



**NATIONAL ENERGY TECHNOLOGY LABORATORY**



**Office of Fossil Energy Fuel Cell Program -  
Solid State Energy Conversion Alliance (SECA)  
Clean Economic Energy for a Carbon Challenged World**

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July 27, 2010

**Dr. Shailesh D. Vora**

Technology Manager, Fuel Cells

National Energy Technology Laboratory

United States Department of Energy



# SECA Mission



- *Enable the generation of efficient, cost-effective electricity from domestic coal with near-zero atmospheric emissions of CO<sub>2</sub> and air pollutants (99% CO<sub>2</sub> 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)

≥ 99% CO<sub>2</sub>  
Capture

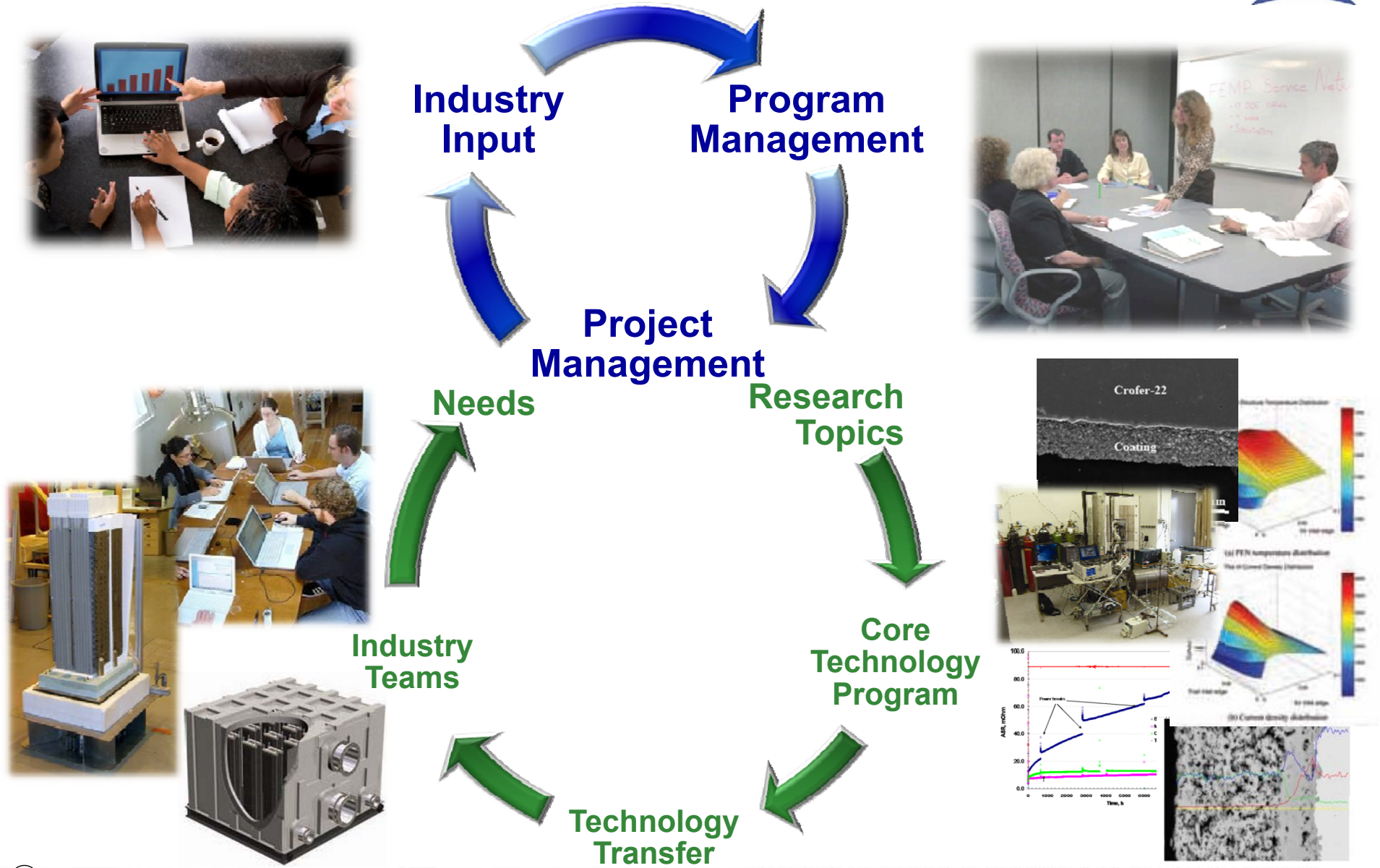
Environmental:  
<0.5ppm NO<sub>x</sub>,  
low H<sub>2</sub>O use

Low Cost,  
similar footprint  
to IGCC

Modular  
Technology

Fuel-Flexible:  
Syngas, NG,  
H<sub>2</sub>, Diesel,  
etc.

# SECA Program Structure

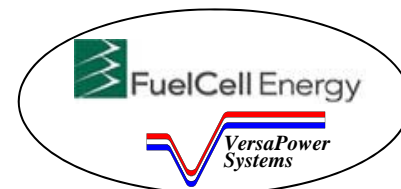
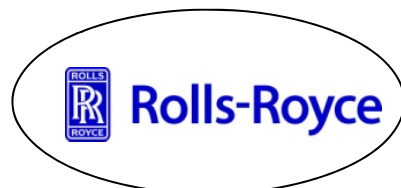


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# Intellectual Property

## Cornerstone of the Alliance

Industry Teams Develop Proprietary Technologies

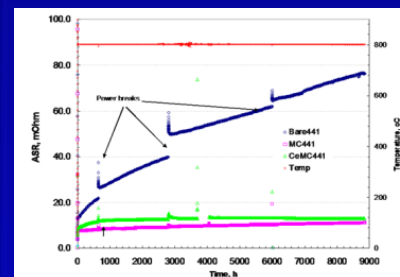
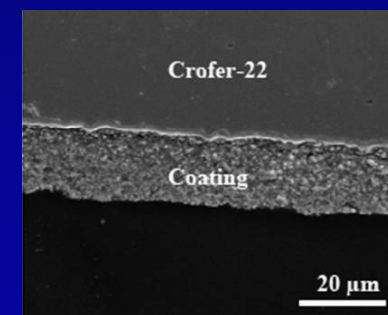


### Non-Exclusive Licenses

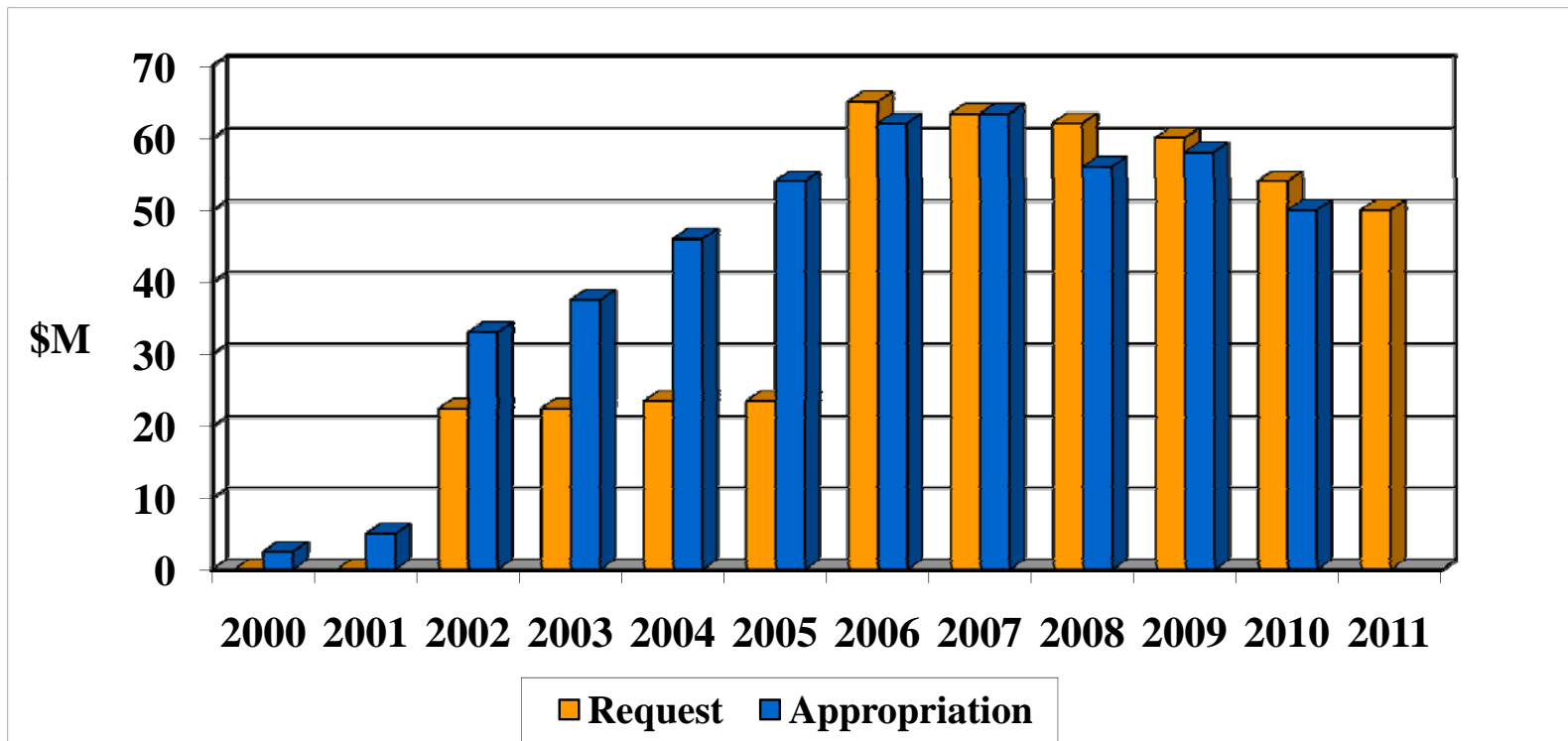
*Exceptional Circumstance to Bayh-Dole Act*

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

### SECA Core Technology R&D



# Fossil Energy Fuel Cell Program SECA Budget – History





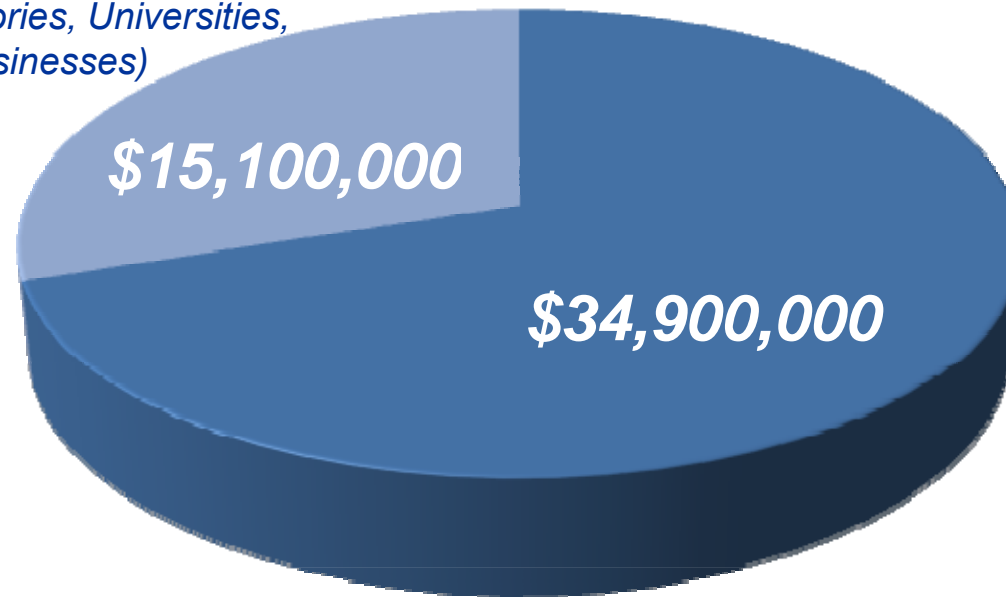
# Fossil Energy Fuel Cell Program

## SECA Budget – FY10

### \$50MM

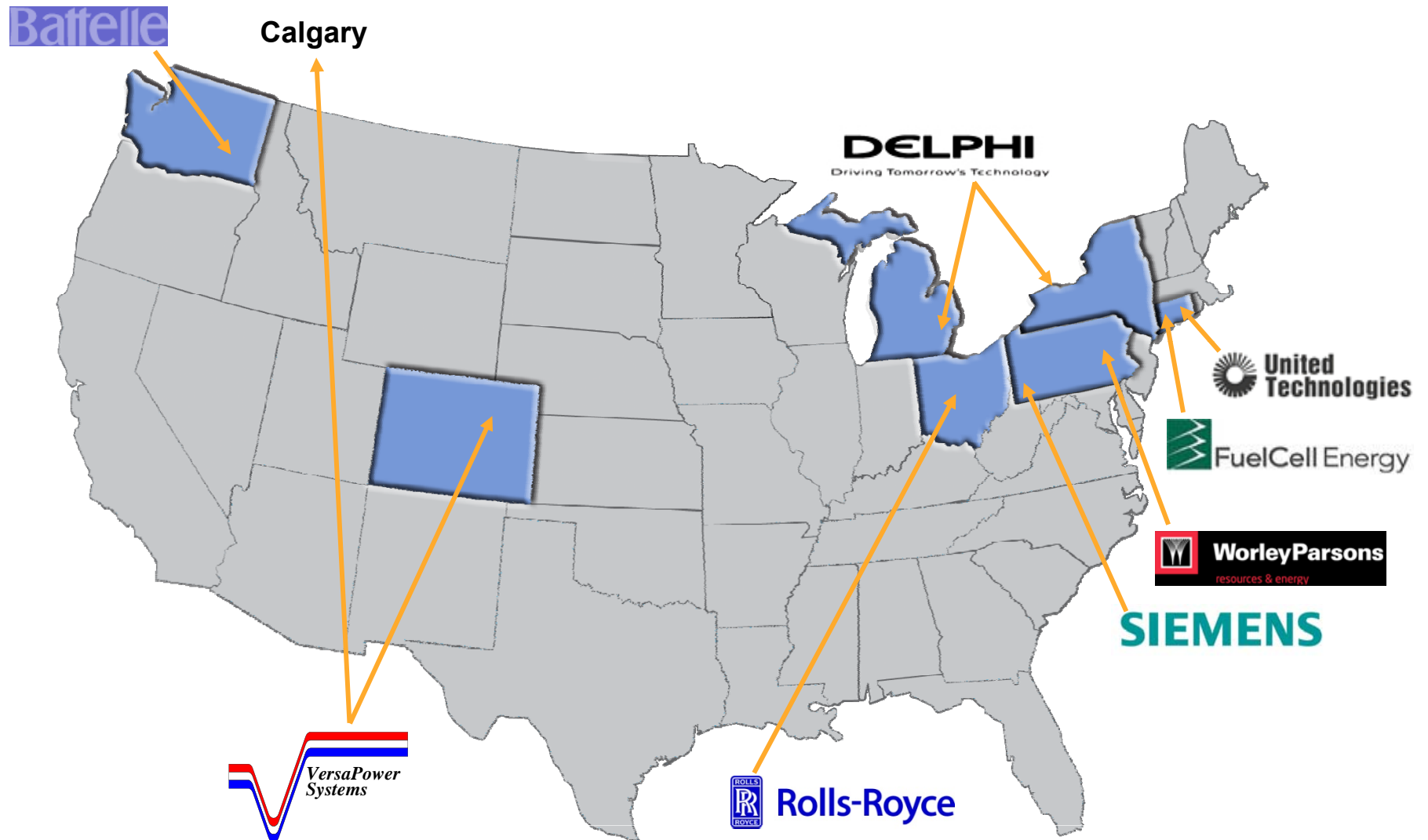


**SECA Core Technology R&D**  
(National Laboratories, Universities,  
Small Businesses)

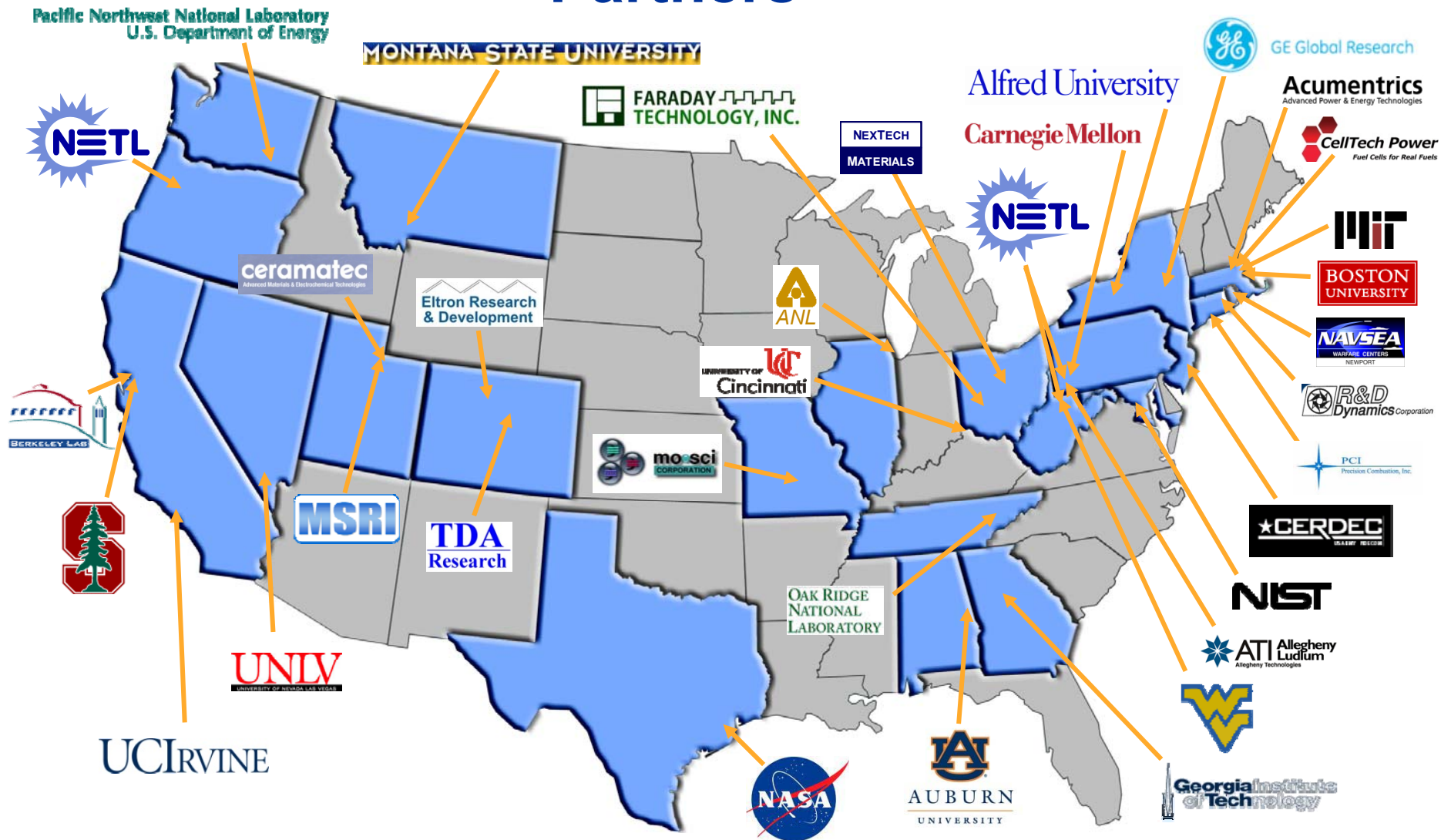


**SECA Industry Teams**  
(Cost Reduction and Coal-Based Systems)

# Industry Teams & Major Subcontractors

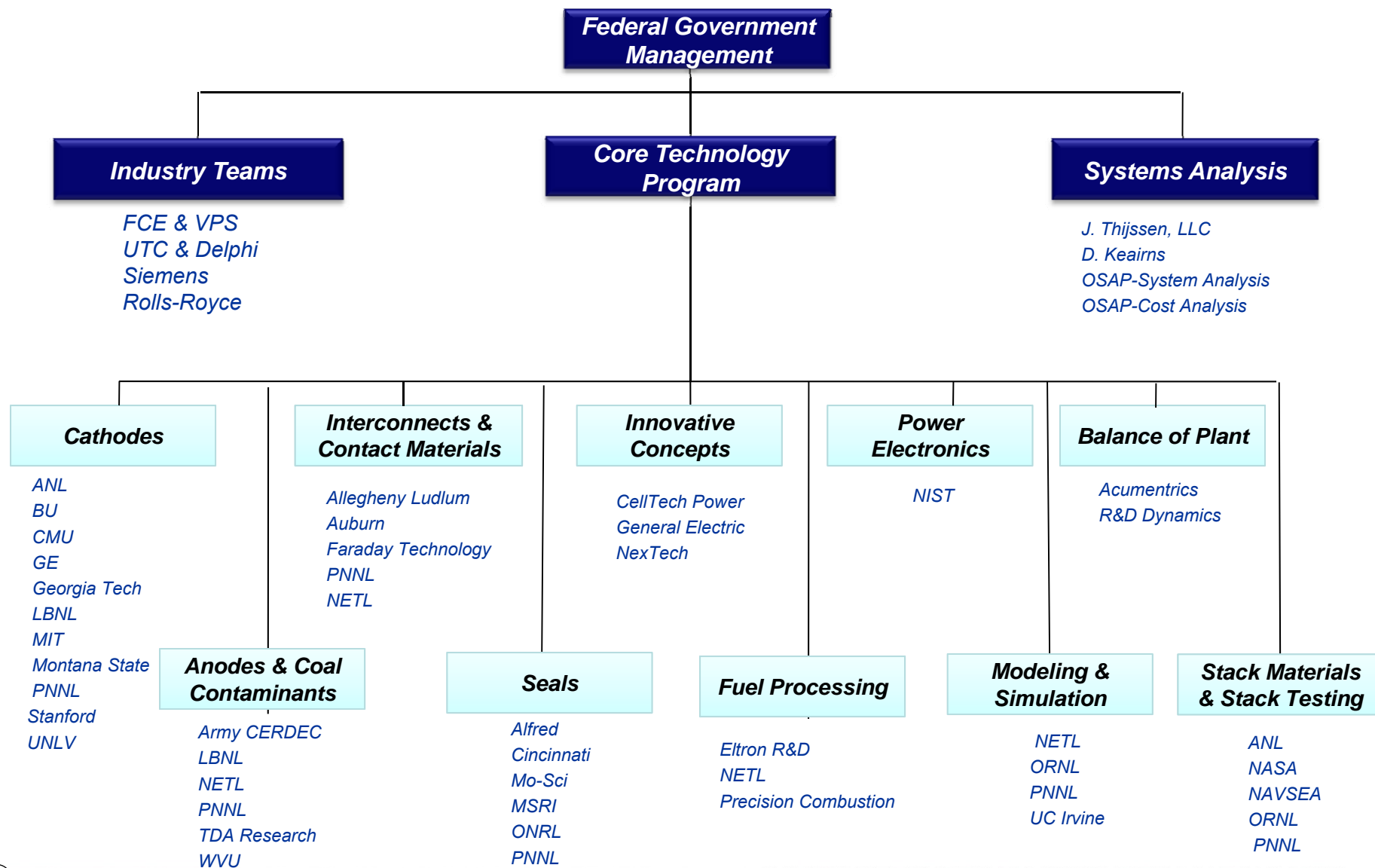


# 2010 SECA Core Technology & Other Partners





# Solid State Energy Conversion Alliance



# DOE's Office of Fossil Energy

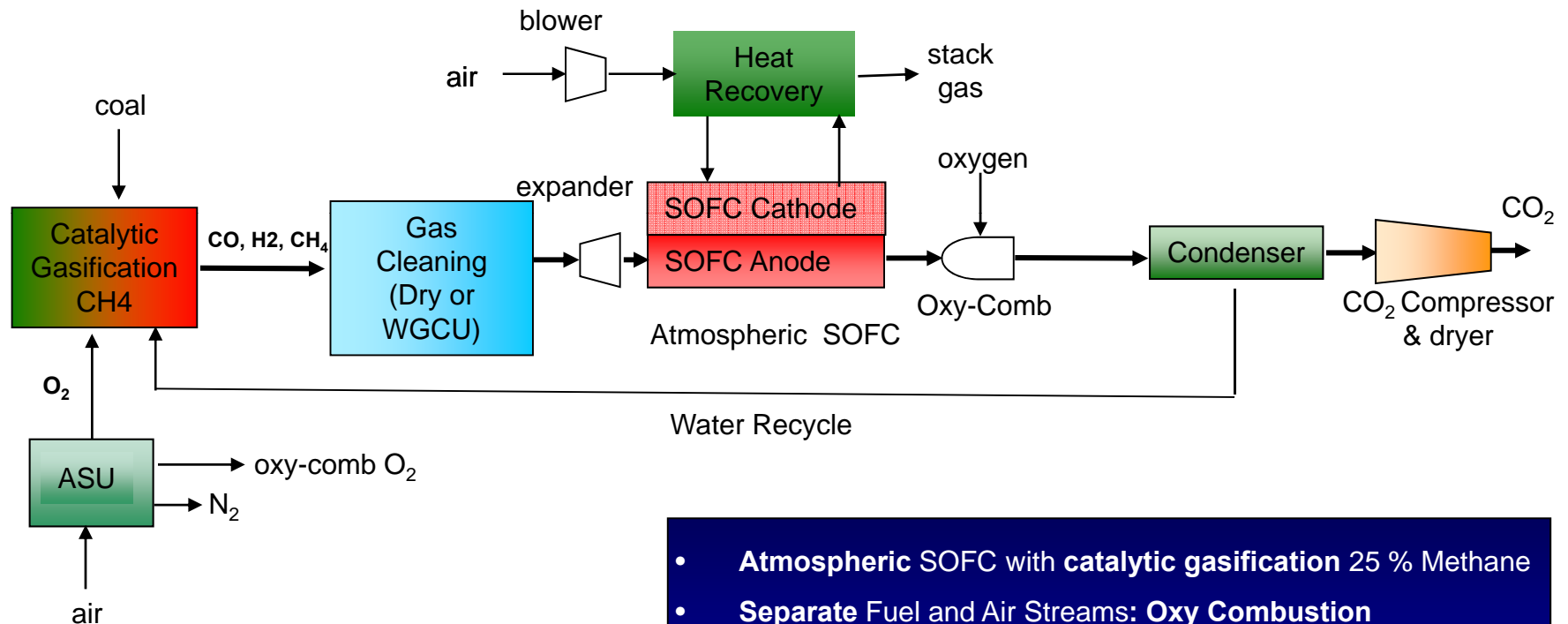
## *Advanced (Coal) Power Systems Goals*

- 2010:
  - 45-47% Efficiency (HHV)
  - 99% SO<sub>2</sub> removal
  - NO<sub>x</sub> < 0.01 lb/MM Btu
  - 90% Hg removal
- 2015:
  - 90% CO<sub>2</sub> capture
  - <10% increase in COE with carbon sequestration
  - Multi-product capability (e.g, power + H<sub>2</sub>)
  - 60% efficiency (measured without carbon capture)



# SECA Coal-Based Systems Atmospheric IGFC

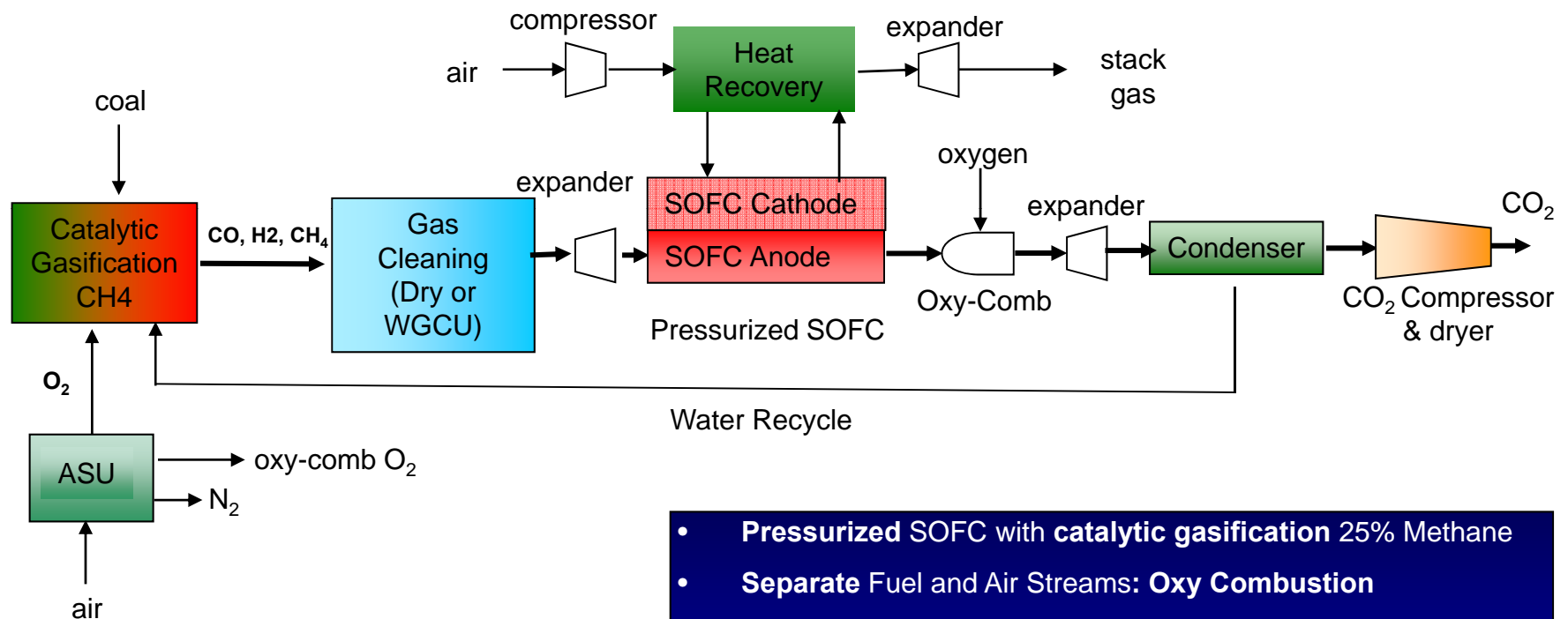
## near-zero water requirement (99% carbon capture, 54% efficiency)



- **Atmospheric SOFC with catalytic gasification 25 % Methane**
- **Separate Fuel and Air Streams: Oxy Combustion**
- **Cycle Efficiency (HHV); 99% Capture**
  - **~51% with CO<sub>2</sub> Compression**
  - **~54% w/out CO<sub>2</sub> Compression**

# SECA Coal-Based Systems Pressurized IGFC

## near-zero water requirement (99% carbon capture, 61% efficiency)



- **Pressurized SOFC with catalytic gasification 25% Methane**
- **Separate Fuel and Air Streams: Oxy Combustion**
- **No steam cycle** – minimal external water requirement
- **Cycle Efficiency (HHV); 99% Capture**
  - ~57% with CO<sub>2</sub> Compression
  - ~61% w/out CO<sub>2</sub> Compression

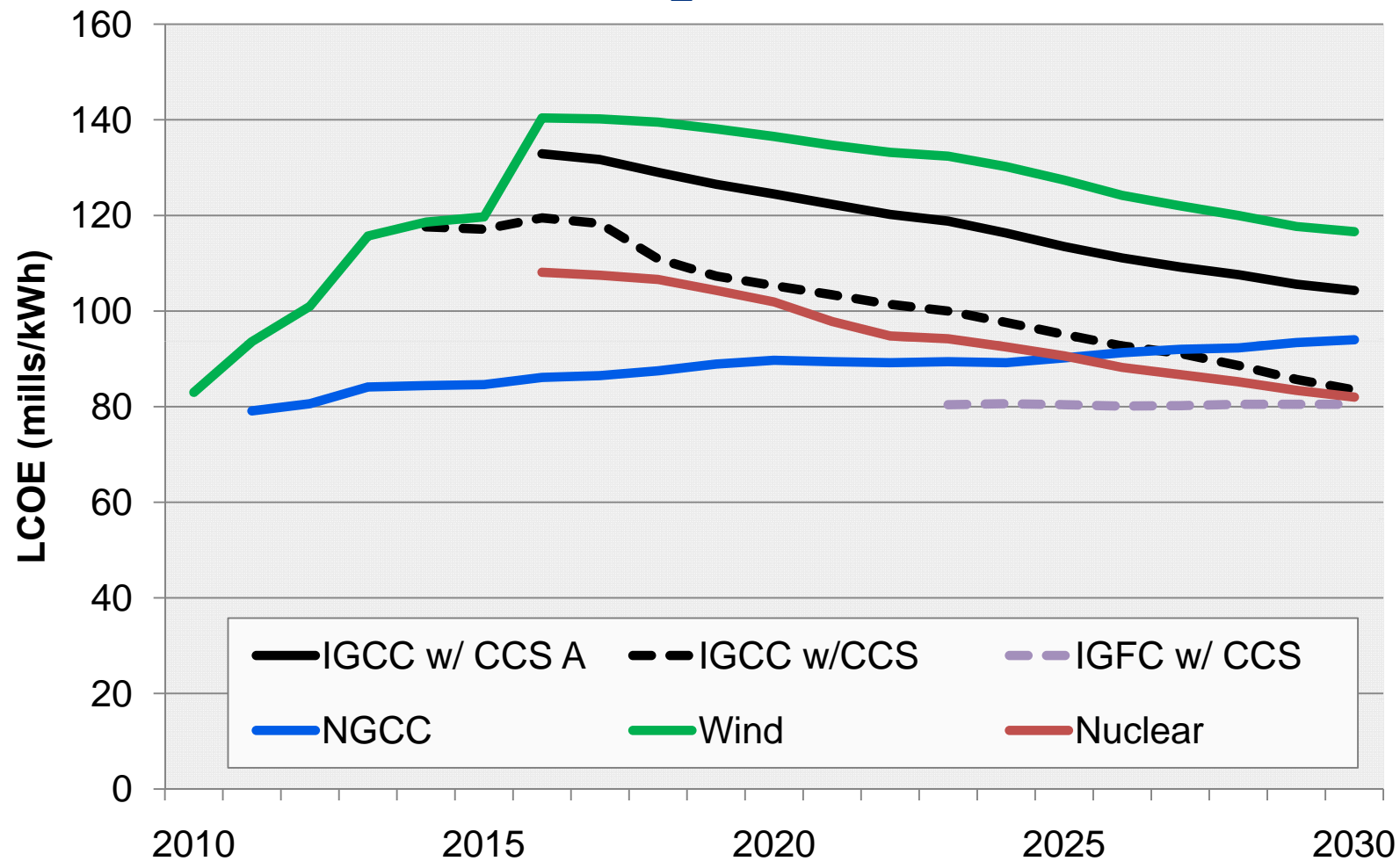
# Impact of Efficiency on COE

Advanced Power Systems With CO <sub>2</sub> Capture, Compression and Storage					
	PC Baseline	IGCC Baseline		IGFC Atm	IGFC Pressure
Efficiency HHV (%)	28.4	32.6		51.1	57.0
Capital Cost \$/kW	3,570	3,330		2,150	2,100
Water Withdrawal gpm/MW <sub>net</sub>	10.7	18.3		2.5	1.8
Levelized Cost-of-Electricity ¢/kW-hr	15.0	15.1		10.8	10.3

Sources: Cost and Performance Baseline for Fossil Energy Plants, Volume 1, Revision 2 DRAFT, 2010 Anticipated Release  
Analysis of Integrated Gasification Fuel Cell Plant Configurations, DRAFT, 2010 Anticipated Release



# NETL R&D Impacts on Baseload LCOE in Mid CO<sub>2</sub> Tax Case\*

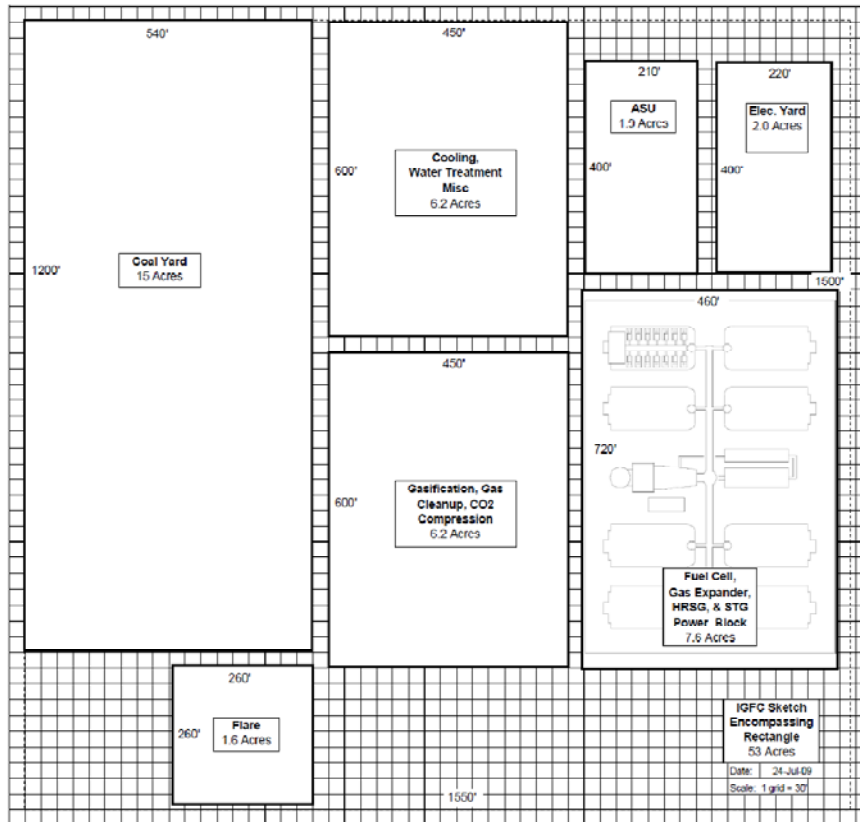


\*\$18/metric ton in 2012 - \$43/metric ton in 2030

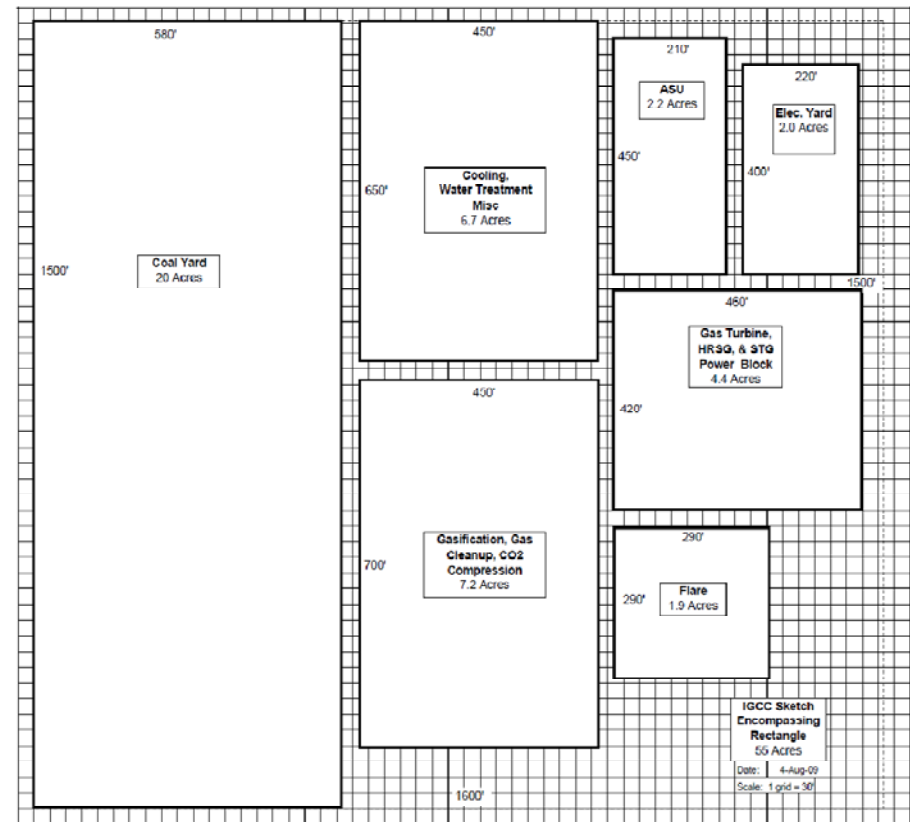
Source: EIA NEMS AEO2009 Results

# Representative Foot Print Comparison: IGFC & IGCC

**IGFC – 53 Acres**



**IGCC – 55 Acres**



- A similarly sized IGCC and IGFC will be comparable in real estate requirement.***

Provided by:



**WorleyParsons**

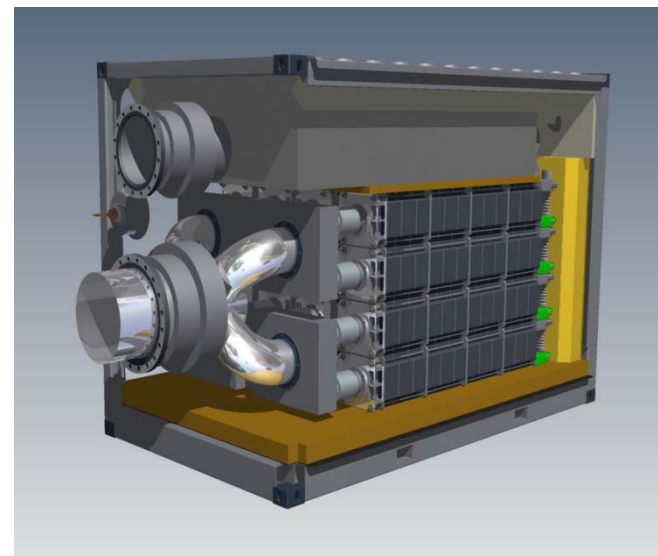
resources & energy

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# SECA Program Milestones – 2010

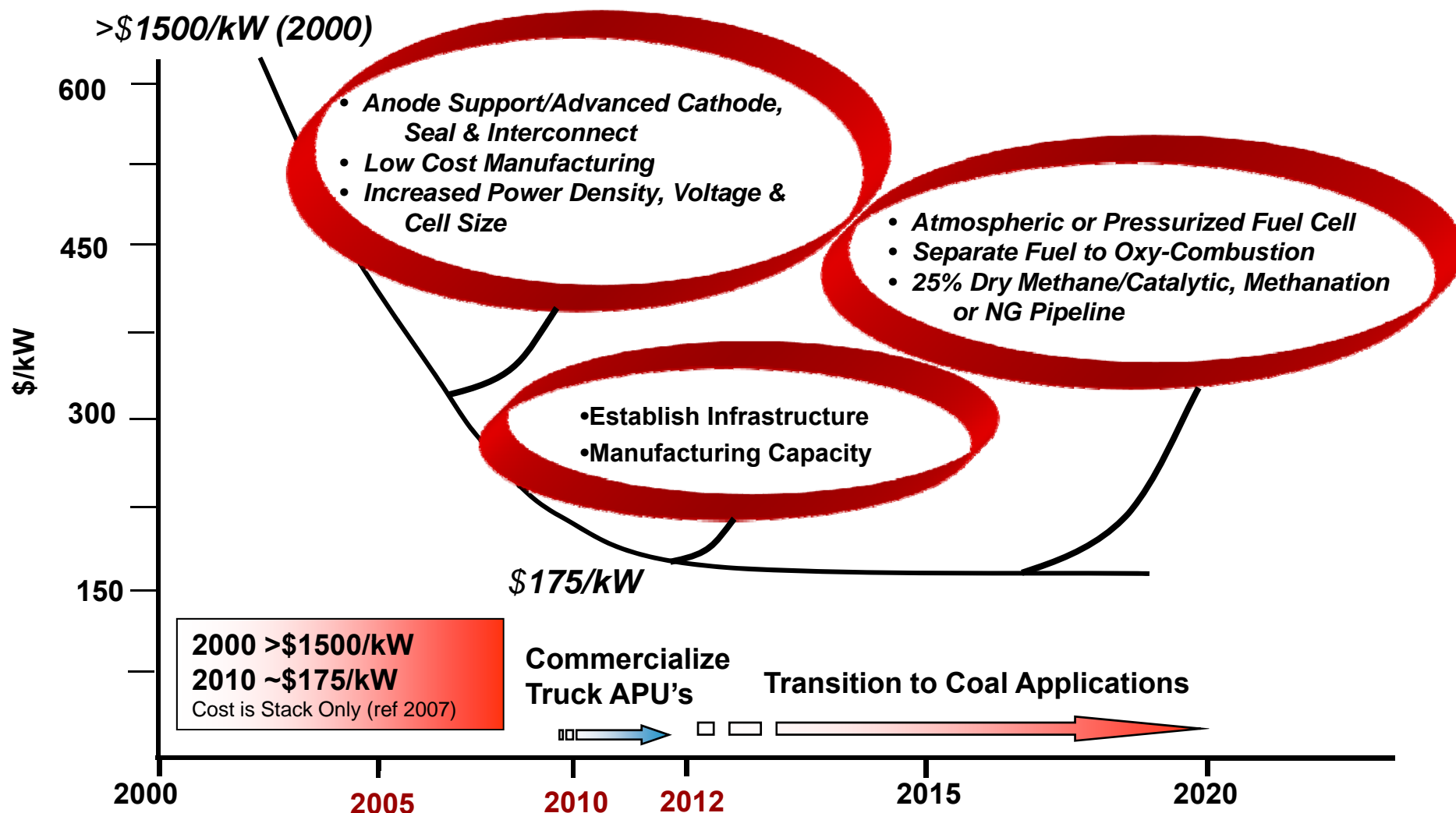
(OMB Performance Assessment Rating Tool)

- **Stack Cost - \$175/kW**
  - 2007 Dollar Basis
- **Power Block - \$700/kW**
- **Maintain Power Density with Increased Scale ~ 300mW/cm<sup>2</sup>**



# Driving Down Costs For Fuels Cells

## (Order of Magnitude Cost Reduction)



# Industry Teams Test Results

2005-2007 Test Results	Size	Efficiency	Degradation	Test Duration	System Cost
Aggregate Team Performance	3 – 7 kW	35.4 – 41%	~0 to 3.6%/1,000 hours	>1500 hours	\$1,267 - \$1356/kW
2008-2009 Test Results	Stack Size $\geq 10$ kW	IGFC Efficiency	Degradation <4%/1,000 hrs	Test Duration	IGFC Power Block Cost
FuelCell Energy	11 kW peak (2 Stacks)	> 50%	1.7% and 2.6% per 1,000 hours	>5000 hours	\$1045/kW
Siemens Energy	10 kW	> 50%	~0	>5000 hours	\$1083/kW

*Costs in 2007 \$*



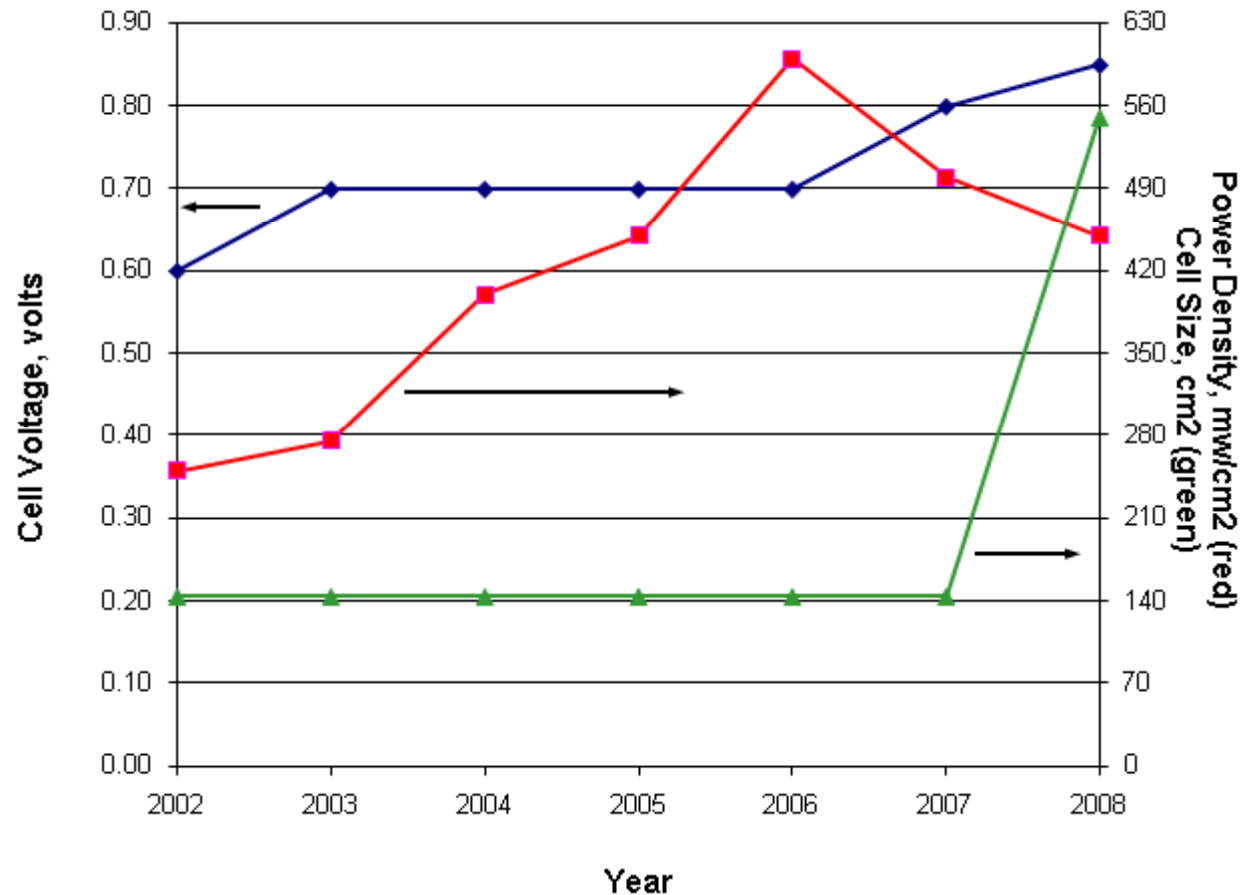
*FuelCell Energy  
64 cells  
550 cm<sup>2</sup> active area*

*Siemens Energy  
24 Delta8 Cells  
4 Bundles (6 cells each)*





# Voltage, Power Density, and Size by Year



- Higher power density implies lower cost
- Higher cell voltage leads to higher efficiency
- No adverse effect of cell size on performance

## Slide 19

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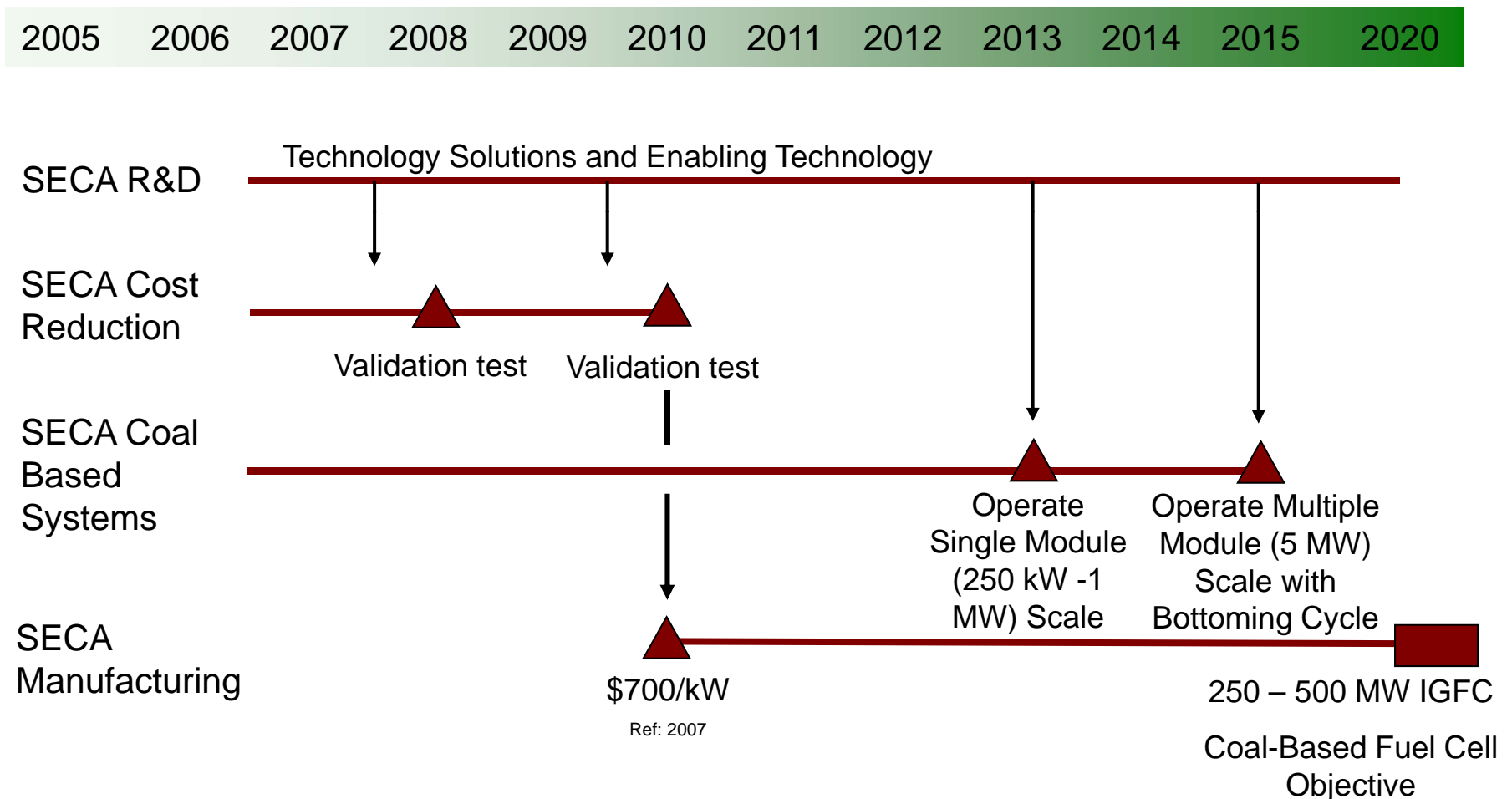
**TRS3**

I'll see what I can dig up for this...

Travis Shultz, 7/22/2010

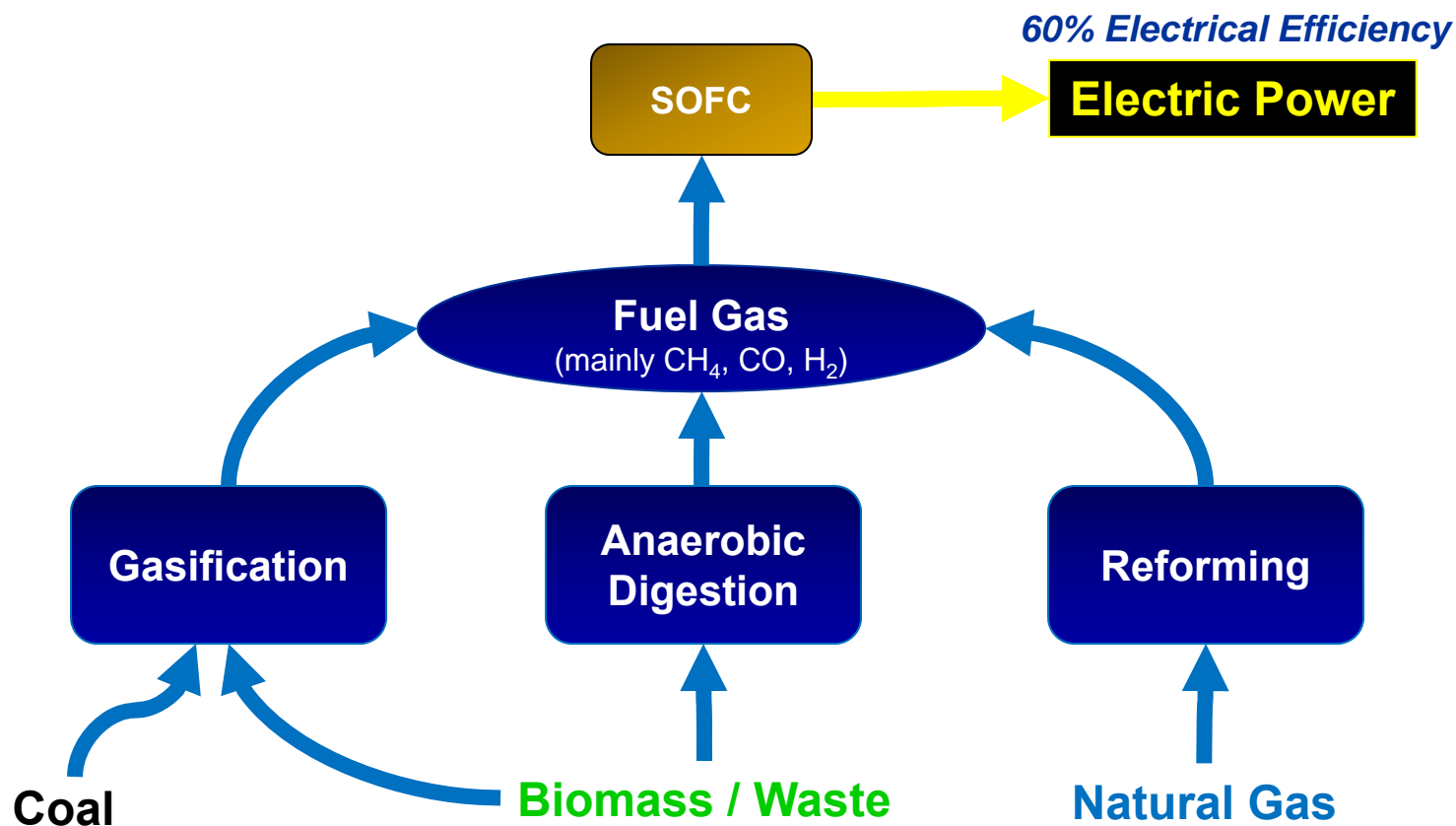
# Solid State Energy Conversion Alliance

## Fuel Cells Technology Timeline



# SECA Fuel Flexibility

*SOFC Systems can produce power from many fuels*



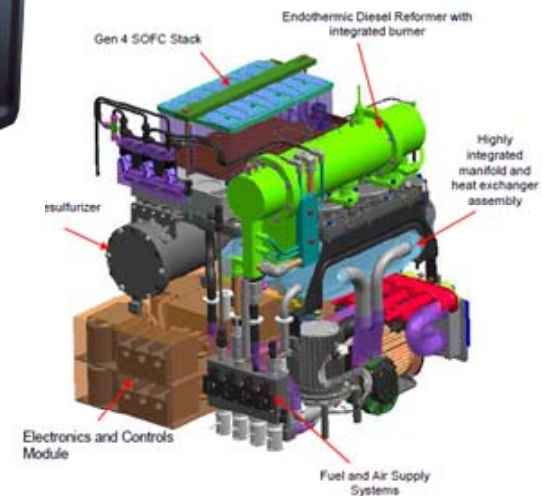
# Delphi Auxiliary Power Unit Demos

## 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





# 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.

# SECA Research Priorities



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

# For More Information on SECA...



## Websites:

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

[www.fe.doe.gov](http://www.fe.doe.gov)




[www.grants.gov](http://www.grants.gov)

## CDs available from the website

- 10<sup>th</sup> Annual SECA Workshop Proceedings
- Fuel Cell Handbook (7th ed.)

**Dr. Shailesh D. Vora**  
Technology Manager, Fuel Cells  
National Energy Technology Laboratory  
U. S. Department of Energy  
(Tel) 412 386-7515  
(Fax) 412 386-4822  
[shailesh.vora@netl.doe.gov](mailto:shailesh.vora@netl.doe.gov)

OFFICE OF FOSSIL ENERGY – NATIONAL ENERGY TECHNOLOGY LABORATORY  
SOLID STATE ENERGY CONVERSION ALLIANCE



  

**Fuel Cells** *Powering AMERICA*

Collaboration <i>Industry, Labs, Universities</i>	Cost Reduction <i>\$400/kW Modules</i>	Coal-Based Systems <i>MW-Scale Power Blocks</i>
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“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.”

– Office of Management and Budget,  
United States Executive Branch

R&D Increases Power Density and Stack Size

*Increase Energy Security*  
*Eliminate Carbon Footprint*  
*Enhance Water Conservation*