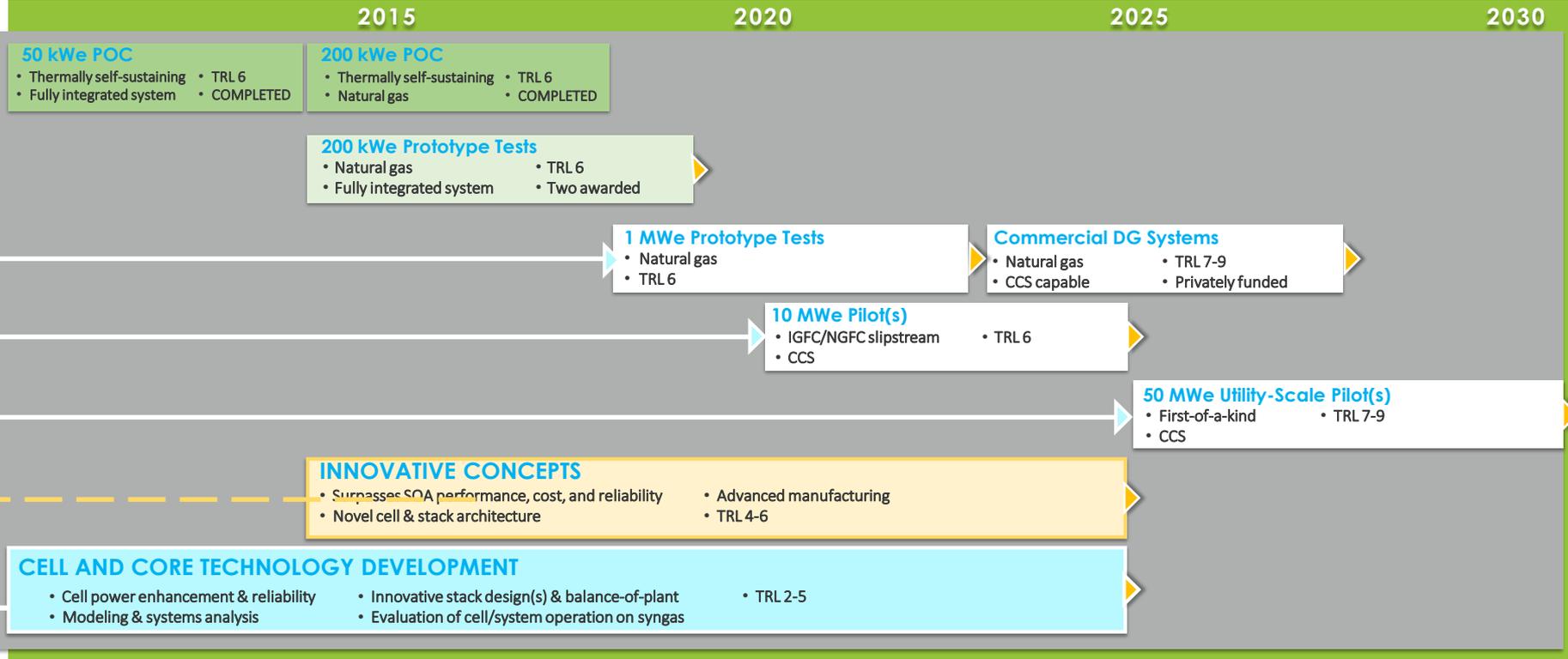
*Single-cell performance and degradation meet targets; system performance, cost and durability are being evaluated*

# 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
<ul style="list-style-type: none"><li>• Development of comprehensive predictive modeling tool</li><li>• Atoms to system scale bridging</li><li>• Validated through experiment</li></ul>	<ul style="list-style-type: none"><li>• Mitigation of prominent degradation modes</li><li>• Successful transfer of technology to industry</li></ul>	<ul style="list-style-type: none"><li>• Public dissemination of SOFC market potential, performance, and cost advantages</li><li>• Hybrid configuration assessment</li><li>• Tie to R&amp;D goals and objectives</li></ul>	<ul style="list-style-type: none"><li>• Multi-application technology under development for high temperature sensing</li><li>• Demonstrated in SOFC</li><li>• In-situ sensing of temperature distribution and gas composition</li></ul>

# SOFC R&D at Pacific Northwest National Laboratory (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 Systems

## 1. FuelCell Energy 200 kW Prototype Field-Test

- 200 kW<sub>e</sub> 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 Systems

## 2. LG 250 kW Prototype Field-Test

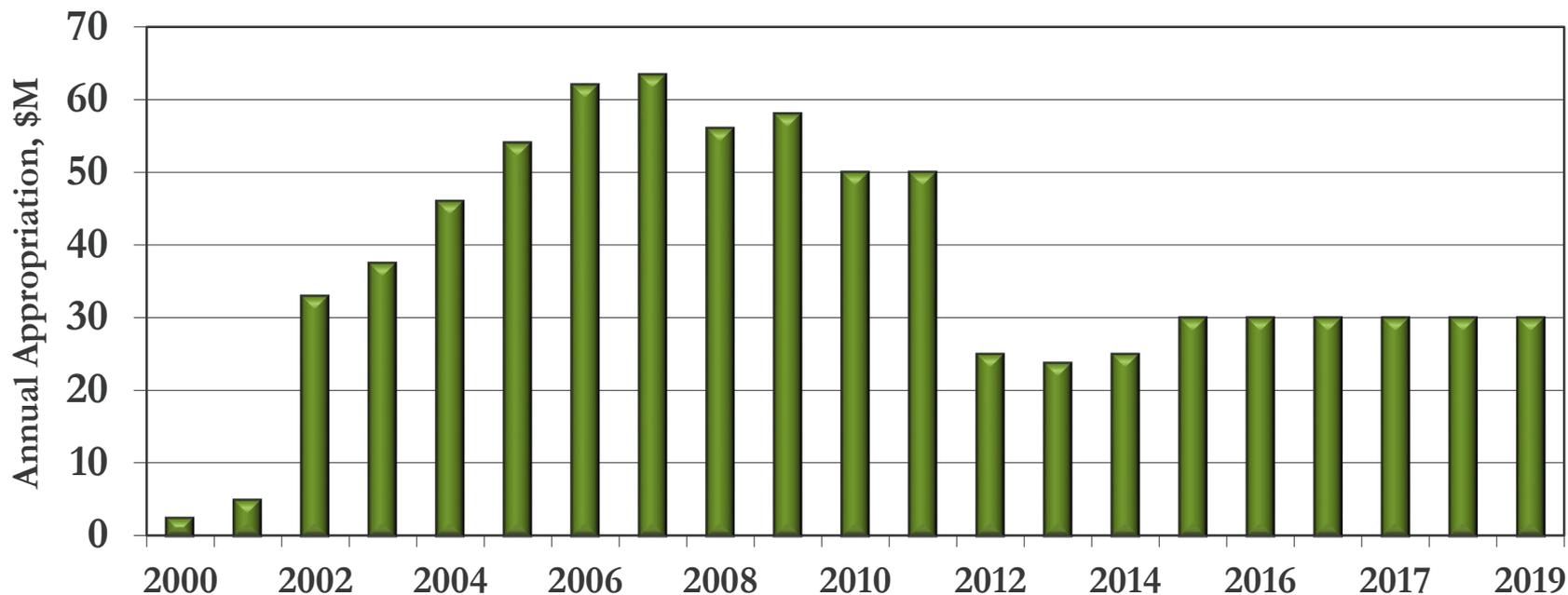
- 250 kW integrated SOFC Power System
- Test site: Stark State College  
North Canton, OH
- Natural gas fuel, grid connected
- 1,300 hrs on load
- Efficiency: 55% AC
- Power degradation: 0.3% per 1000 hrs



Photo courtesy LG Fuel Cell Systems

# SOFC Program

## DOE Funding History



# SOFC Program

## *Key Takeaways*



- **Emphasizing the resolution of design, operation, and performance considerations at the system level**
- **Acquiring fabricating and operational experience on integrated, prototype field tests**
- **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](http://www.energy.gov/fe/office-fossil-energy)

NETL Website: [www.netl.doe.gov/](http://www.netl.doe.gov/)

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