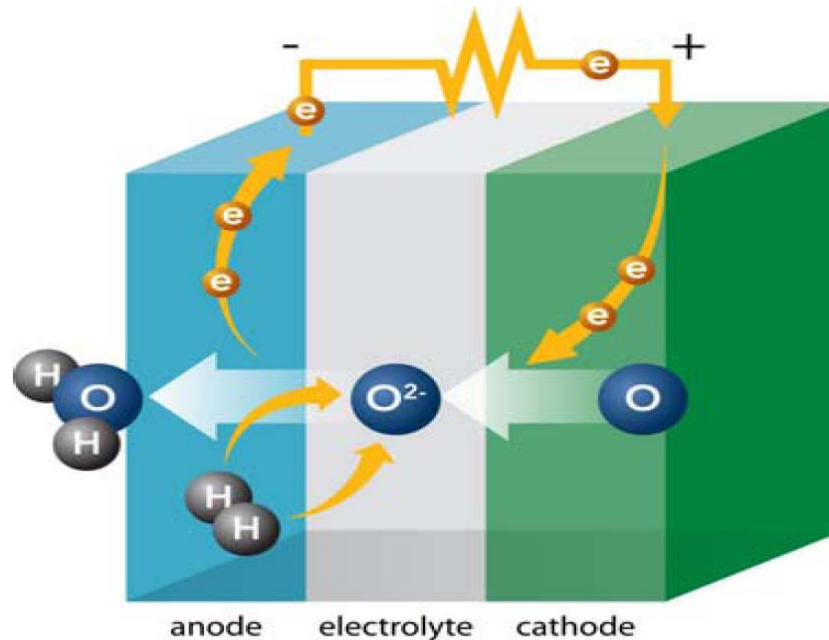


Hydrogen & Fuel Cell Technical Advisory Committee

June 3, 2010



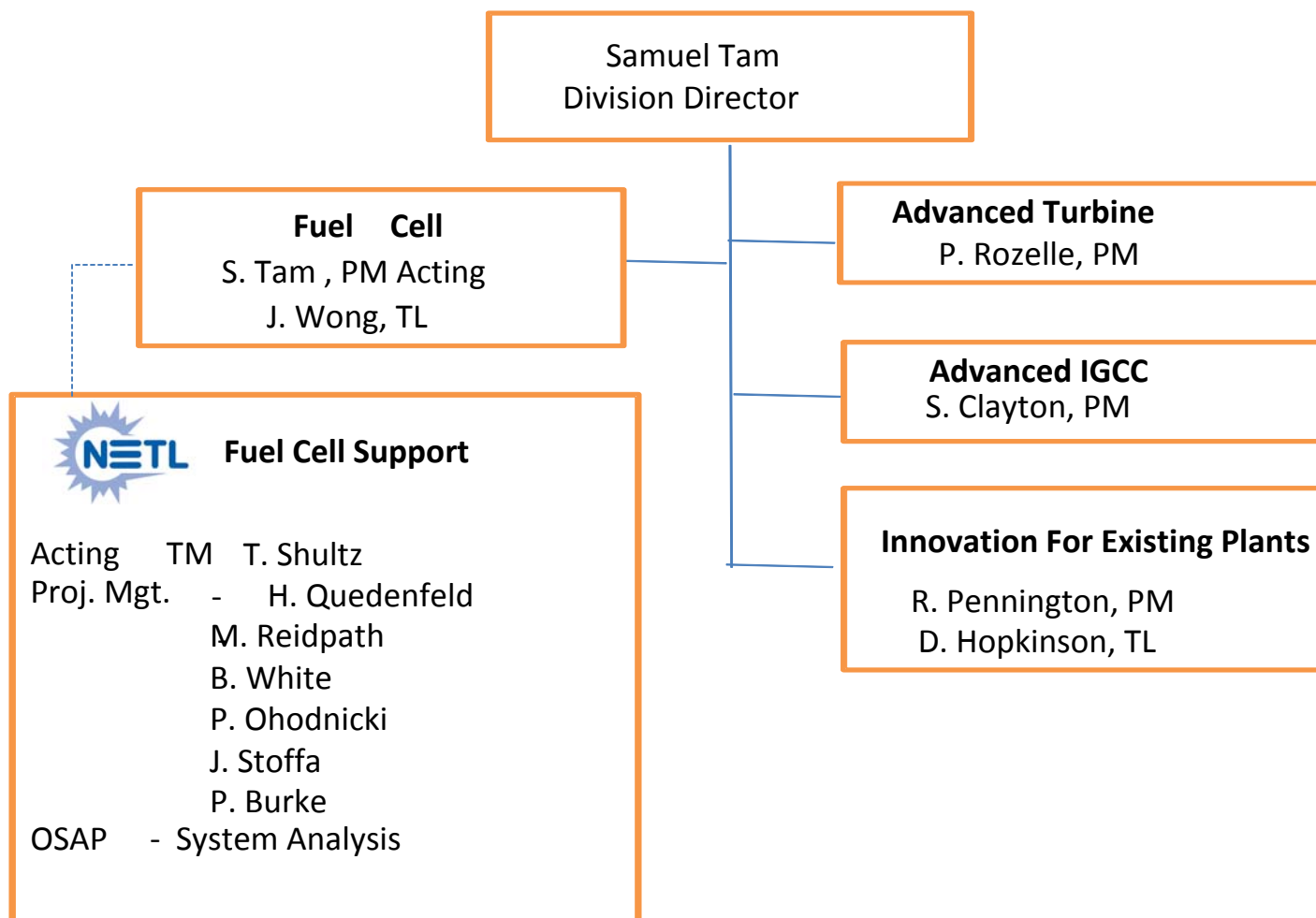
Fuel

Samuel Tam
Director

Division of Clean Energy Research



Division of Clean Coal Energy Research Office of Clean Energy Systems





Revolutionizing Power Production & Use

SECA as a key part of DOE's Strategy to Reduce Electrical Energy Losses

Current Technology

Coal Generation



35% Efficiency
(65% Loss)

Transmission & Distribution



31% Efficiency
(11% Loss)

End-Use Light



4% Efficiency
(87% Loss)

DOE Programs for Tomorrow

SECA IGFC System



60% Efficiency
(40% Loss)

Smart Grid



55% Efficiency
(8% Loss)

Solid-State Lighting



>40% Efficiency
(27% Loss)



DOE's Office of Fossil Energy

Advanced (Coal) Power Systems Goals

- 2010:
 - **45-50% Efficiency (HHV)**
 - **99% SO₂ removal**
 - **NO_x < 0.01 lb/MM Btu**
 - **90% Hg removal**
- 2012:
 - **90% CO₂ capture**
 - **<10% increase in COE with carbon sequestration**
- 2015
 - **Multi-product capability (e.g., power + H₂)**
 - **60% efficiency (measured without carbon capture)**



Green – fuel cell has impacts

- Enable the generation of efficient, cost-effective electricity from domestic coal with near-zero atmospheric emissions of CO₂ and air pollutants (99% CO₂ capture) and minimal use of water in central power generation applications.
- Provide the technology base to permit grid-independent distributed generation applications.

*60% Efficiency
(Coal HHV
w/o CCS)*

*≥ 99% CO₂
Capture*

*Environmental:
<0.5ppm NO_x,
low H₂O use*

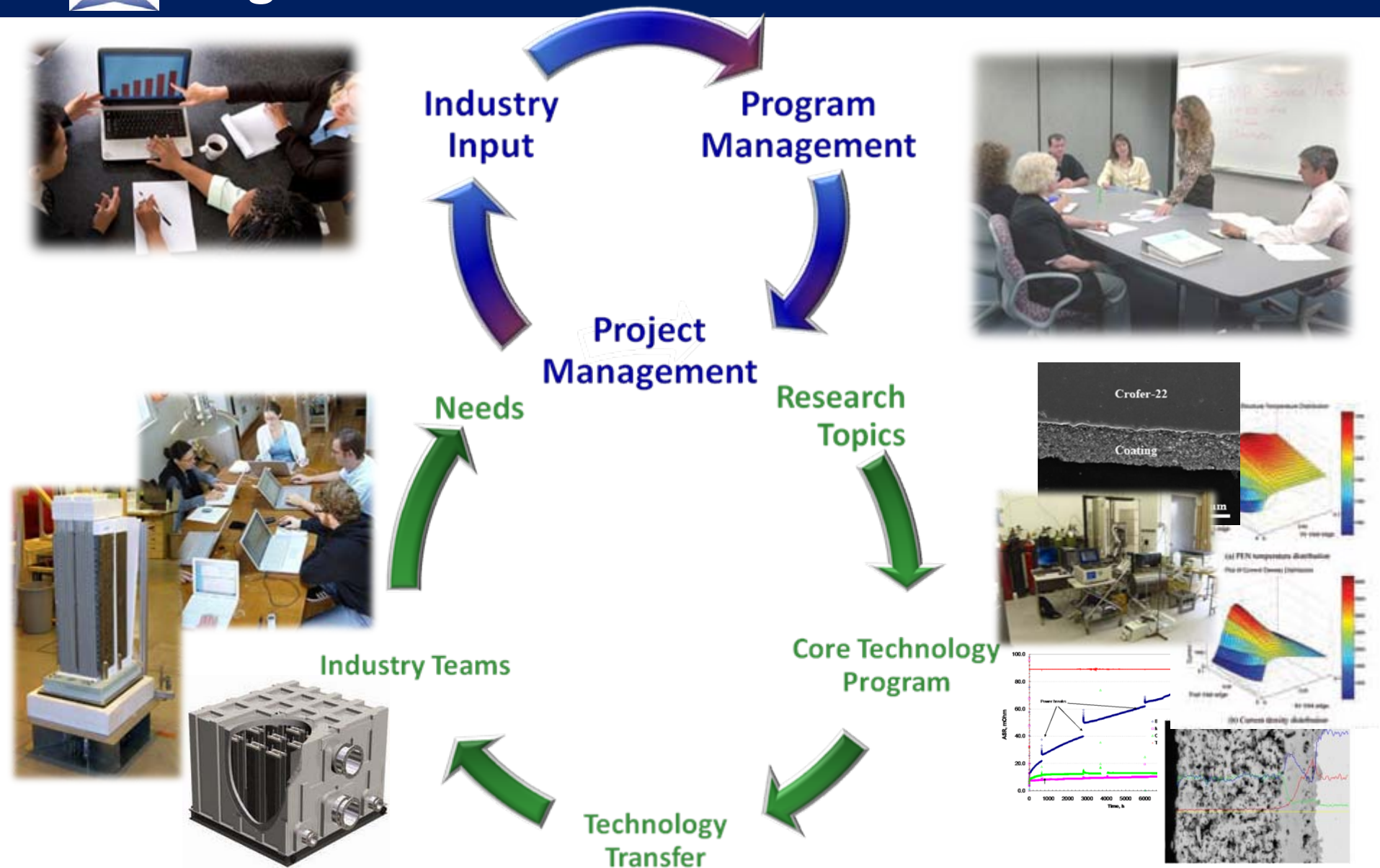
*Low Cost,
similar footprint
to IGCC*

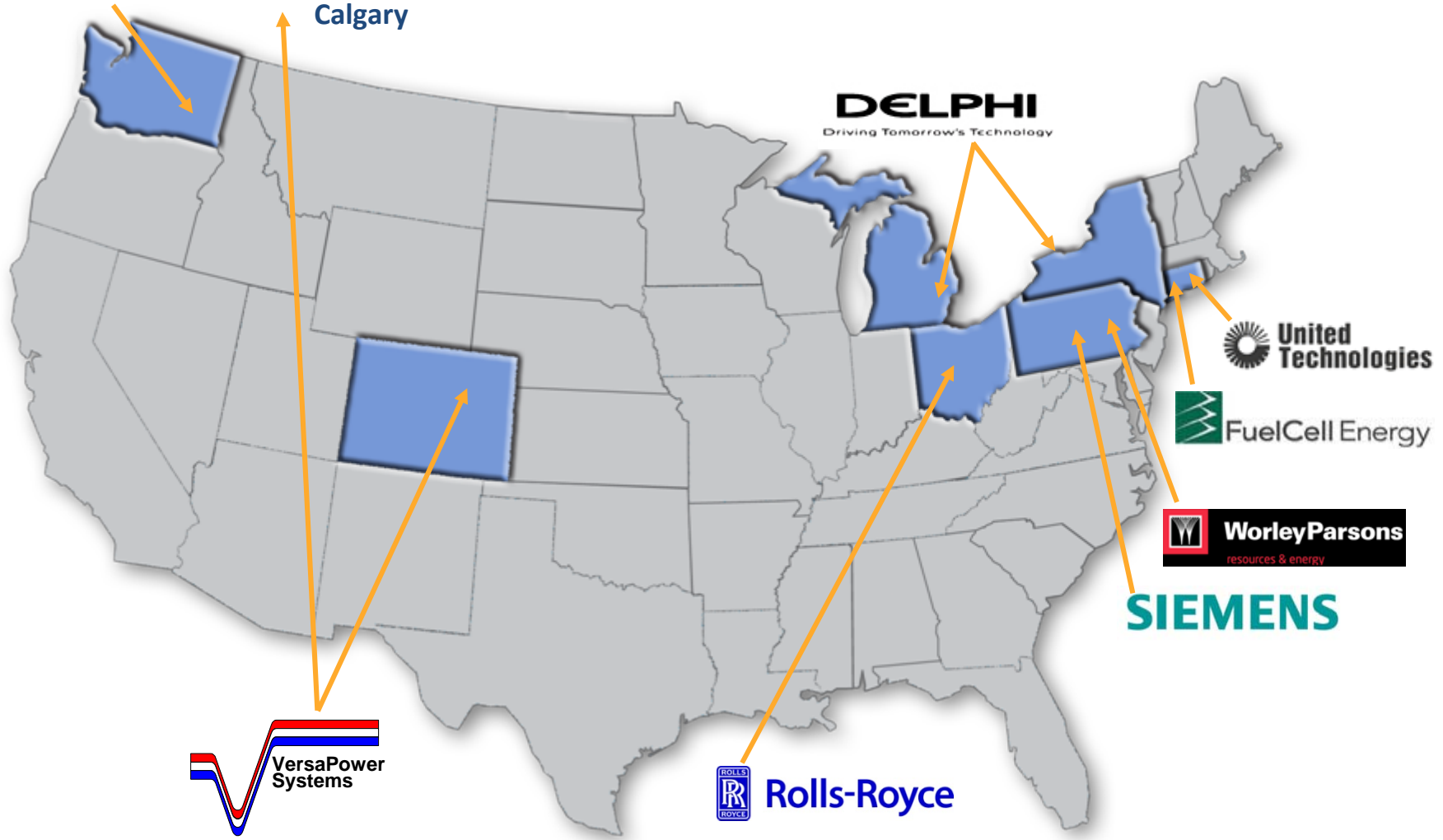
*Modular
Technology*

*Fuel-Flexible:
Syngas, NG,
H₂, Diesel,
etc.*



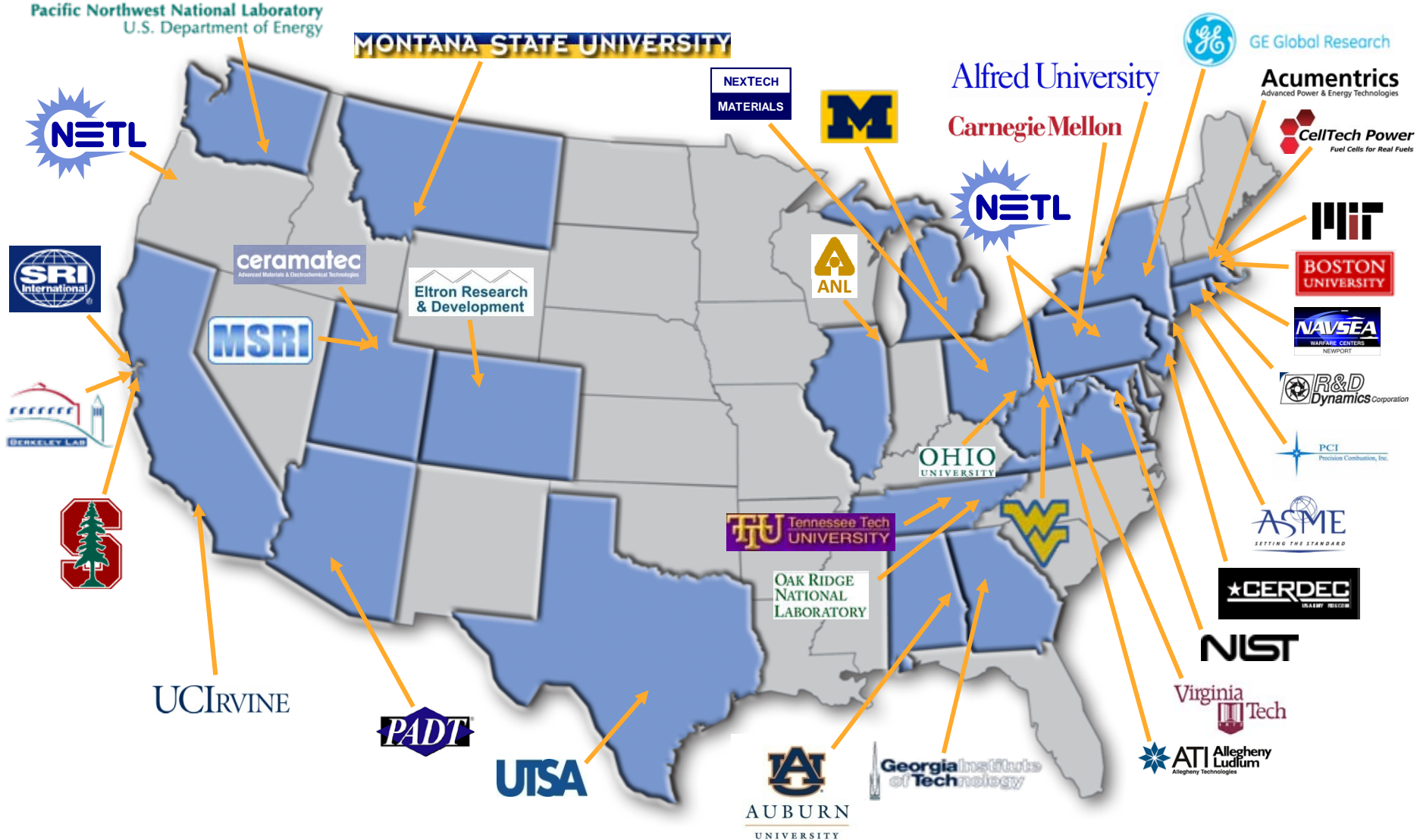
Program Structure







Core Technology & Other Partners

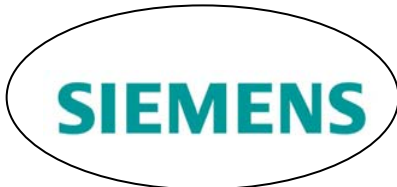
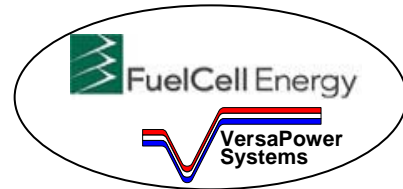




Intellectual Property

Cornerstone of the Alliance

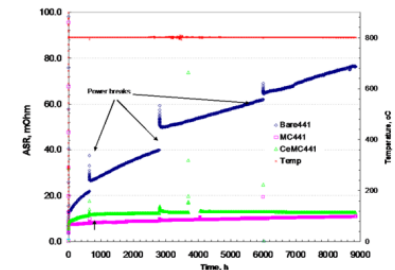
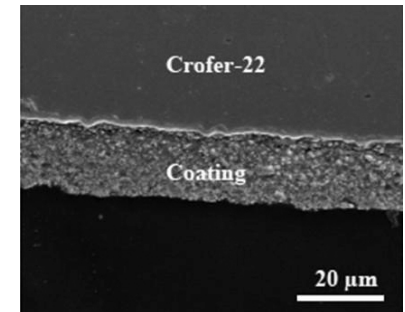
Industry Teams Develop Proprietary Technologies



Non-Exclusive Licenses

Exceptional Circumstance to Bayh-Dole Act

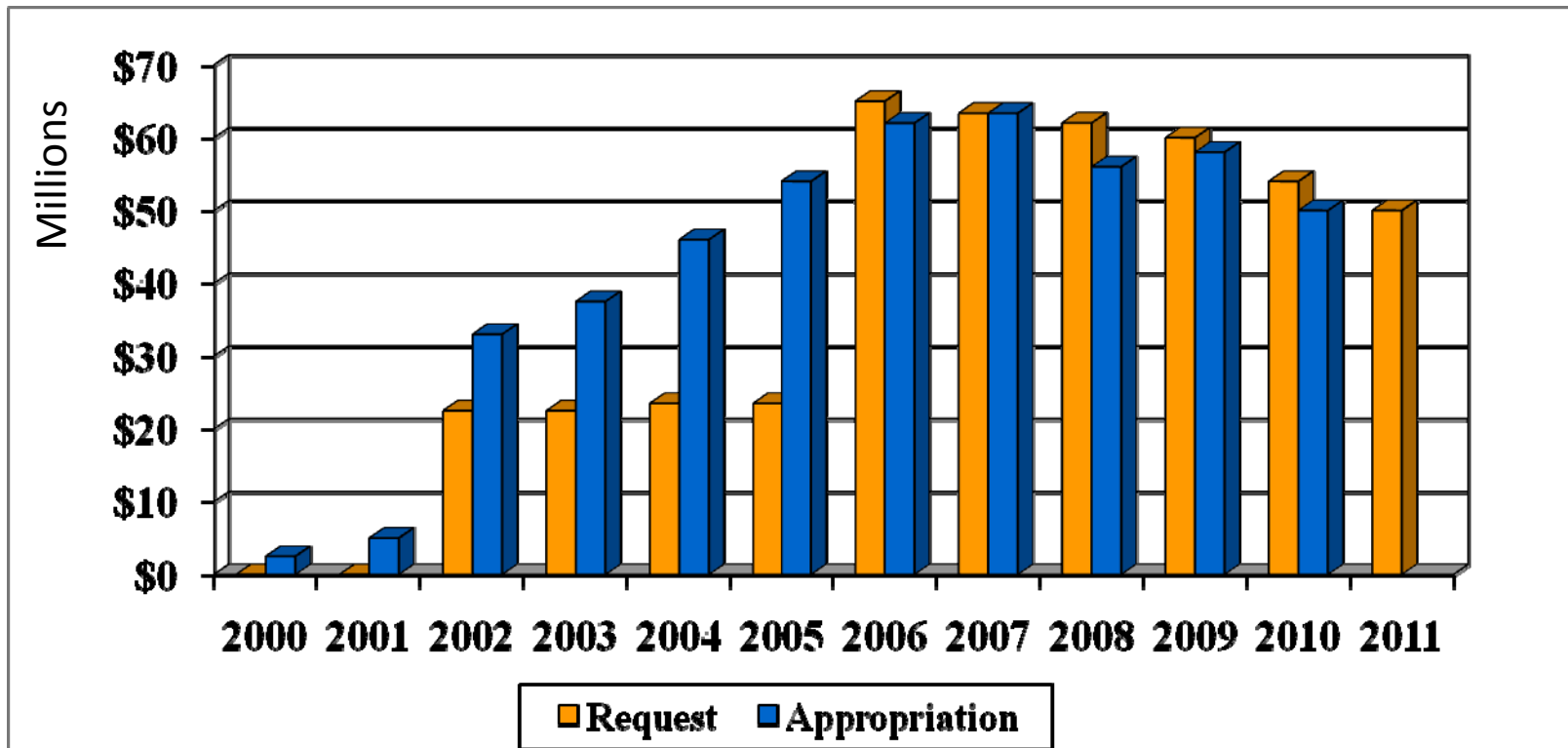
- Promotes collaboration
- Limits research redundancy
- Technology solution not “locked up”





Fossil Energy Fuel Cell Program

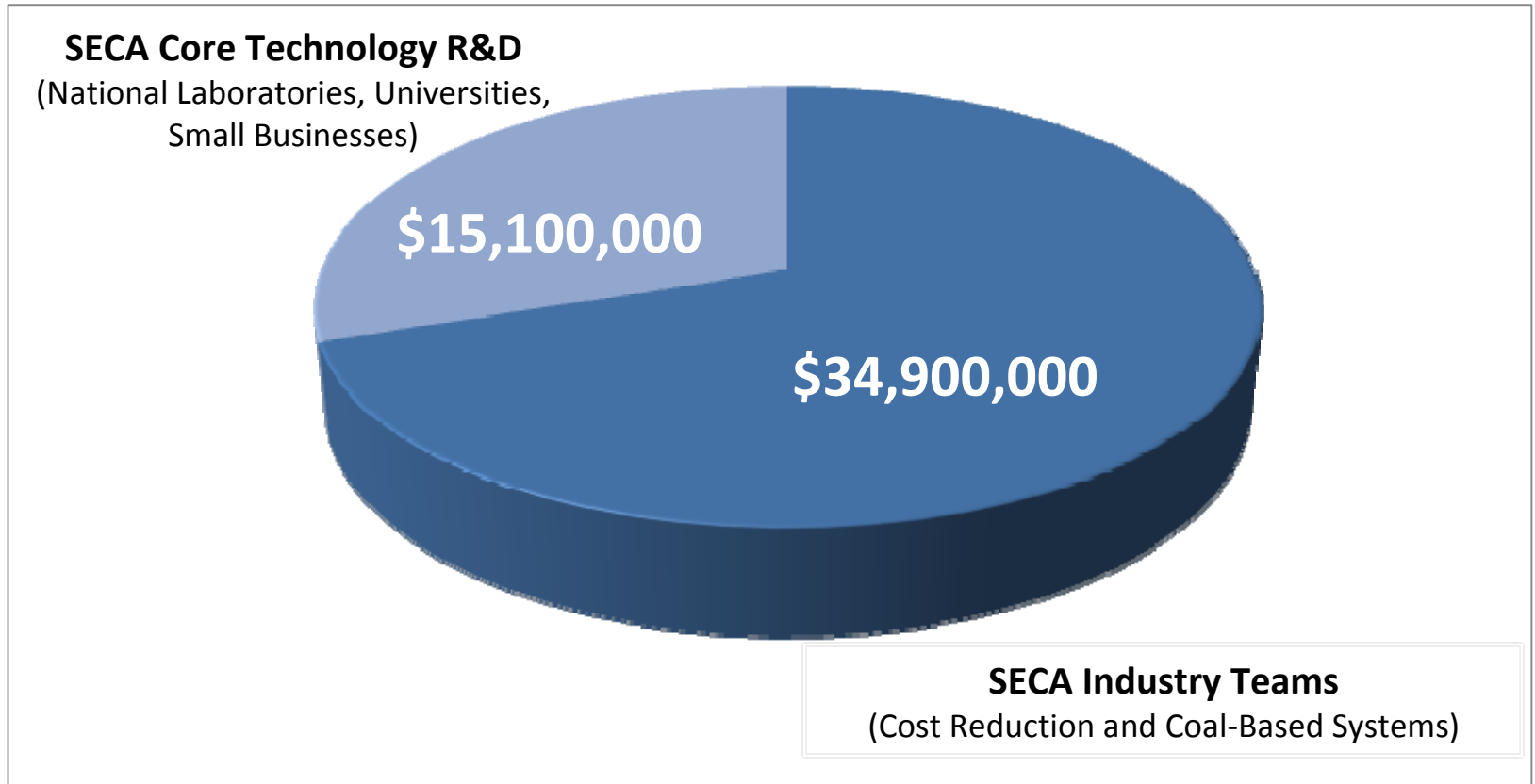
SECA Budget History





Fossil Energy Fuel Cell Program

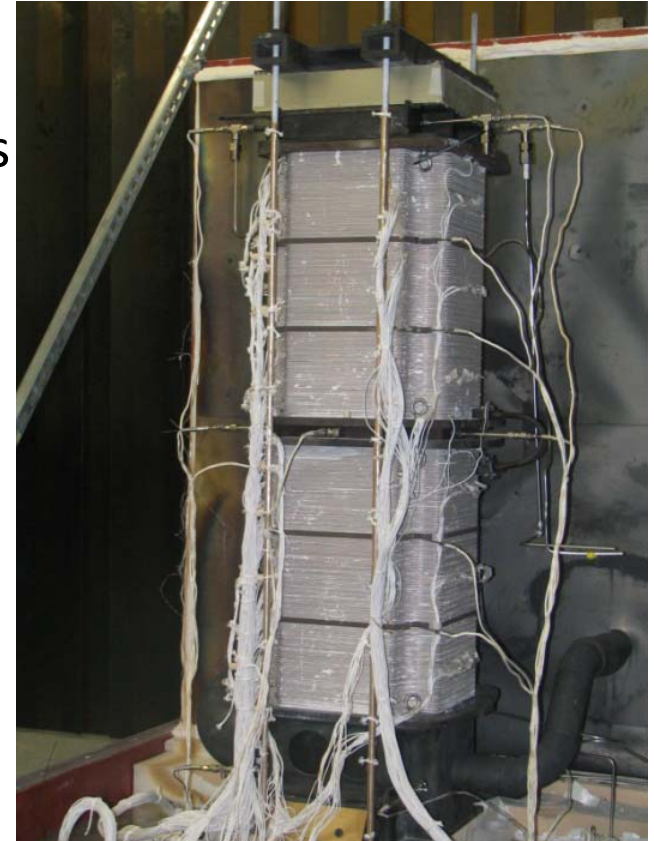
SECA FY10 Budget – \$50MM



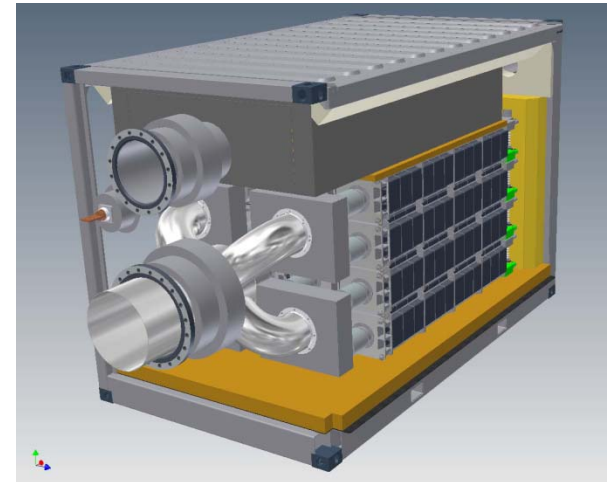


High-Level FY10 Technical Status

- Lab-Scale Testing
 - 25kWe planar SOFC stacks
 - FuelCell Energy/Versa Power Systems and UTC Power/Delphi
 - Validation of performance and cost
 - 5000 hour test on simulated syngas
- Cost
 - \$700/kW IGFC power block
 - \$175/kW SOFC module
 - Consistent with Pathway Study assumptions



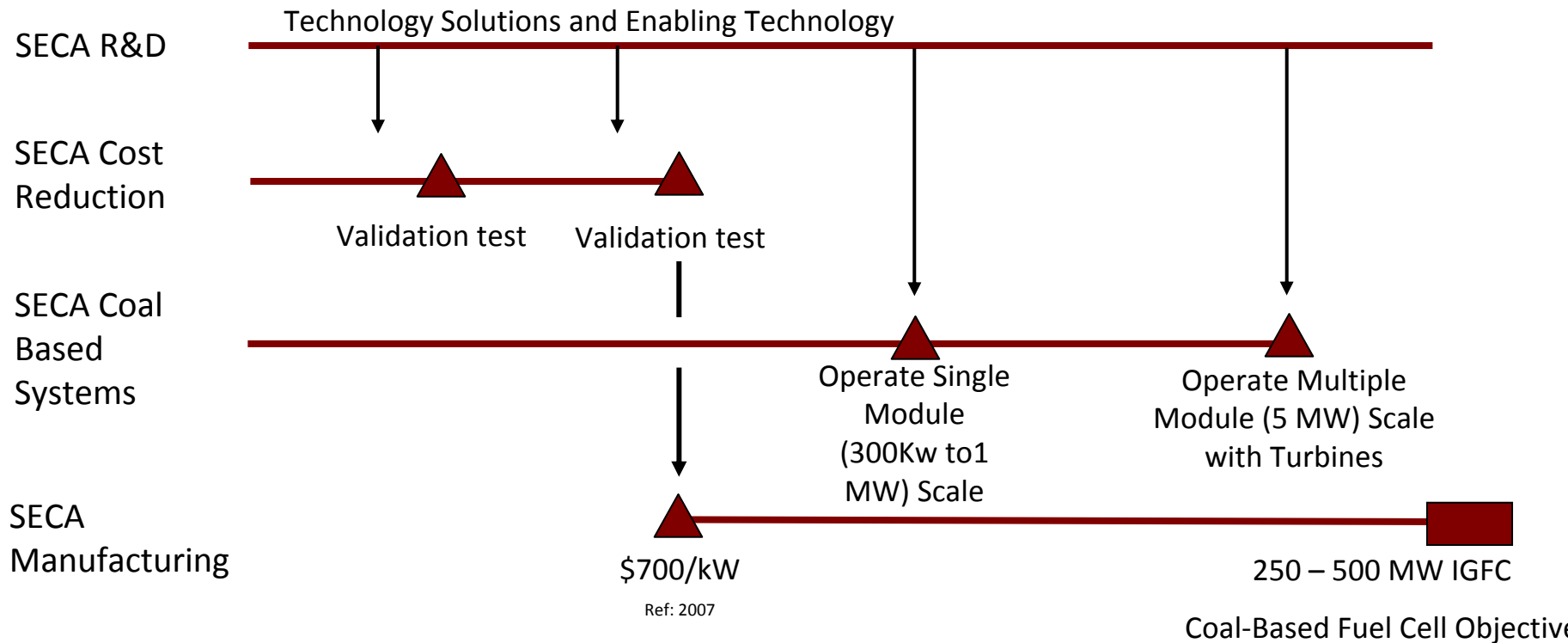
- Integration and Validation of current Core Technology R&D
 - Seal Concepts: Refractory and Viscous Engineered Composite
 - Cathode Contact: Alternative materials and sintering aids for enhanced strength
 - Interconnects: Refinement of ferritic SS interconnect coatings and application processes
 - Trace Contaminants: Establish coal syngas specification
 - Modeling and Simulation: Establish methodologies to evaluate operating window
- Module Design and Operation
 - Engineering design and fabrication of 250kW – 1MW SOFC Modules
 - Demonstrate long-term (40,000+ hour) operation at scale
 - Operational in 2013





SOFC Technology timeline

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2020





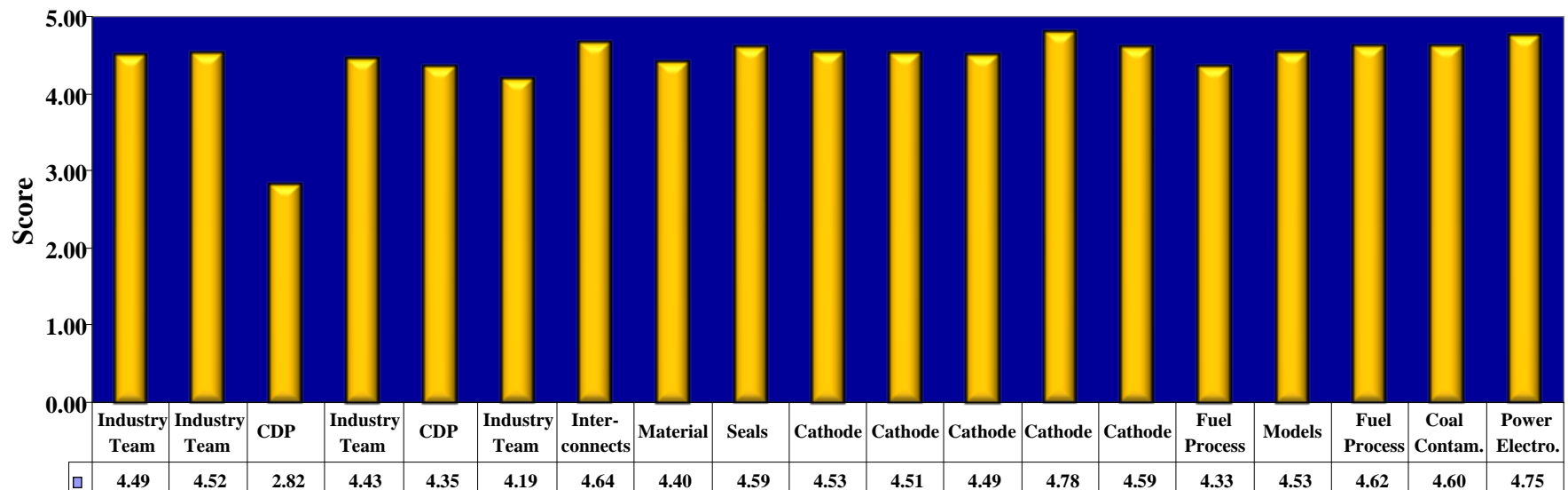
OMB cited SECA as Leading the Way in Government-Industry Partnerships

“The SECA program leverages private-sector ingenuity by providing Government funding to Industry Teams developing fuel cells, as long as the Teams continue to exceed a series of stringent technical performance hurdles. This novel incentive structure has generated a high level of competition between the Teams and an impressive array of technical approaches. The SECA program also develops certain core technologies that can be used by all the Industry Teams to avoid duplication of effort. The program exceeded its 2005 performance targets, and it is on track to meet its goal for an economically competitive technology by 2010.”



ASME Peer Review of SECA Program 2008

All Projects -- Overall Average



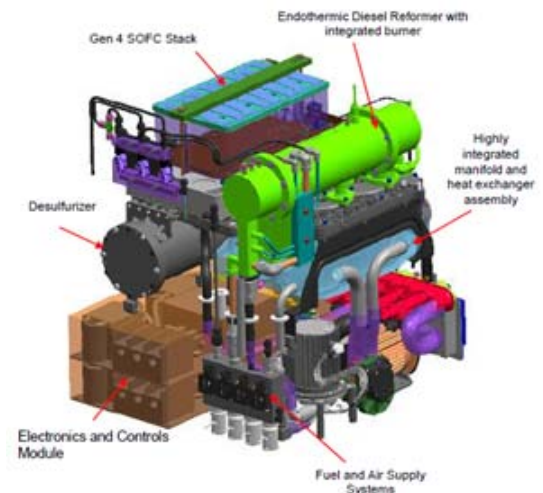


Delphi Auxiliary Power Unit Demos

Commercial in 2012

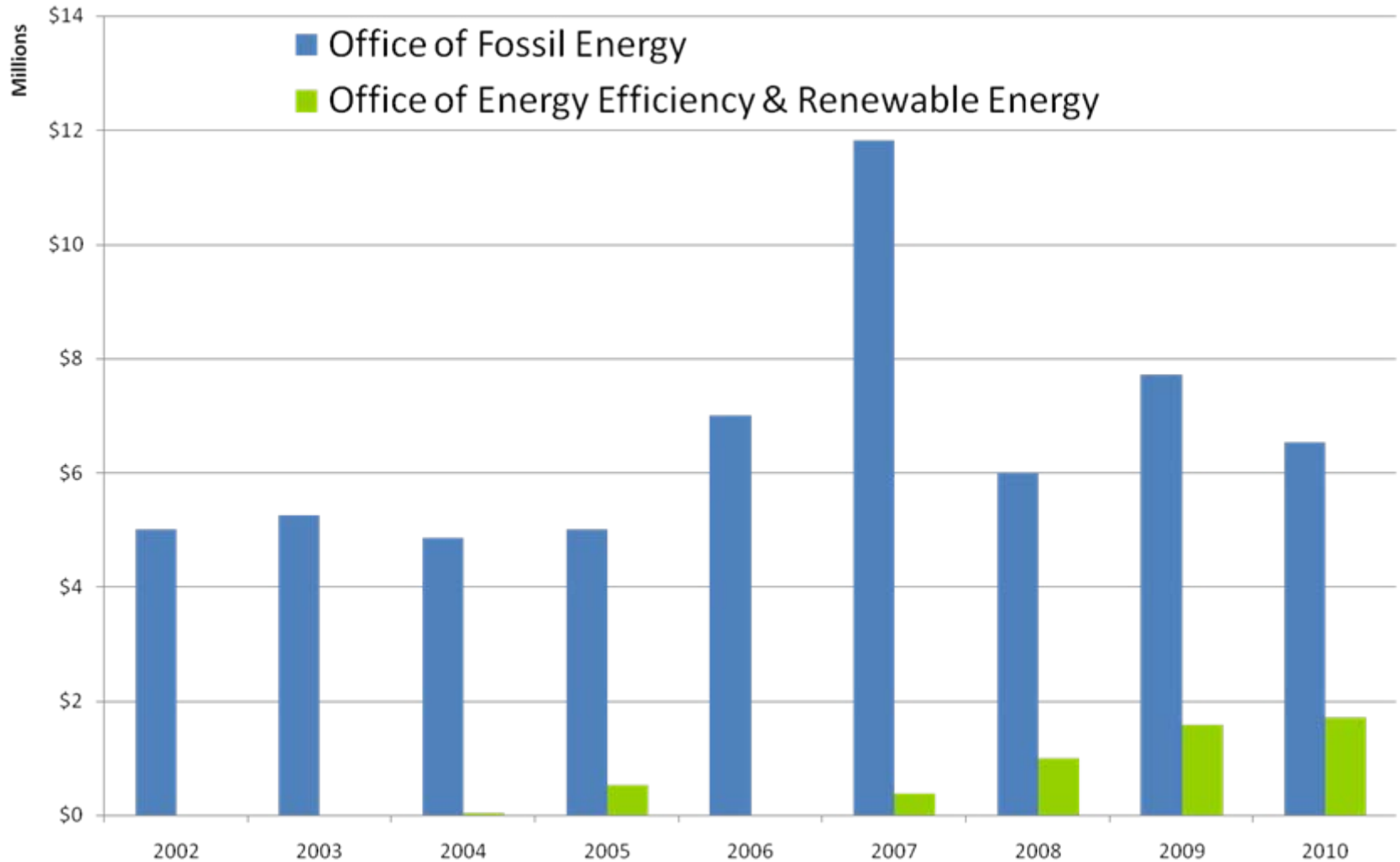
Pathway to Coal Plants

- Gain operational experience
- Develops infrastructure for fuel cell stack manufacture
- Delphi's diesel SECA APU demonstrated by Peterbilt and Daimler





Delphi Fuel Cell Funding by Source





SOFCs in Unmanned Undersea Vehicles (UUVs)



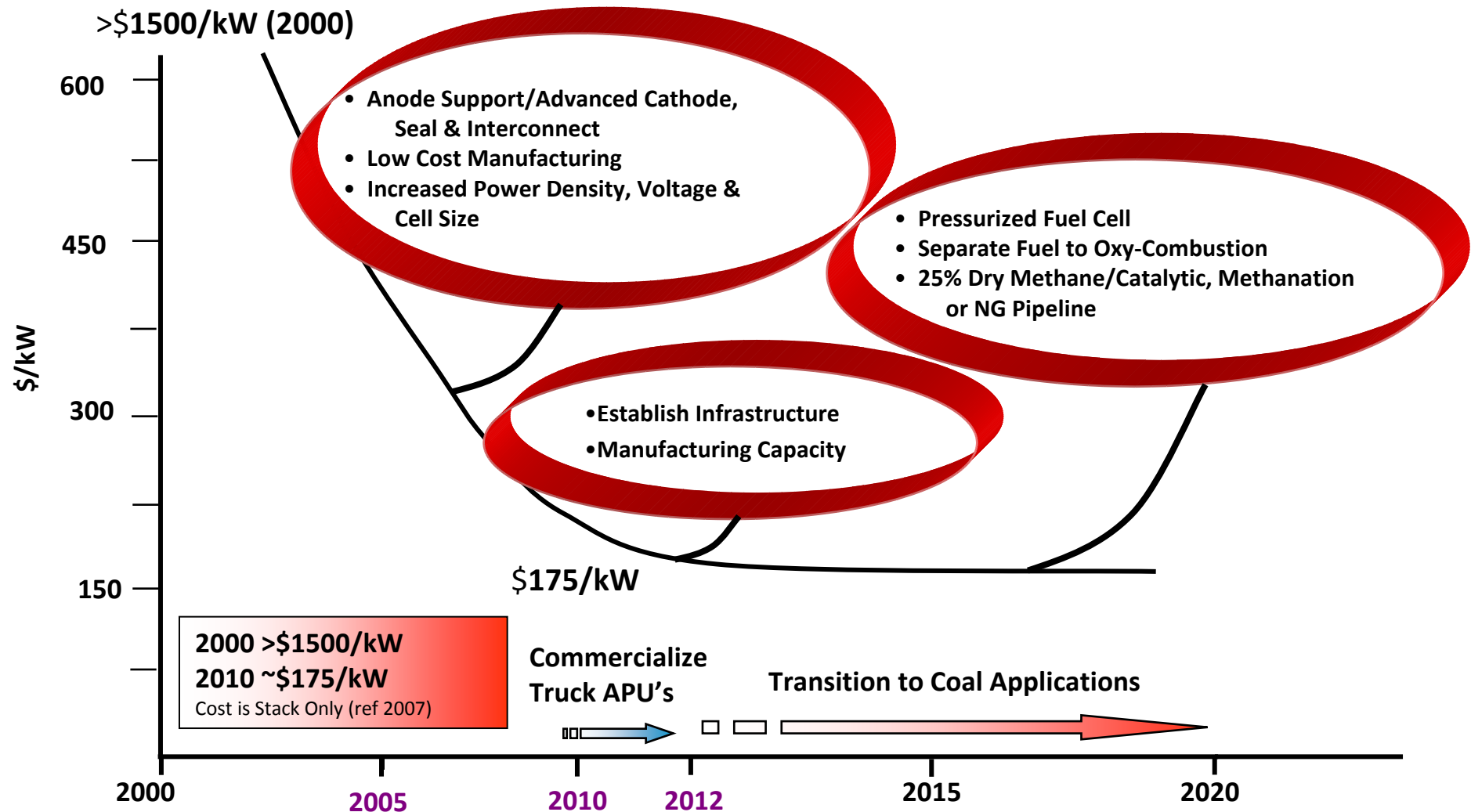
21UUV (2-5 kW)

- Fisher-Tropsch & Logistics Fuels
- SECA Stacks and Blower

- Naval Undersea Warfare Center, Division Newport, (NUWC DIVNPT) successfully tested SECA SOFCs in extreme conditions. Used SECA Stacks (2 Developers) and SECA developed High Temperature Blower.
- SOFC technology has the potential to greatly increase UUV mission time compared with current battery technology.
- Although SECA has a coal-based, central generation focus, spin-off applications are encouraged. Military applications like UUVs provide operating experience and independent validation for SECA.
- Cost and operational lifetime are not necessarily major concerns for military applications, as long as new mission capability can be delivered.



Order of Magnitude Reduction in Mass Producible Fuel Cell Costs





Research Priorities

Gas Seals	<ul style="list-style-type: none">▪ Glass and Compressive Seals▪ Compliant Seals▪ Self-healing Materials▪ High Temperature Refractive Seal
Failure Analysis	<ul style="list-style-type: none">▪ Models with Electrochemistry & EMF▪ Define Operating Window (Not possible experimentally)▪ Structural Failure Analysis & Design Criteria (ASME)
Cathode performance	<ul style="list-style-type: none">▪ Understand Mechanism<ul style="list-style-type: none">▪ Ad-atom Modification of Surfaces▪ Modification through Infiltration <p>} Electronic Effect versus Defect Chemistry</p>
Interconnect	<ul style="list-style-type: none">▪ Coatings▪ Electrode to Interconnect Interface - Contact Material
Anode / fuel processing	<ul style="list-style-type: none">▪ Establish Fuel Specification▪ Characterize Thermodynamics/Kinetics/ Contaminants
Heat Exchangers/ High Temperature Blowers	<ul style="list-style-type: none">▪ Cost and Reliability▪ Design Guidelines



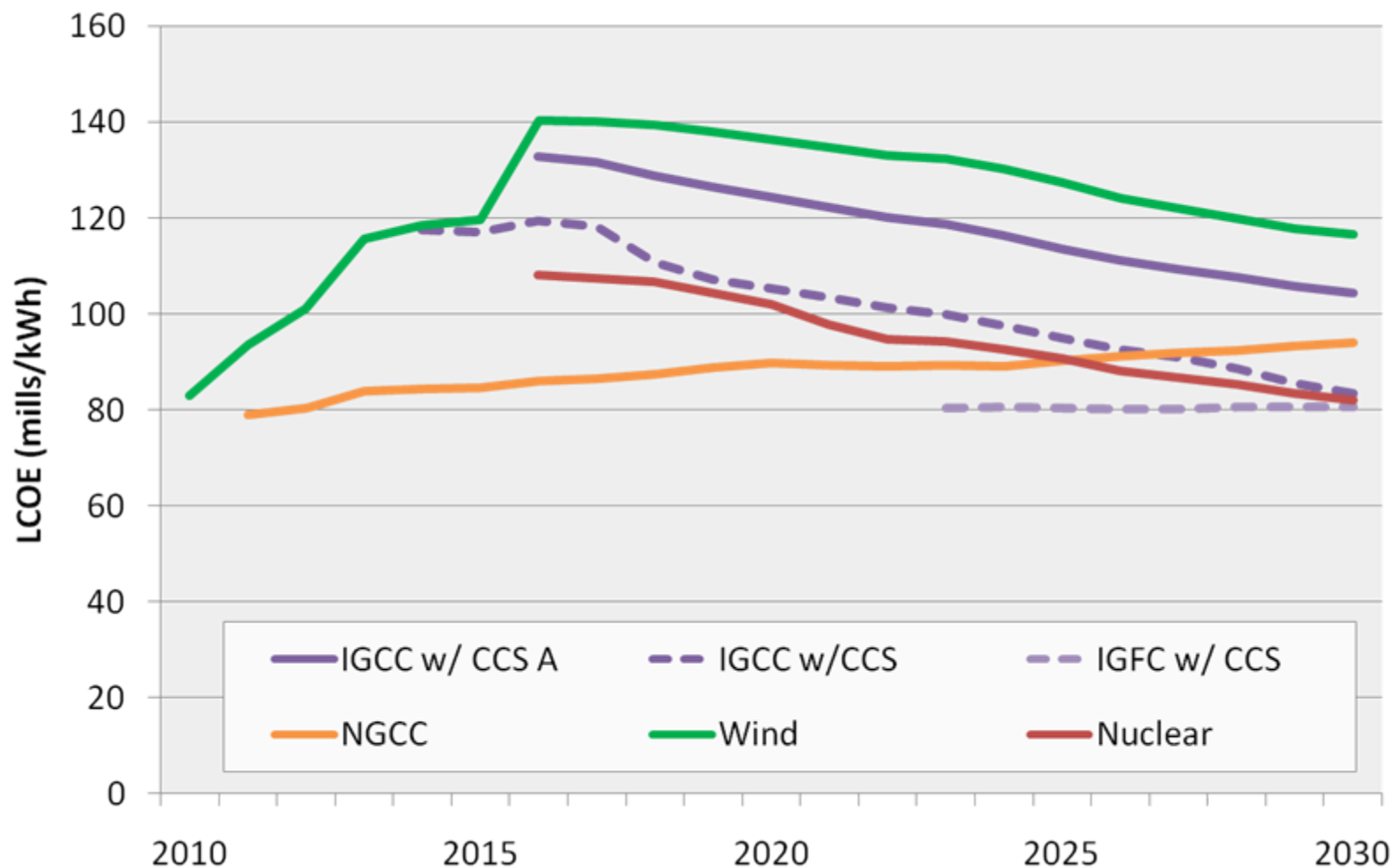
Key Hurdles Remaining

- Demonstration of large-scaled SOFC integrated system (gas cleaning, gas processing, inverters, fuel circulation, heat integration, and other hardware)
- Durability (degradation, thermal cycles, 20,000-40,000 hours life)
- Demonstration of 5-MW SOFC unit
- Power plant developer acceptance
- Development of pressurized SOFC for higher efficiency



NETL R&D Impacts on Baseload LCOE

Mid CO2 Tax Case*

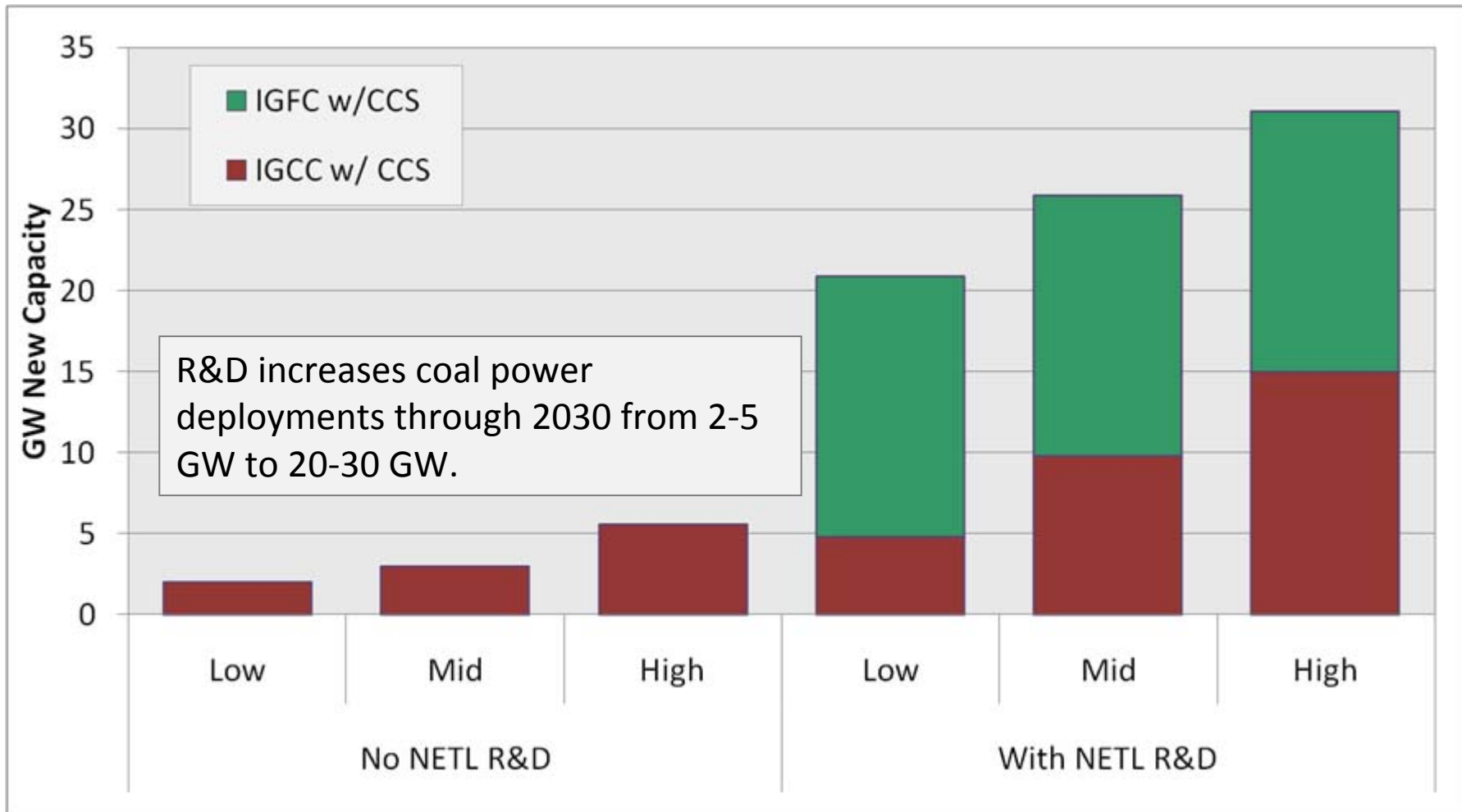


*\$18/metric ton in 2012 - \$43/metric ton in 2030

Source: EIA NEMS AEO2009 Results



IGCC and IGFC Builds by Year 2030



*Mid: \$18/metric ton in 2012 - \$43/metric ton in 2030
Source: EIA NEMS AEO2009 Results

More Information

DOE-HQ Fuel Cells Website

<http://fossil.energy.gov/programs/powersystems/fuelcells/index.html>

NETL SECA Website

<http://www.netl.doe.gov/technologies/coalpower/fuelcells/seca/>

DOE-OSTI Website

<http://www.osti.gov>

- CDs are available from the above website
- 10th Annual SECA Workshop
- Proceedings (2000-2009)
- SECA Peer Reviews (2002-2006, 2008)
- Fuel Cell Handbook (7th ed.)

