Office of Fossil Energy's Solid Oxide Fuel Cell Program Overview

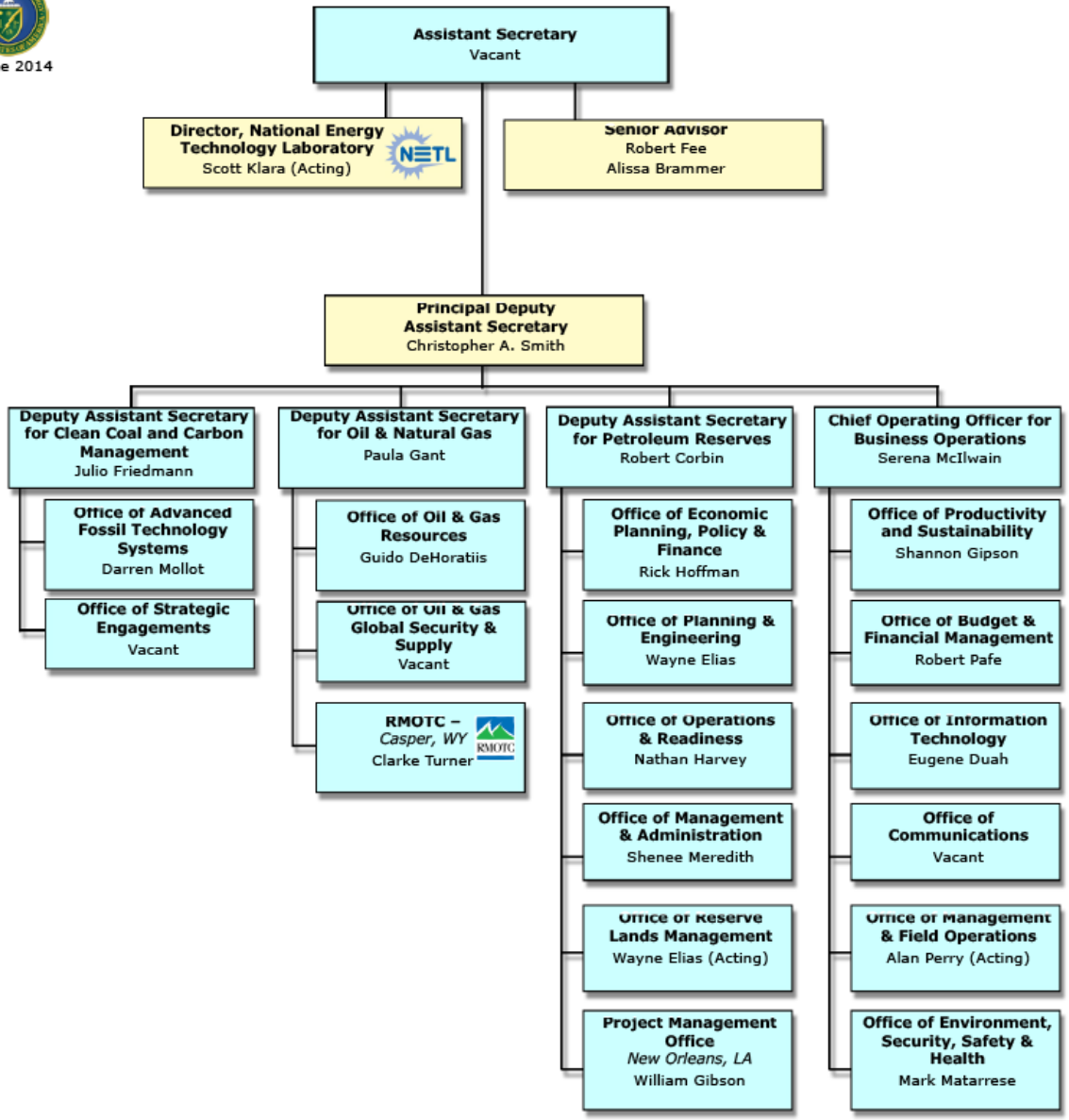
Shailesh D. Vora
Technology Manager, Fuel Cells
National Energy Technology Laboratory

15th Annual SECA Workshop
Pittsburgh, PA
July 22 -23, 2014

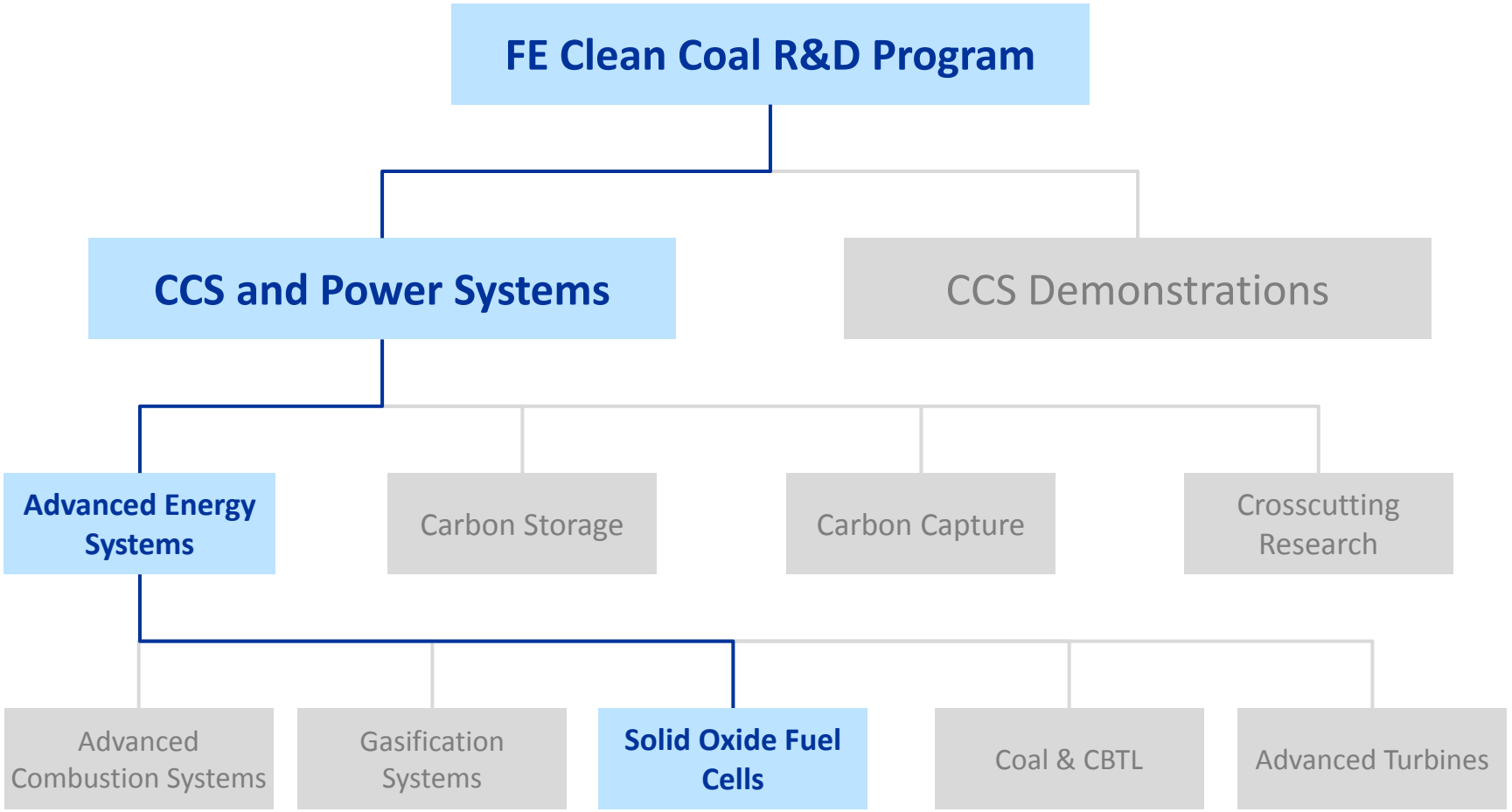
U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

Office of Fossil Energy (FE)

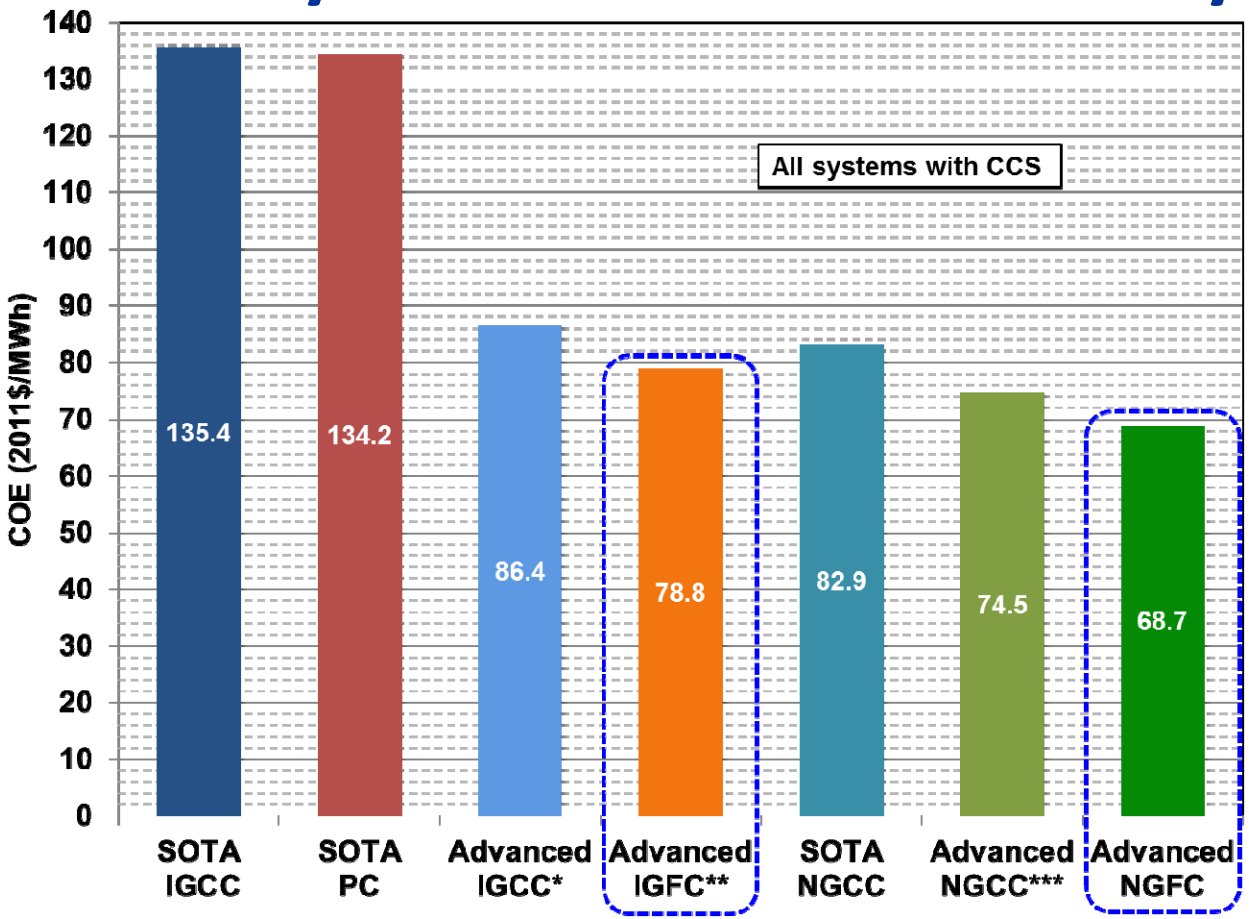
June 2014



FE Solid Oxide Fuel cells (SOFC) Program



SOFC Power Systems – Cost of Electricity (COE)



SOTA: State of the Art
IGCC: Integrated Gasification Combined Cycle
PC: Pulverized Coal
IGFC: Integrated Gasification Fuel Cell
NGCC: Natural Gas Combined Cycle
NGFC: Natural Gas Fuel Cell

*** Advanced IGCC system includes: coal feed pump, warm gas cleanup, H_2 membrane, advanced H_2 turbine, and ITM**

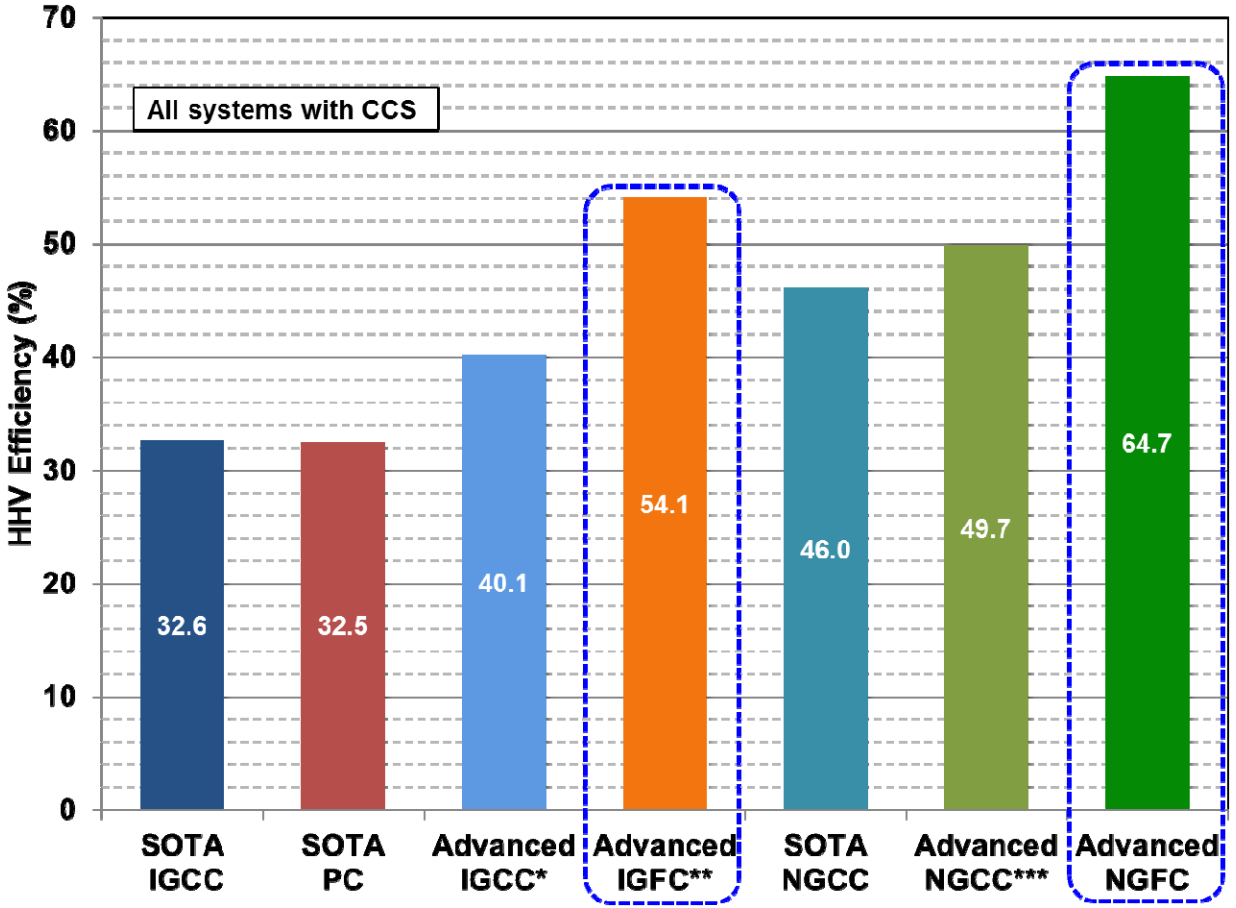
**** Advanced IGFC system includes catalytic gasifier, 0.2% degradation rate, and internal reforming**

***** Advanced NGCC system features a J-class turbine with a state-of-the-art carbon capture system**

Advanced SOFC systems are cost-competitive with IGCC and NGCC Systems

Source: NETL Systems Analysis

SOFC Power Systems - Efficiency



SOTA: State of the Art
IGCC: Integrated Gasification Combined Cycle
PC: Pulverized Coal
IGFC: Integrated Gasification Fuel Cell
NGCC: Natural Gas Combined Cycle
NGFC: Natural Gas Fuel Cell

*** Advanced IGCC system includes: coal feed pump, warm gas cleanup, H_2 membrane, advanced H_2 turbine, and ITM**

**** Advanced IGFC system includes catalytic gasifier, 0.2% degradation rate, and internal reforming**

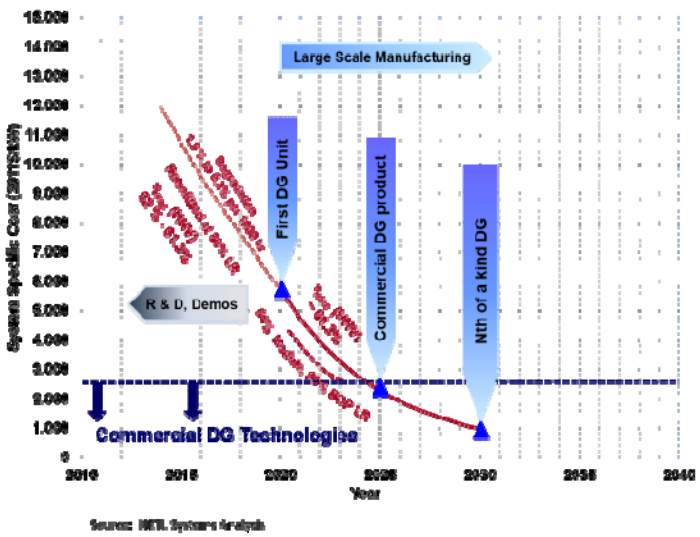
***** Advanced NGCC system features a J-class turbine with a state-of-the-art carbon capture system**

SOFC system performance is superior to all other systems

Source: NETL Systems Analysis

SOFC: Meets DG Market Need

- **SOFC Natural Gas DG all-electric power application**
  - Provides > 20 percentage point gain in efficiency
  - Substantially reduces CO_2 emissions (lb/kWh)



- **Cost-competitive SOFC DG product by circa 2020**
- **Projected learning curve to achieve competitive cost is consistent with similar technology commercialization experience**

SOFC Natural Gas DG applications will provide pathway to utility scale coal and natural gas-fueled power plants with >97% carbon capture

SOFC Program

- **Focus:**
  - Near Term: Natural gas distributed generation (DG)
  - Long Term: Coal and natural gas central station applications with CCS
- **Targets:**
  - System Performance Degradation: 0.2%/1,000 hours
  - Stack Cost: $225/kWe*
  - Power Block Cost: $900/kWe*
- **Development Timeline**

  FY2016: 125 kWe-class Module Test

  FY2018: FOAK** 250 kWe Power System Field Test

  FY2020: FOAK ** 1 MWe-class Power System at customer site

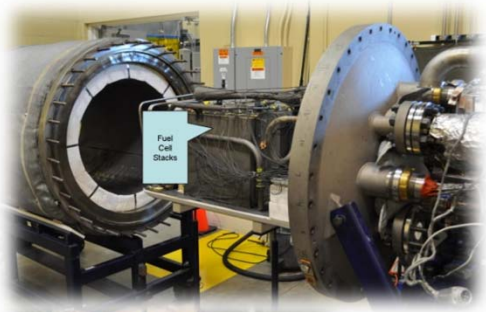
  Post-FY2020: Utility-scale IGFC/NGFC Central Station

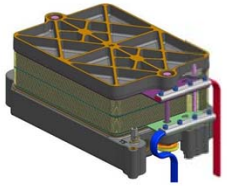
Based on progressively larger natural gas-fueled validation tests, MWe-class DG SOFC Power Systems that are *cost-competitive* with existing DG technologies are envisioned circa 2020

* N^{th} –of-a-kind at specified volume, 2011$s

*** FOAK – First-of-a-Kind*

SOFC Program - Structure





R &D Needs
Research Topics

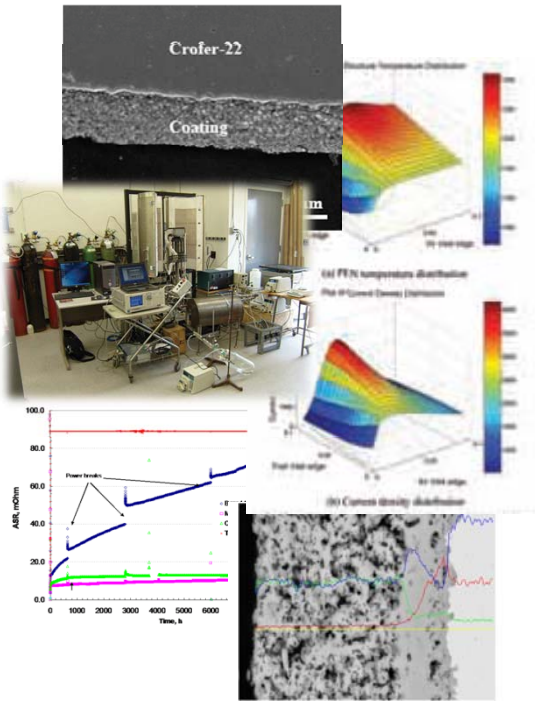
Core Technology
Program

(Universities, NLs)

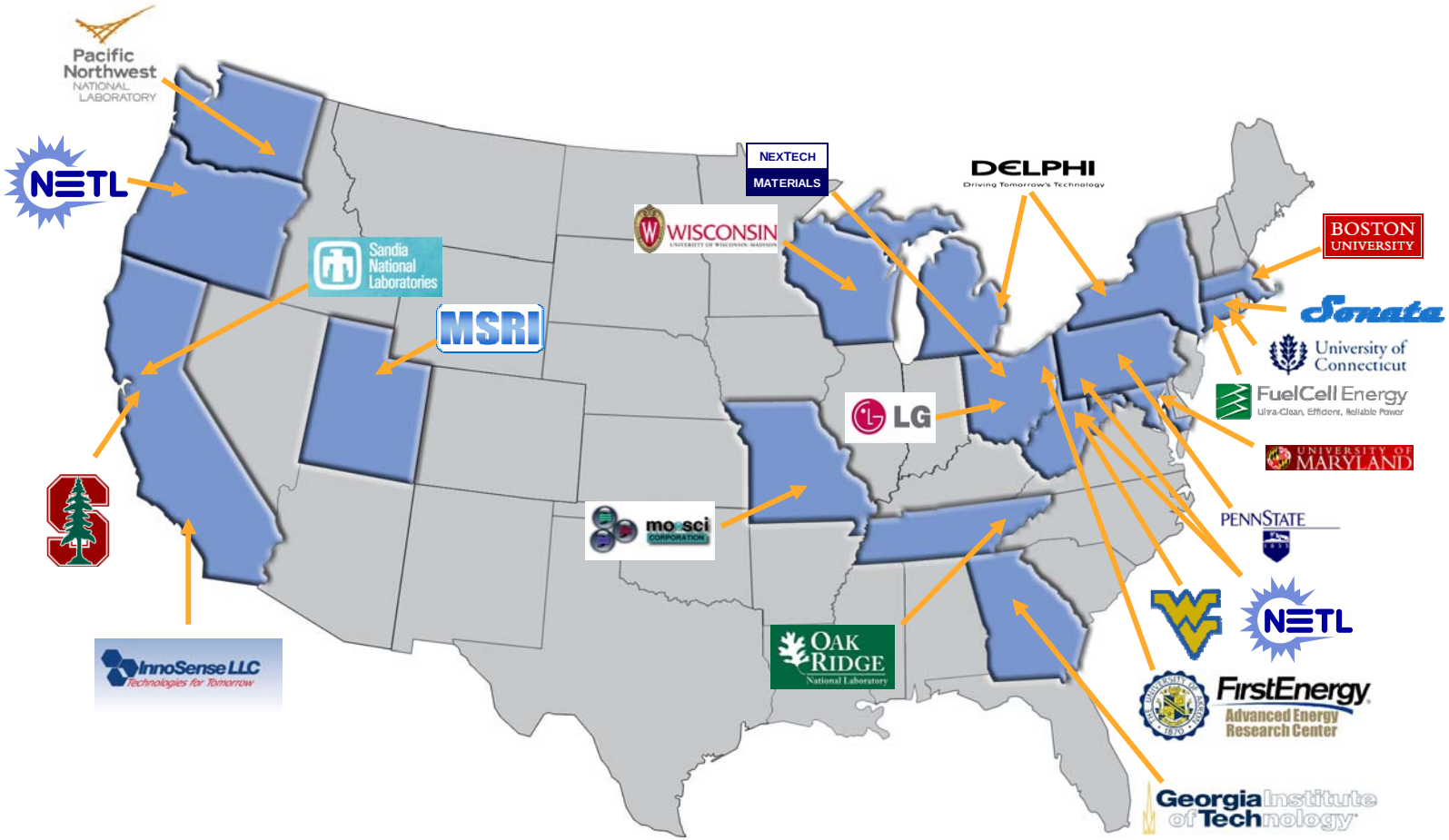
Technology
Transfer

Industry

Teams

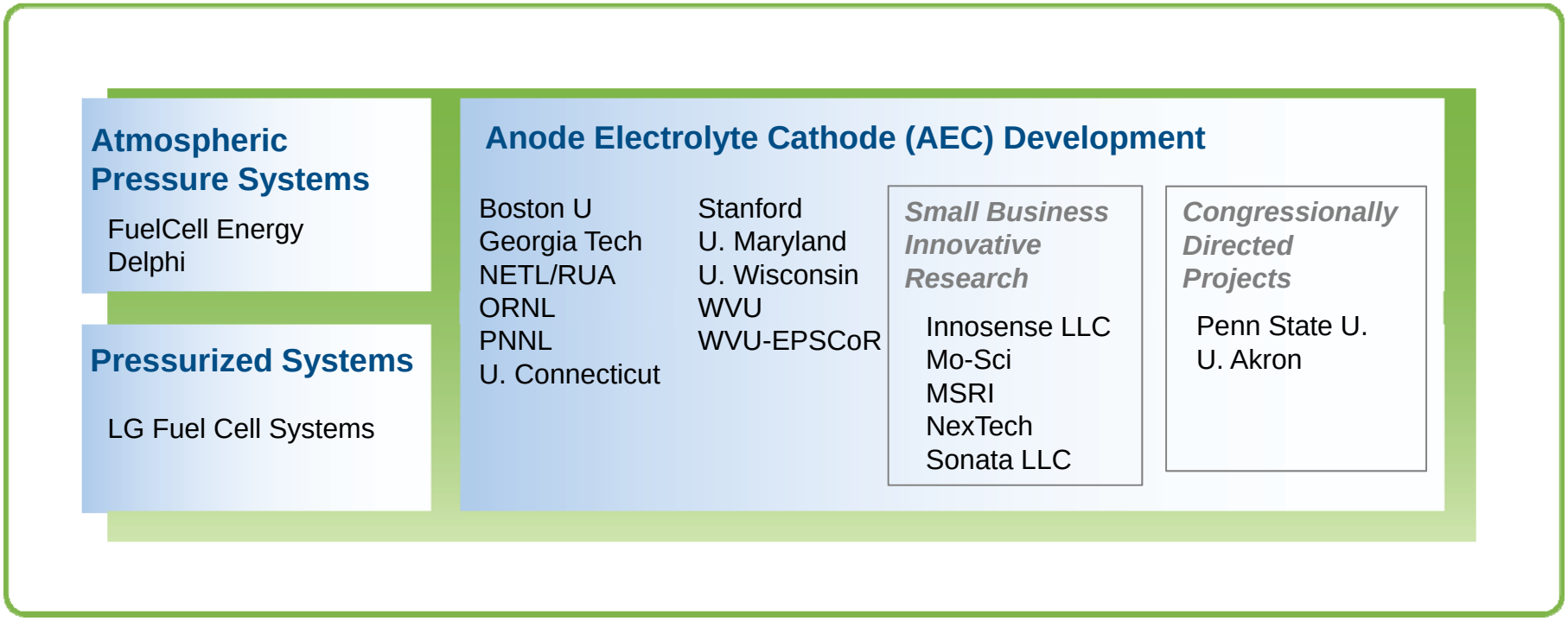


SOFC Program – FY 14 Projects

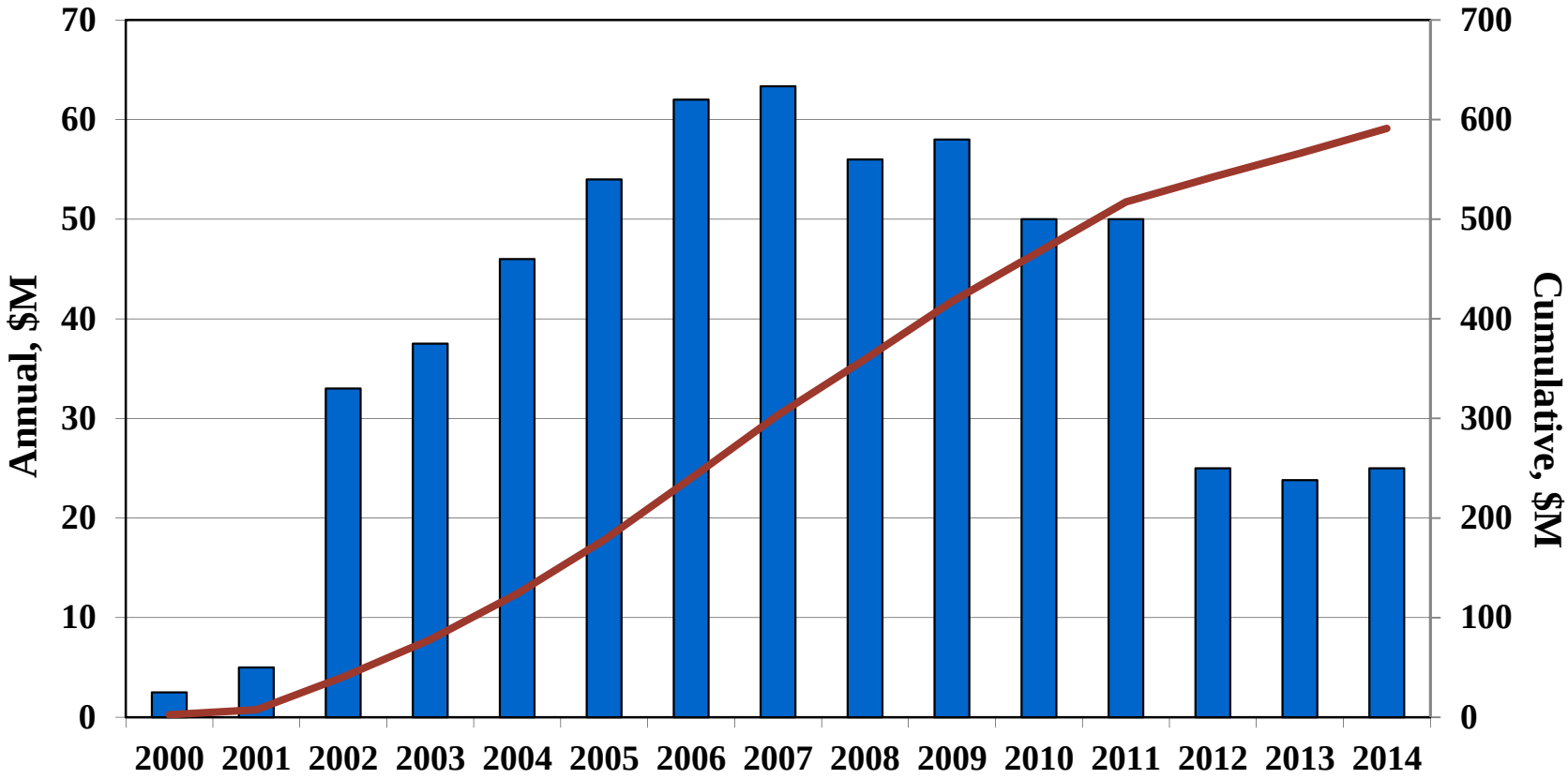


The SOFC program supports a diversified portfolio of ~20 R&D projects

SOFC Program - Project Portfolio



SOFC Program - Budget History



Since its inception as the Solid State Energy Conversion Alliance (SECA), the U.S. Department of Energy has invested nearly $600M in SOFC technology

SOFC Program - Challenges

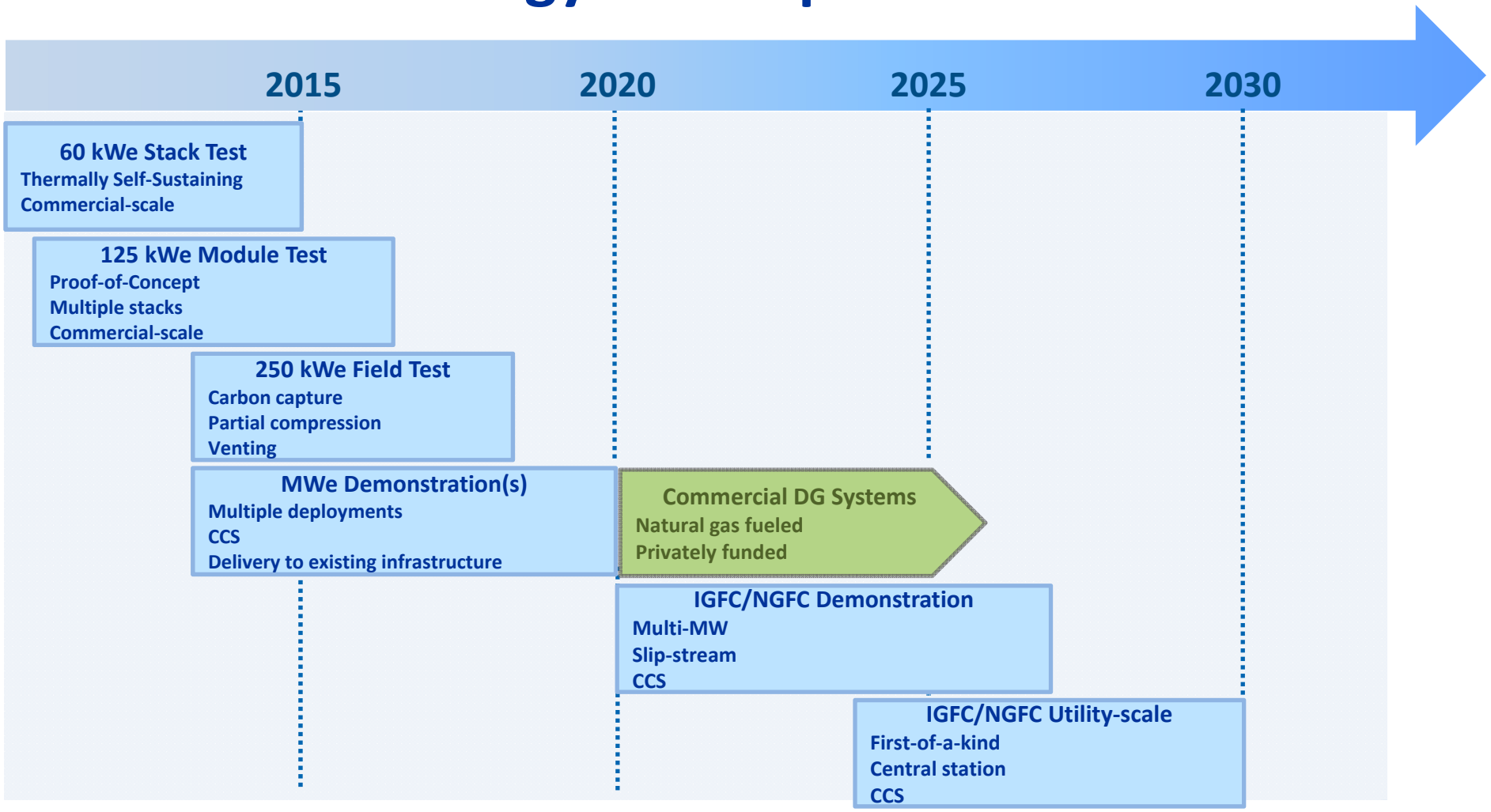
- **Improved Cell Performance**
  - Today: Overpotential = 140 mV at normal operating conditions
  - Target: Overpotential = 70mV at normal operating conditions
- **Improved Durability and Reliability**
  - Today: Lab-scale stack tests
  - Target: Fully-integrated SOFC power systems
- **Reduced System Performance Degradation**
  - Today: 1 – 1.5% per 1,000 hours
  - Target: 0.2% per 1,000 hours
- **Fuel Reformation**
  - Today: Primarily external fuel (natural gas) conditioning/reformation
  - Target: 100% integrated fuel reformation inside fuel cell stack
- **Manufacturing**
  - Today: Batch processing
  - Target: Advanced manufacturing techniques

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

FY14 SOFC Program Update

- Two competitive solicitations
  - 11 projects selected
  - 2 Industry Teams, 9 Core Technology
- Increased emphasis on system level testing
- Increased emphasis on Industry Team – Core Technology collaboration
- Peer Review of 7 Projects
- Updated NETL and SOFC Program website
- Web-based SOFC Program Portfolio
- Three new SBIR projects

Technology Development Timeline



Natural gas fueled DG systems will establish the manufacturing and operational experience necessary to validate and advance the technology for both natural gas and gasified coal-based central power generation

SOFC Program … *Key Takeaways*

- **Focus on cost reduction and increased reliability**
- **Demonstrations at system-level are critical**
- **Industry Team - Core Technology collaboration is essential**
- **Look out for and take advantage of revolutionary advances in materials and manufacturing processes**

A technically and economically viable SOFC system will create market-pull

15th Annual SECA Workshop - Overview

Tuesday

- *Plenary Session: ARPA-E, Booz Allen Hamilton*
- *Industry Team Presentations*
- *National Laboratories*

Tuesday Evening Poster Session and Reception

Wednesday

- *Plenary Session: Synopsis of Interconnection Development*
- *Core Technology Teams: Cathodes*
- *Core Technology Teams: Modeling*
- *Core Technology Teams: Protective Coatings*

15th Annual SECA Workshop Participants

Web-sites and Contact Information

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

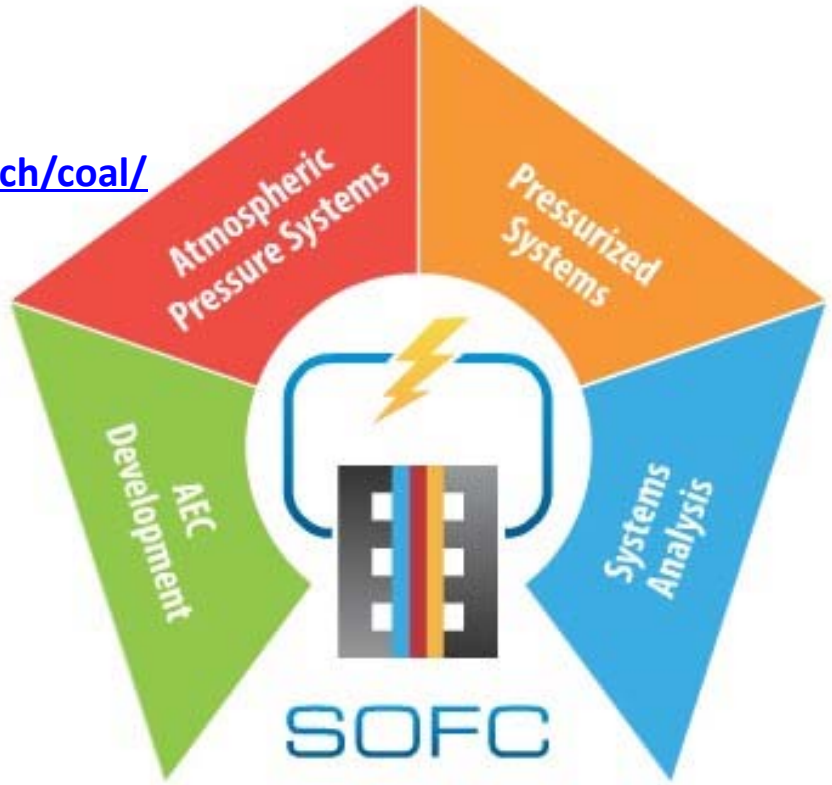
NETL Website: www.netl.doe.gov/

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

Reference Shelf:

- SOFC Program FY14 Project Portfolio
- SOFC Technology Program Plan
- Technology Readiness Assessment
- Past SECA Workshop Proceedings
- Systems Analysis
- Fuel Cell Handbook

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



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

SOFC Program – FY14 Selections

Recipient	Title	DOE Share	Recipient Cost Share
Acumentrics	Advanced SOFC Quality Control and the Role of Manufacturing Defects on Stack Reliability	$788,267	$197,067
Boston University	Mitigation of Chromium Impurity Effects and Degradation in SOFCs: Understanding Transport and Thermodynamics	$800,000	$200,000
Case Western Reserve University	Long Term Degradation of LSM-Based SOFC Cathodes: Use of a Proven Accelerated Test Regimen	$798,175	$326,759
University of Connecticut	Materials and Approached for the Mitigation of SOFC Cathode Degradation in SOFC Power Systems	$800,000	$202,125
Michigan State University	Durable, Impermeable Brazes for Solid Oxide Fuel Cells	$694,026	$173,506
University of Pennsylvania	Cost-Effective Manufacturing and Morphological Stabilization of Nanostructured Cathodes for Commercial SOFCs	$800,000	$200,070
University of South Carolina	University-Industry Driven Partnership to Develop Reliable, Robust and Active SOFC Cells and Stacks	$500,000	$283,170
West Virginia University Research Corporation	Novel Nanostructured-Tailored Highly Active and Stable Electro-Catalytic Architecture on Surface of Cathode of SOFCs	$500,000	$157,822
West Virginia University Research Corporation	Scalable and Cost-Effective Barrier Layer Coating to Improve Performance and Stability of SOFC Cathode	$800,000	$243,586
FuelCell Energy Inc.	Reliable SOFC Systems	$7,500,000	$1,875,000
LG Fuel Cell Systems	Improved Reliability of Solid Oxide Fuel Cell Systems	$7,500,000	$1,875,000