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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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_2 and air pollutants (99% CO_2 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_2 Capture*	*Environmental: <0.5ppm NOx, low H_2O use*	*Low Cost, similar footprint to IGCC*	*Modular Technology*	*Fuel-Flexible: Syngas, NG, H_2, Diesel, etc.*

SECA Program Structure

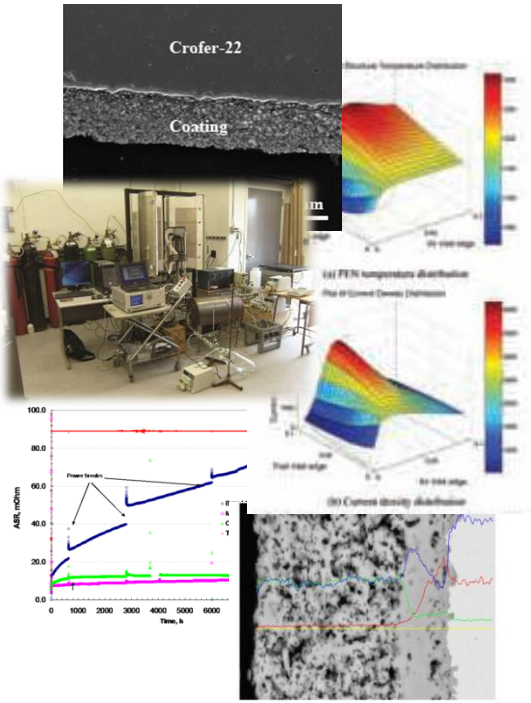
Industry Input

Program Management

Project Management

Needs

Research Topics



Industry Teams

Core Technology Program

Technology Transfer

Intellectual Property

Cornerstone of the Alliance

Industry Teams Develop Proprietary Technologies

United Technologies DELPHI
Driving Tomorrow's Technology

Rolls-Royce

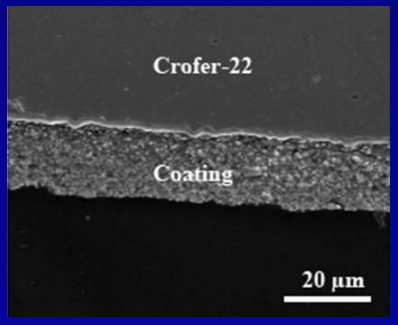
FuelCell Energy
VersaPower Systems

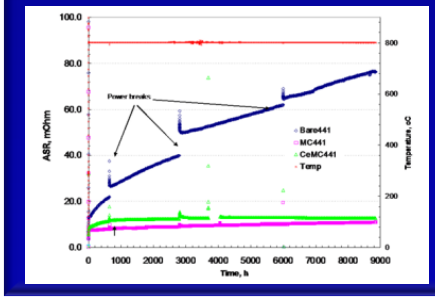
Non-Exclusive Licenses

Exceptional Circumstance to Bayh-Dole Act

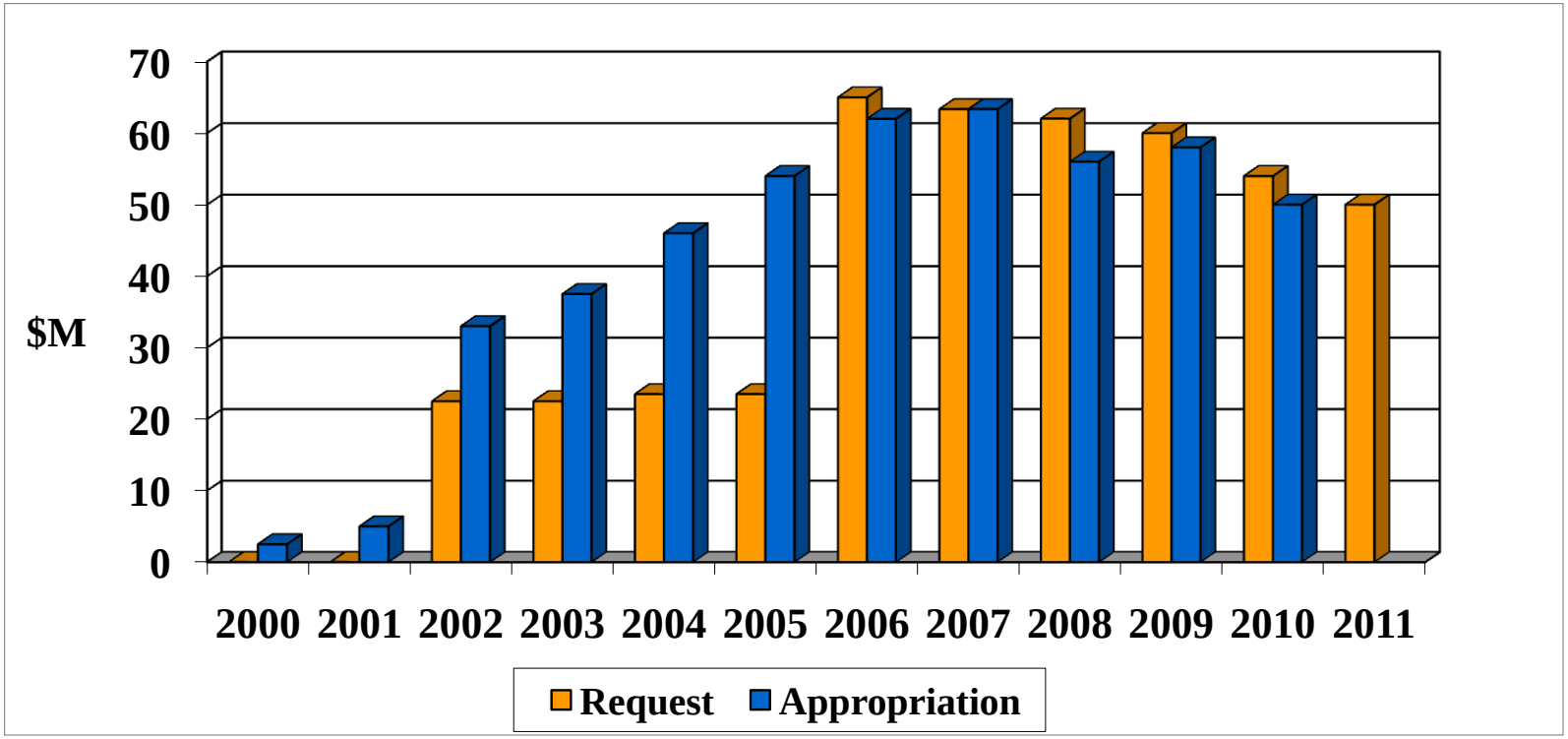
- Promotes collaboration
- Limits research redundancy
- Technology solution not "locked up"

SECA Core Technology R&D

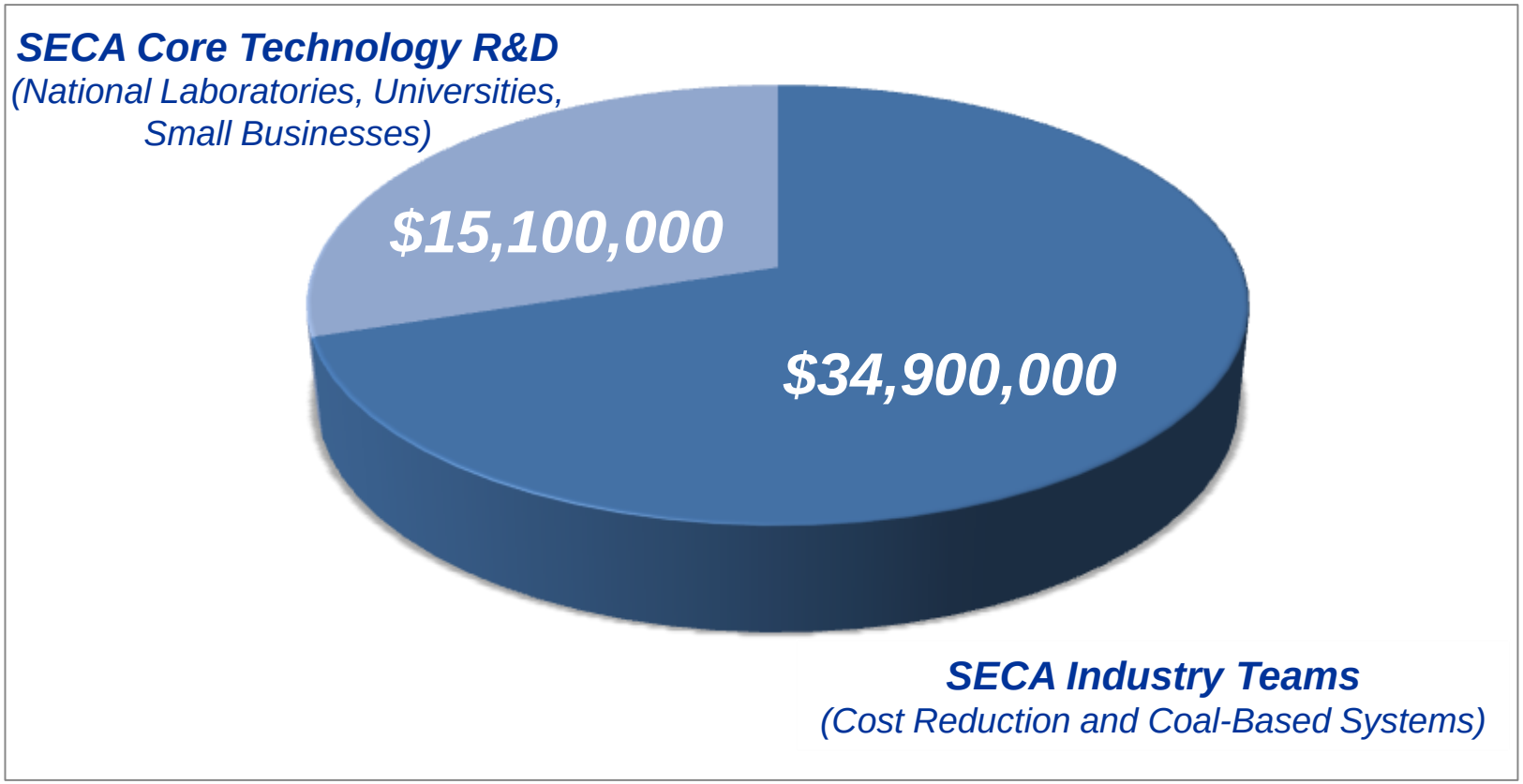




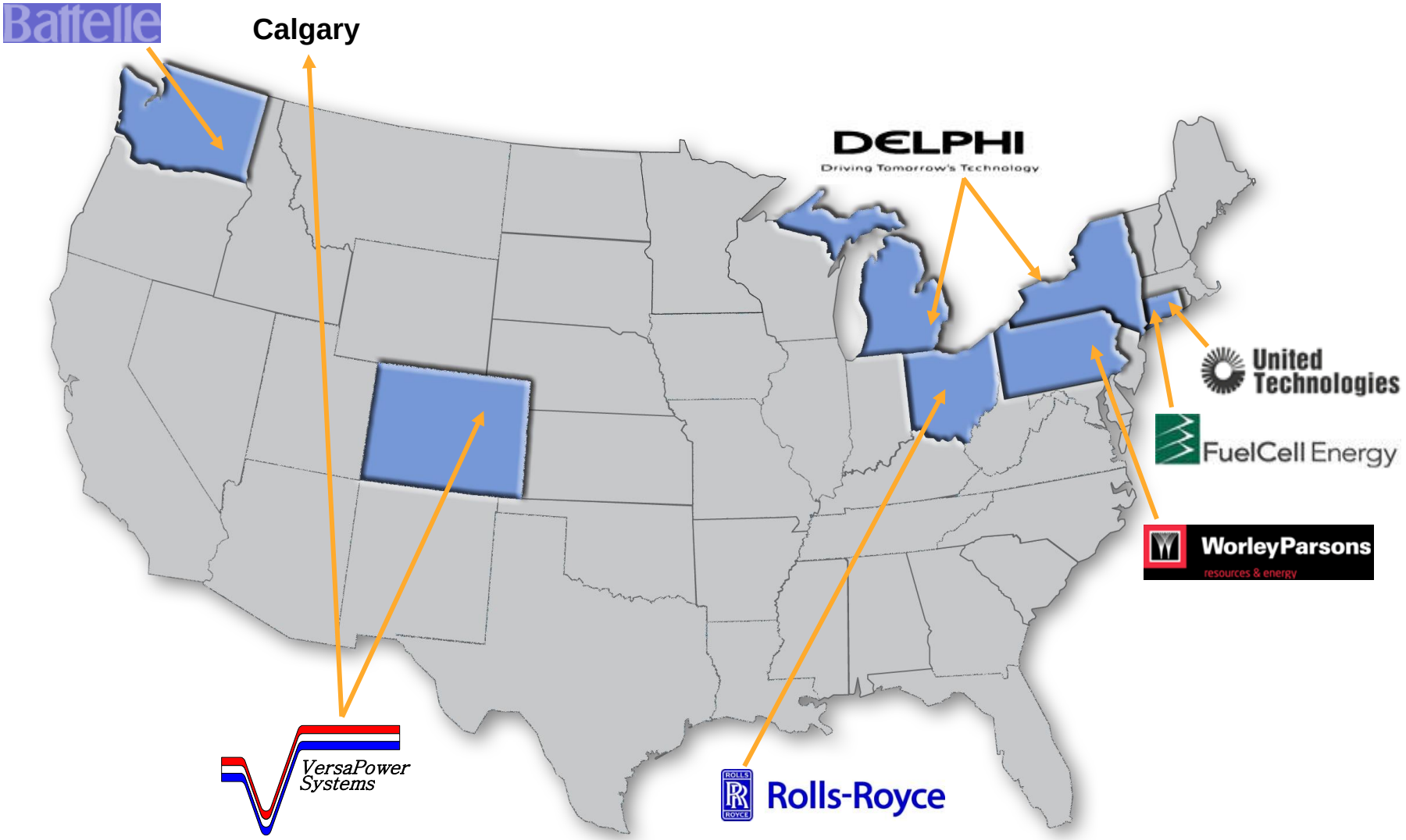
Fossil Energy Fuel Cell Program
SECA Budget – History



Fossil Energy Fuel Cell Program
SECA Budget – FY10
$50MM



Industry Teams & Major Subcontractors



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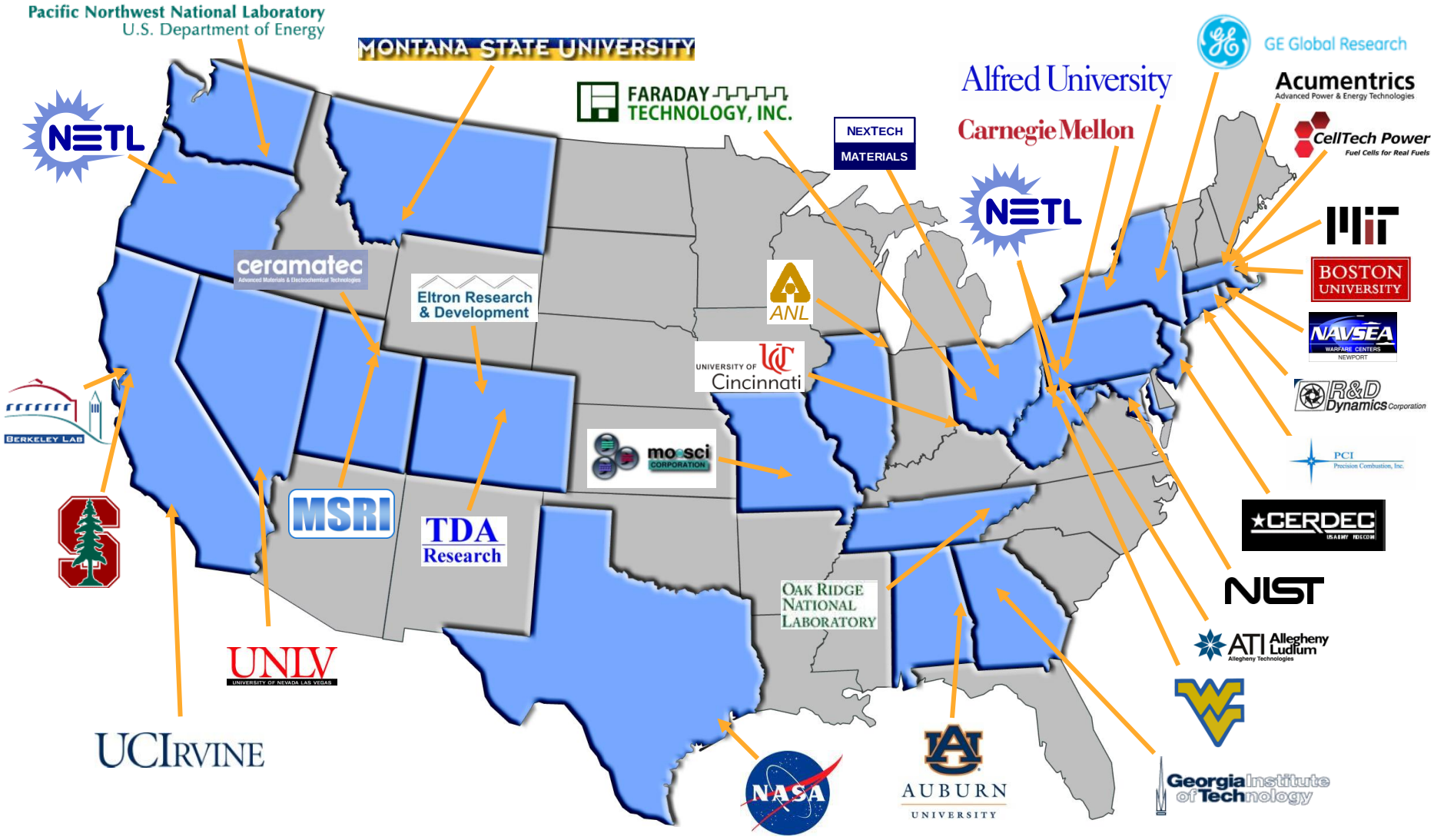
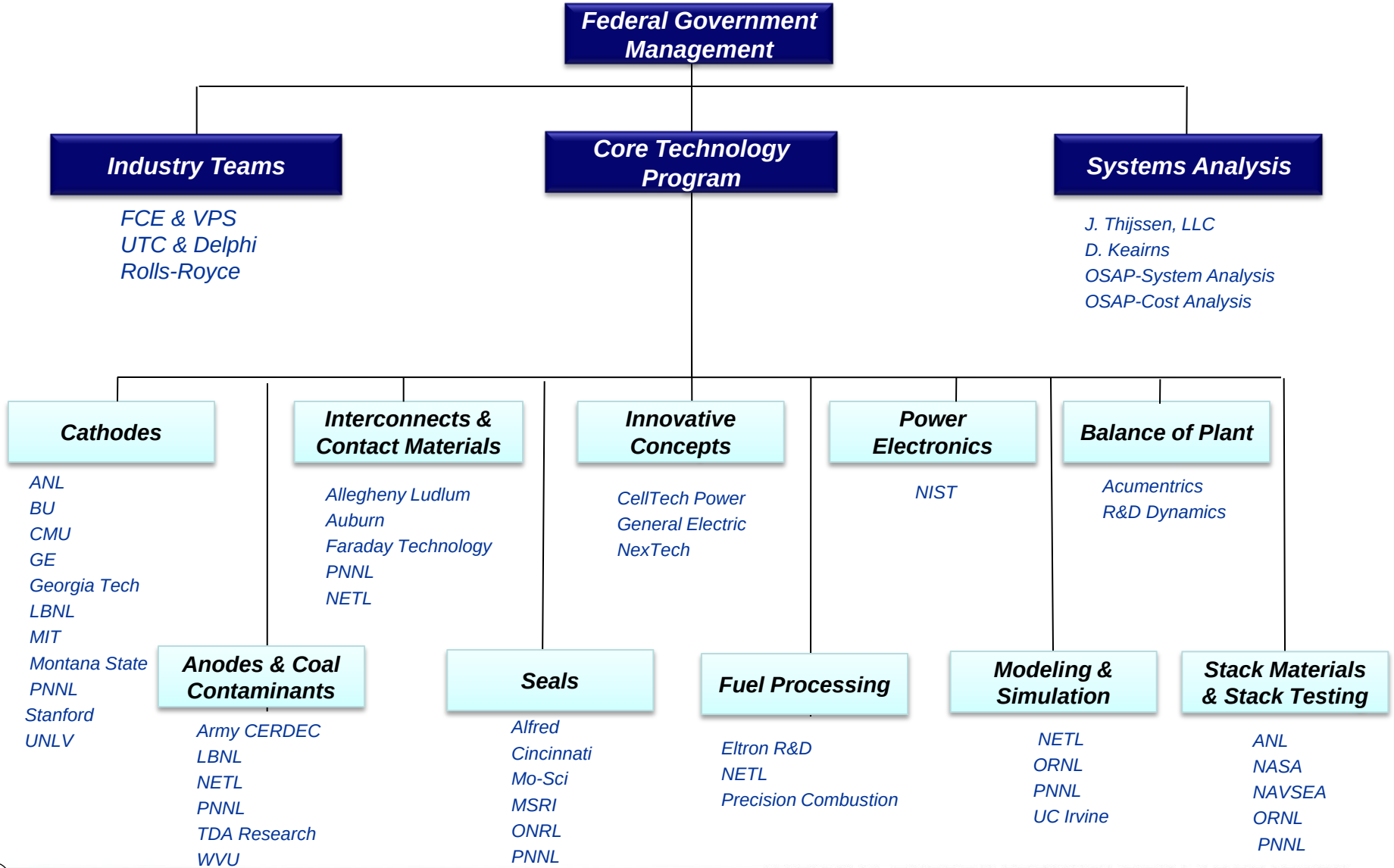
2010 SECA Core Technology & Other Partners



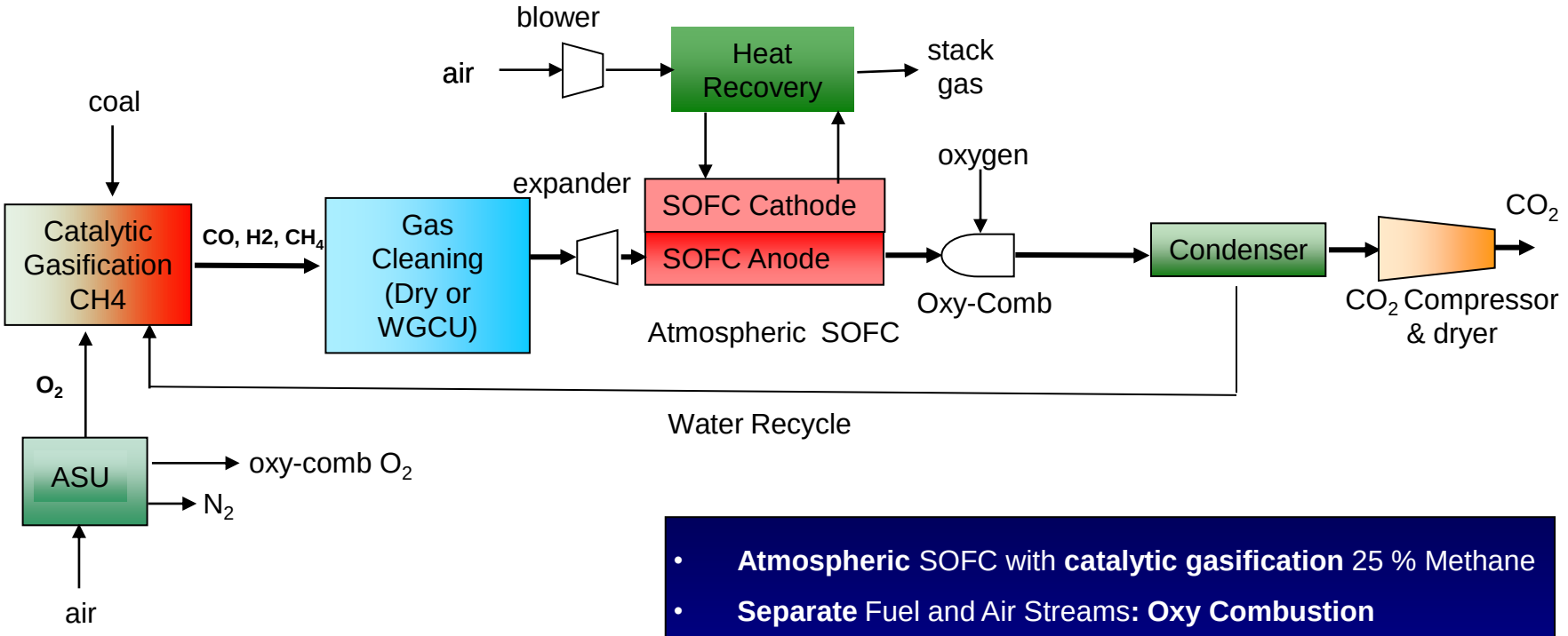
Solid State Energy Conversion Alliance



DOE's Office of Fossil Energy
Advanced (Coal) Power Systems Goals

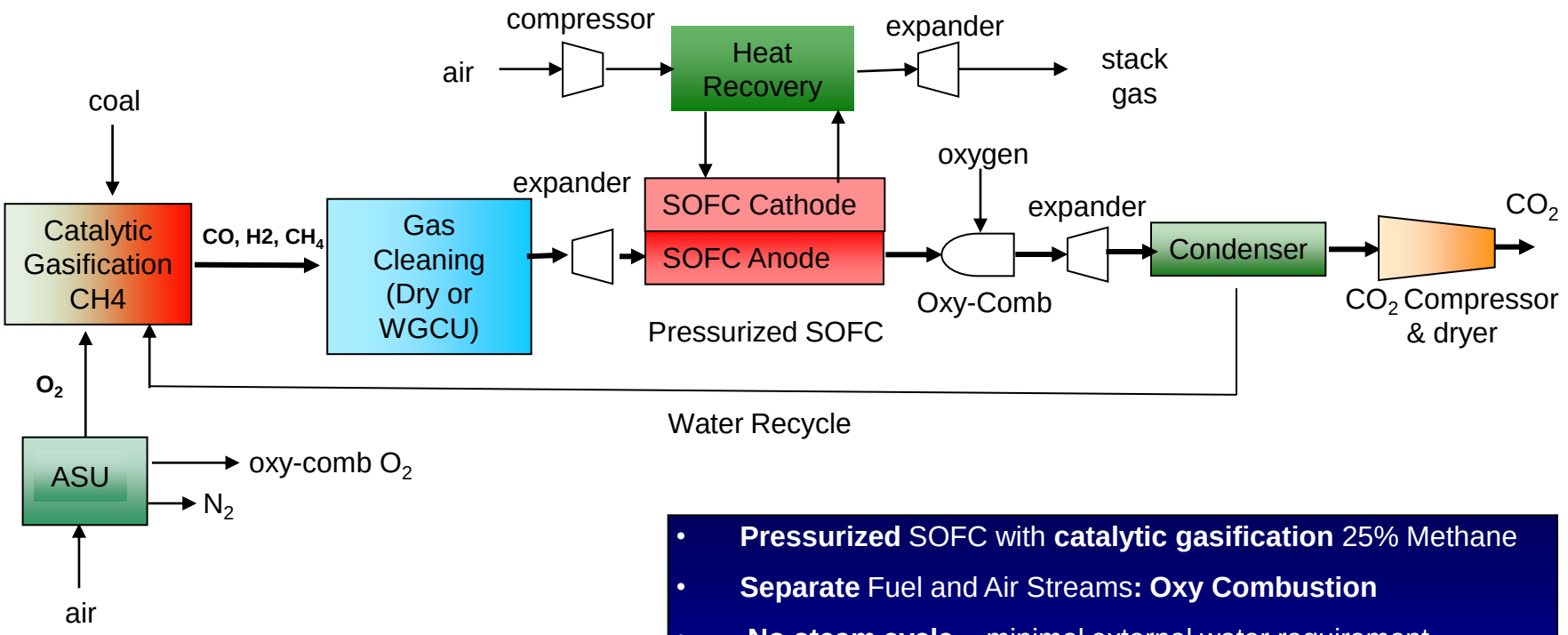
- **2010:**
  - **45-47% Efficiency (HHV)**
  - **99% SO_2 removal**
  - **NOx< 0.01 lb/MM Btu**
  - **90% Hg removal**
- **2015:**
  - **90% CO_2 capture**
  - ***<10% increase in COE with carbon sequestration***
  - **Multi-product capability (e.g, power + H_2)**
  - **60% efficiency (measured without 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 CO2 Compression**
  - **~54% w/out CO2 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 CO2 Compression**
  - **~61% w/out CO2 Compression**

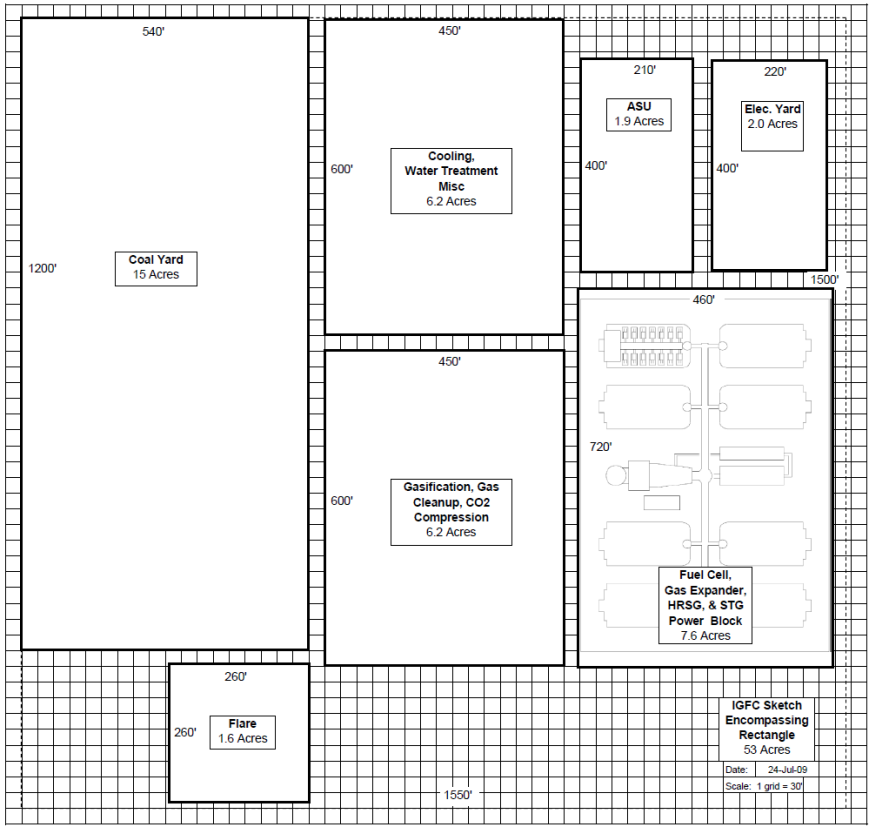
Impact of Efficiency on COE

Advanced Power Systems With CO_2 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_{net}	10.7	18.3		2.5	1.8
Levelized Cost-of-Electricity ¢/kW-hr	15.0	15.1		10.8	10.3

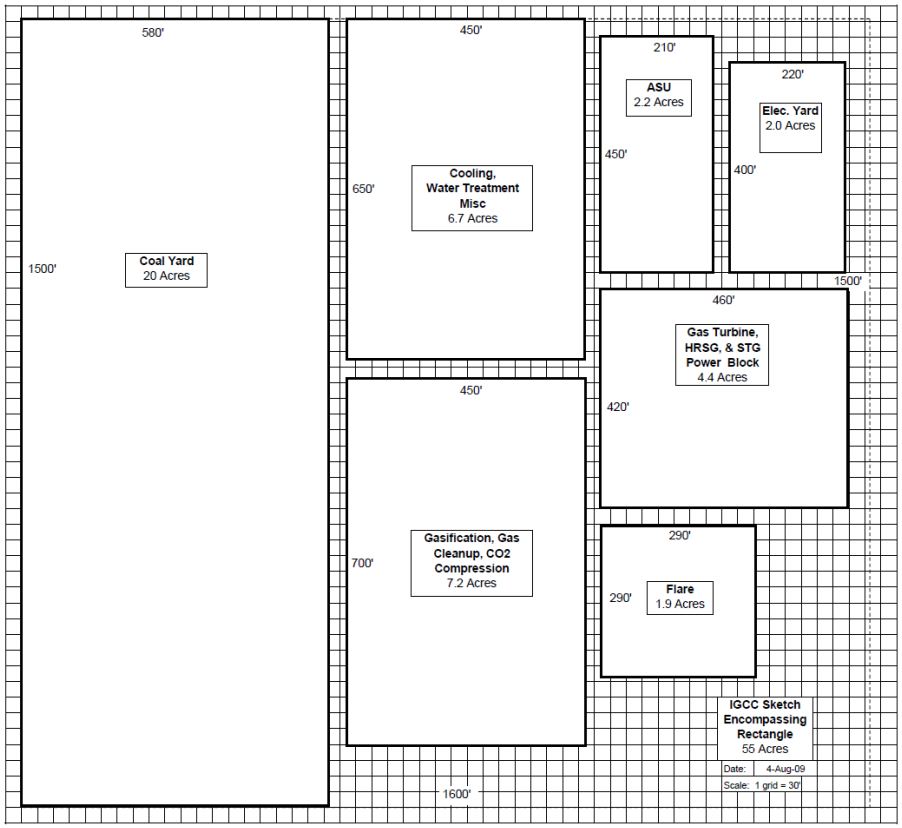
Sources: Cost and Performance Baseline for Fossil Energy Plants, Volume 1, Revision 2 DRAFT, 2010 Anticipated Release
Analysis of Integrated Gasification Fuel Cell Plant Configurations, DRAFT, 2010 Anticipated Release

Representative Foot Print Comparison: IGFC & IGCC

IGFC – 53 Acres



IGCC – 55 Acres



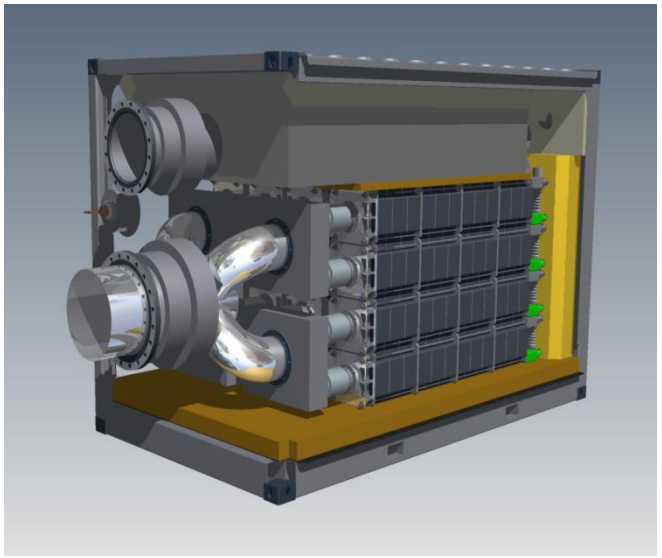
- ***A similarly sized IGCC and IGFC will be comparable in real estate requirement.***

Provided by:

WorleyParsons
resources & energy

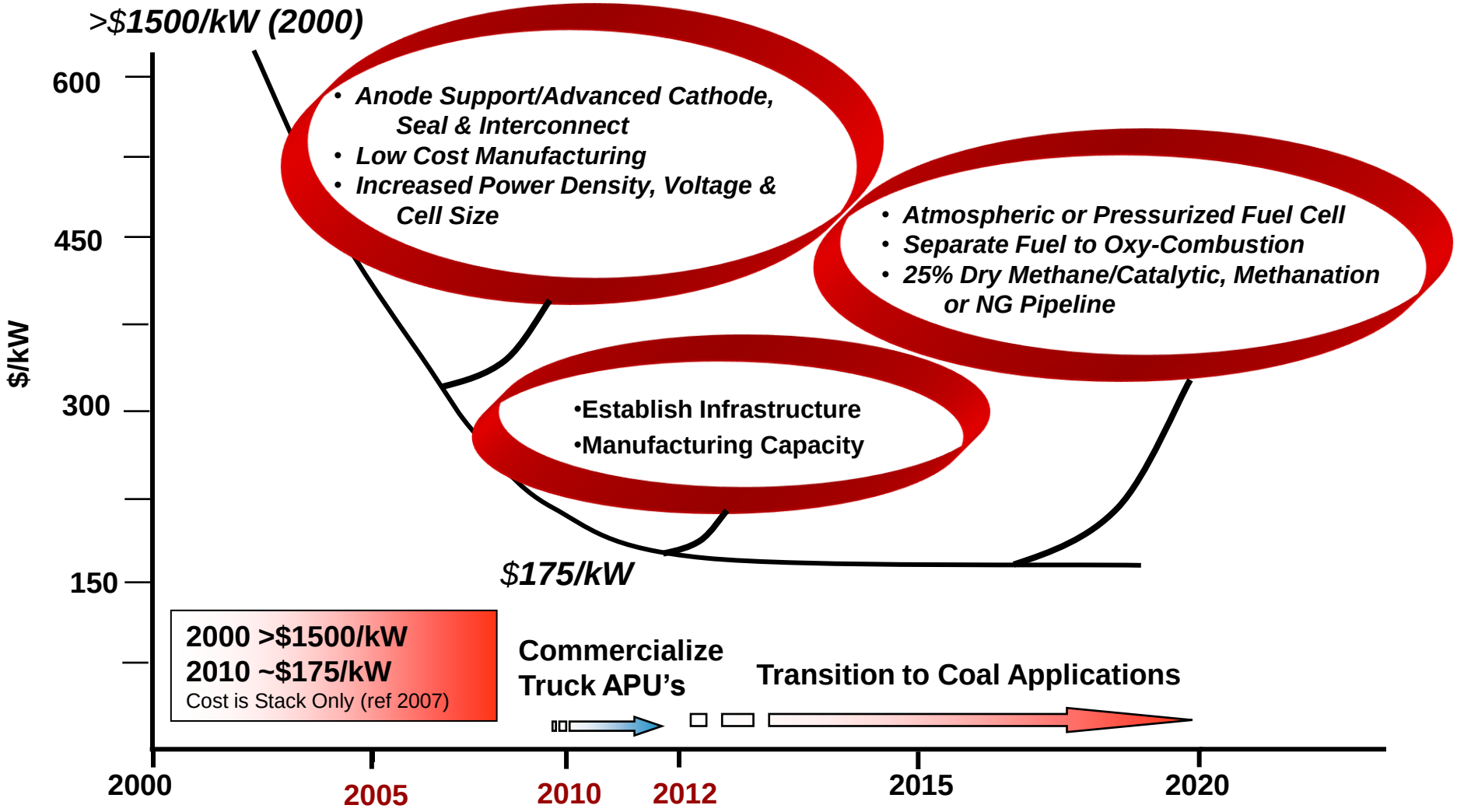
SECA Program Milestones – 2010
(OMB Performance Assessment Rating Tool)

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



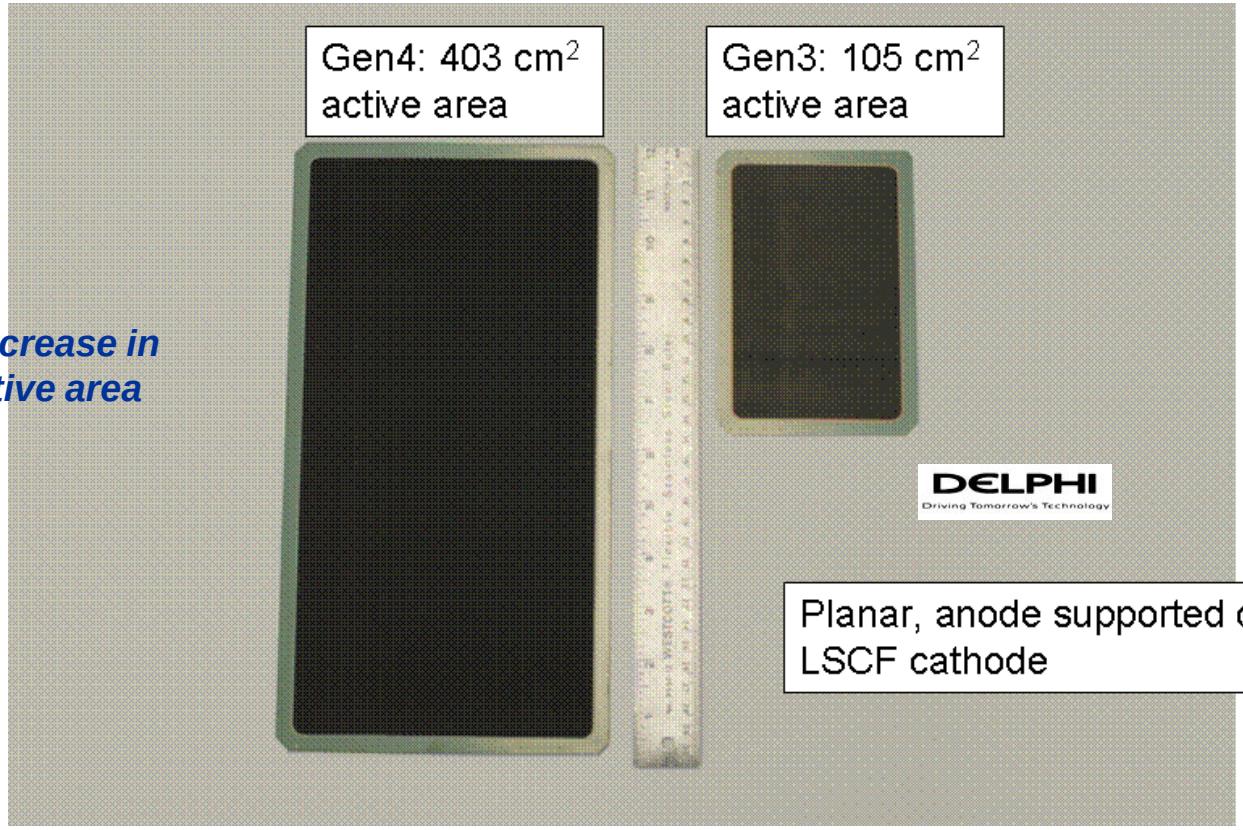
Driving Down Costs For Fuels Cells

(Order of Magnitude Cost Reduction)



Increase in Cell Size (Active Area)

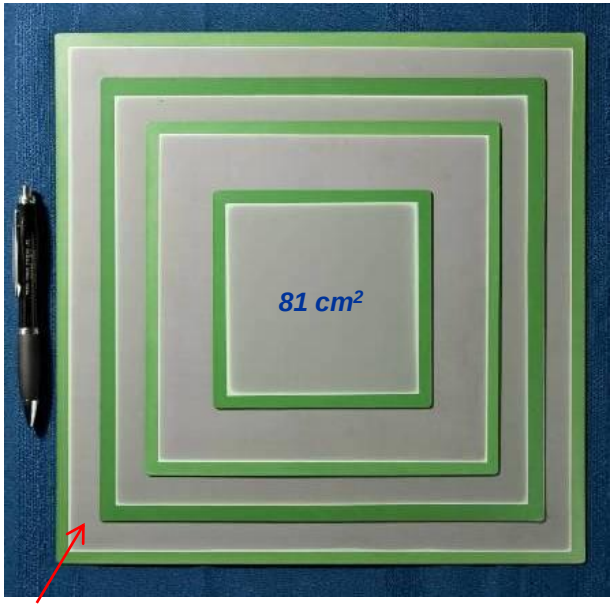
~ 4X increase in cell active area



- **Higher active area leads to higher power per cell**
- **Less number of cells per system**
- **Low parts count**

Increase in Cell Size (Active Area)

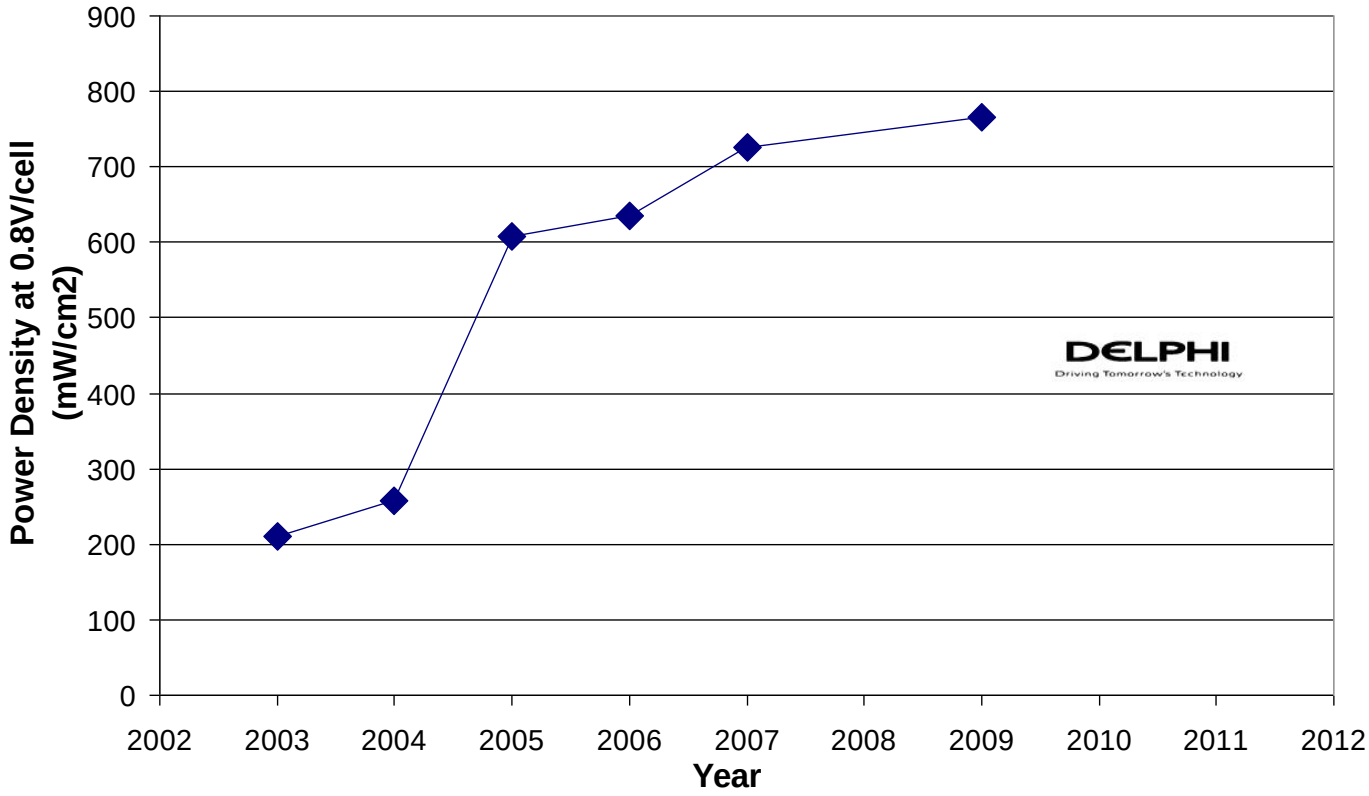
~ 7X increase in cell active area



FuelCell Energy
VersaPower Systems

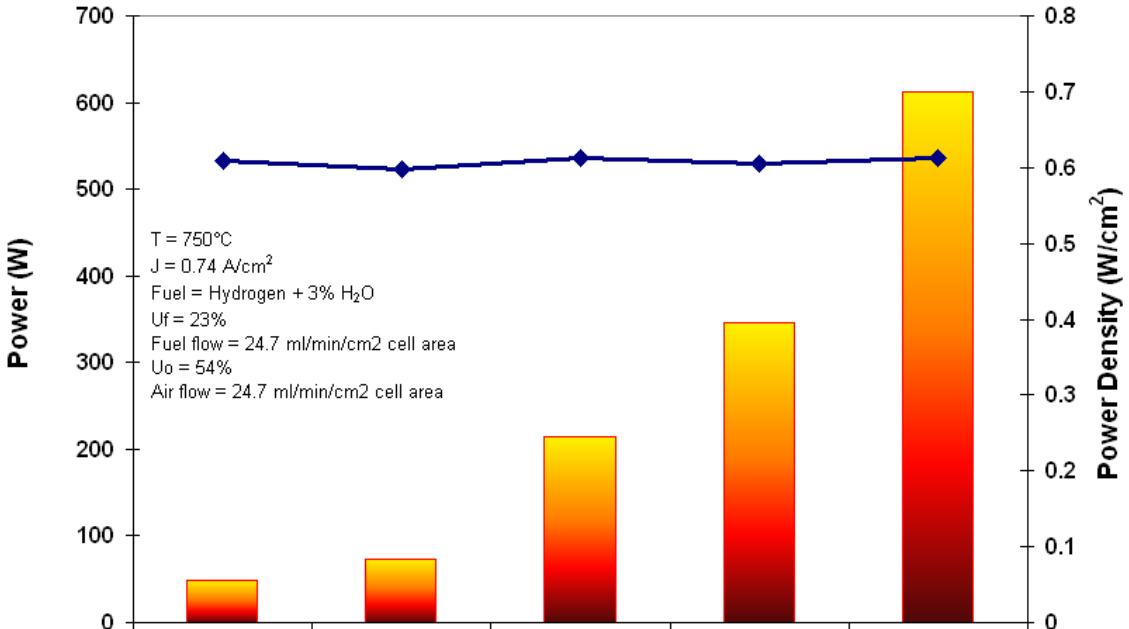
- **Higher active area leads to higher power per cell**
- **Less number of cells per system**
- **Low parts count**

Increase in Cell Power Density



- ~ 4 X increase in cell power density
- Power density independent of cell size

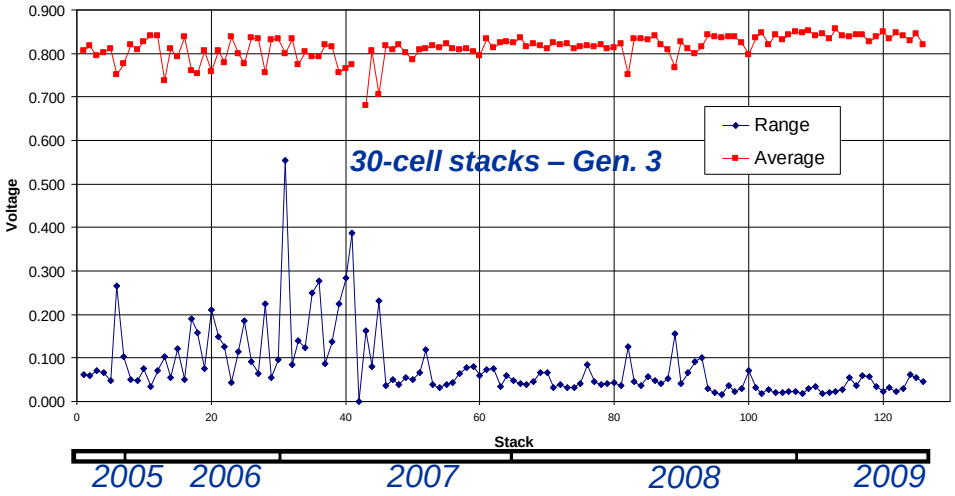
Increase in Cell Power Density



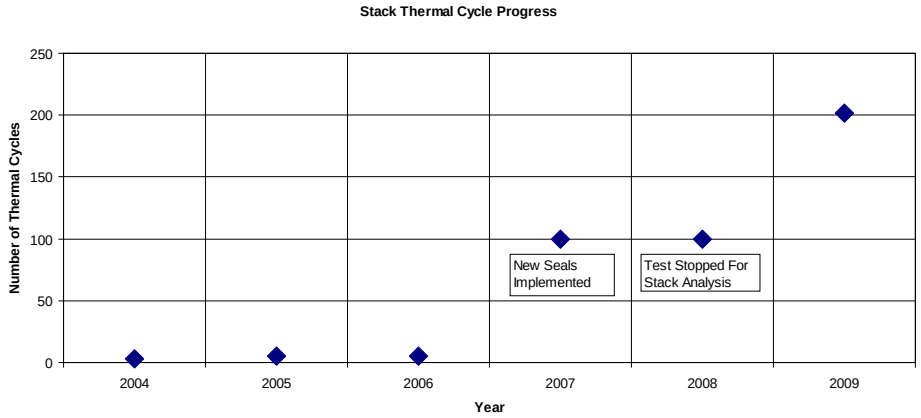
	2002	2004	2007	2008	2008
Power	49	72	214	346	612
Power Density	0.608	0.598	0.612	0.606	0.612

- ~ 4 X increase in cell power density
- Power density independent of cell size

Cell/Stack Reliability

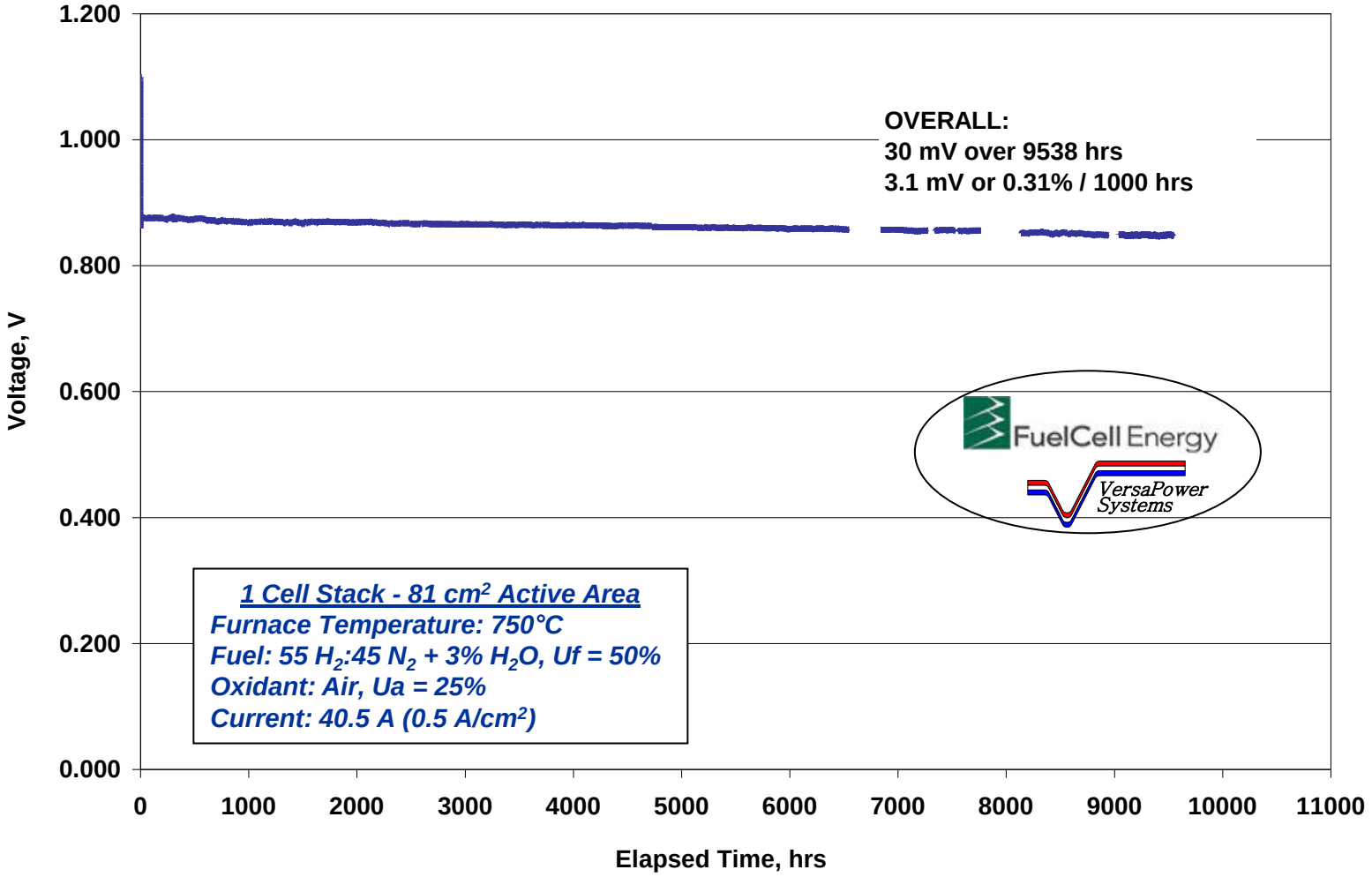


DELPHI
Driving Tomorrow's Technology

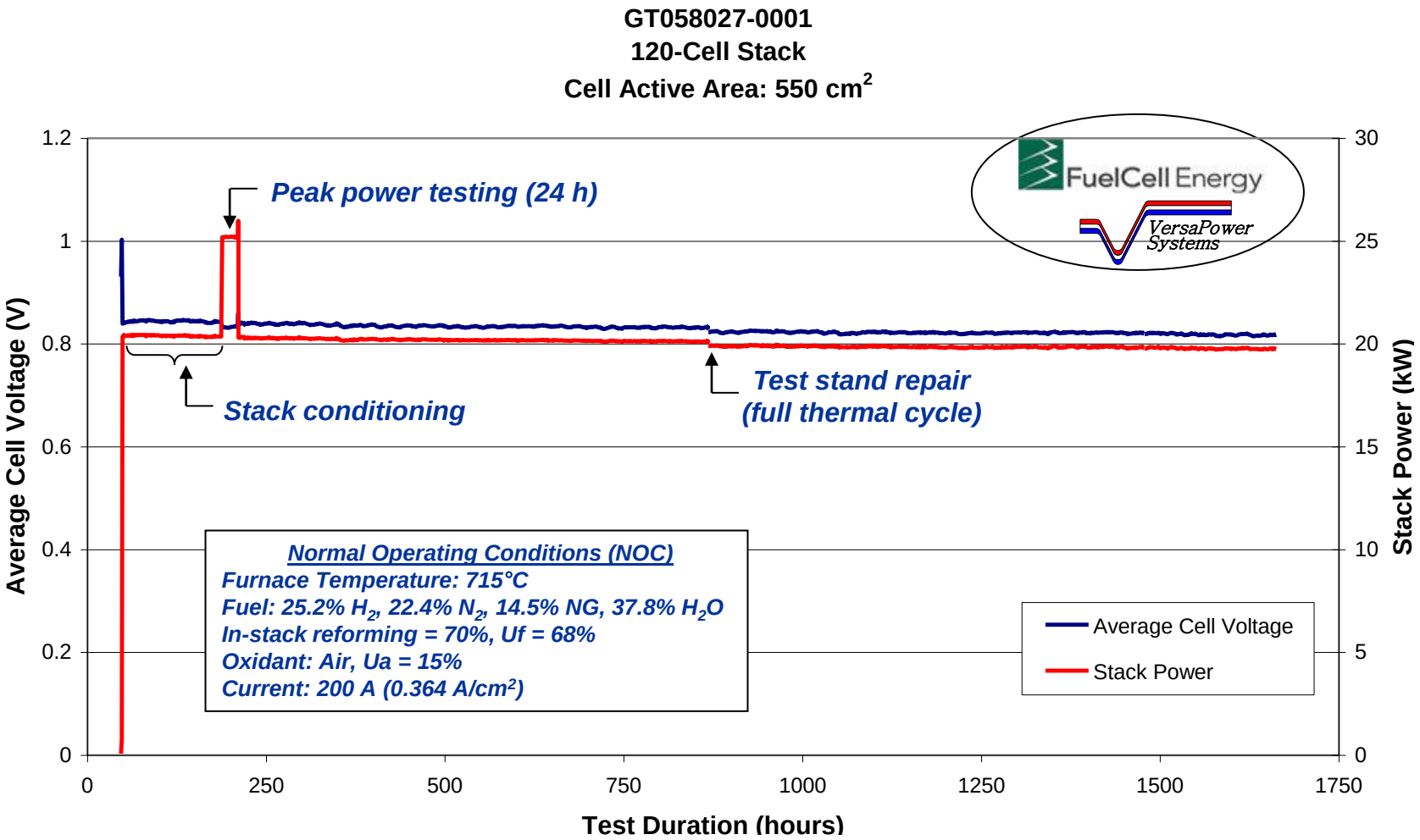


- **Tight control over stack output since 2007**
- **Excellent thermal cycling capability**

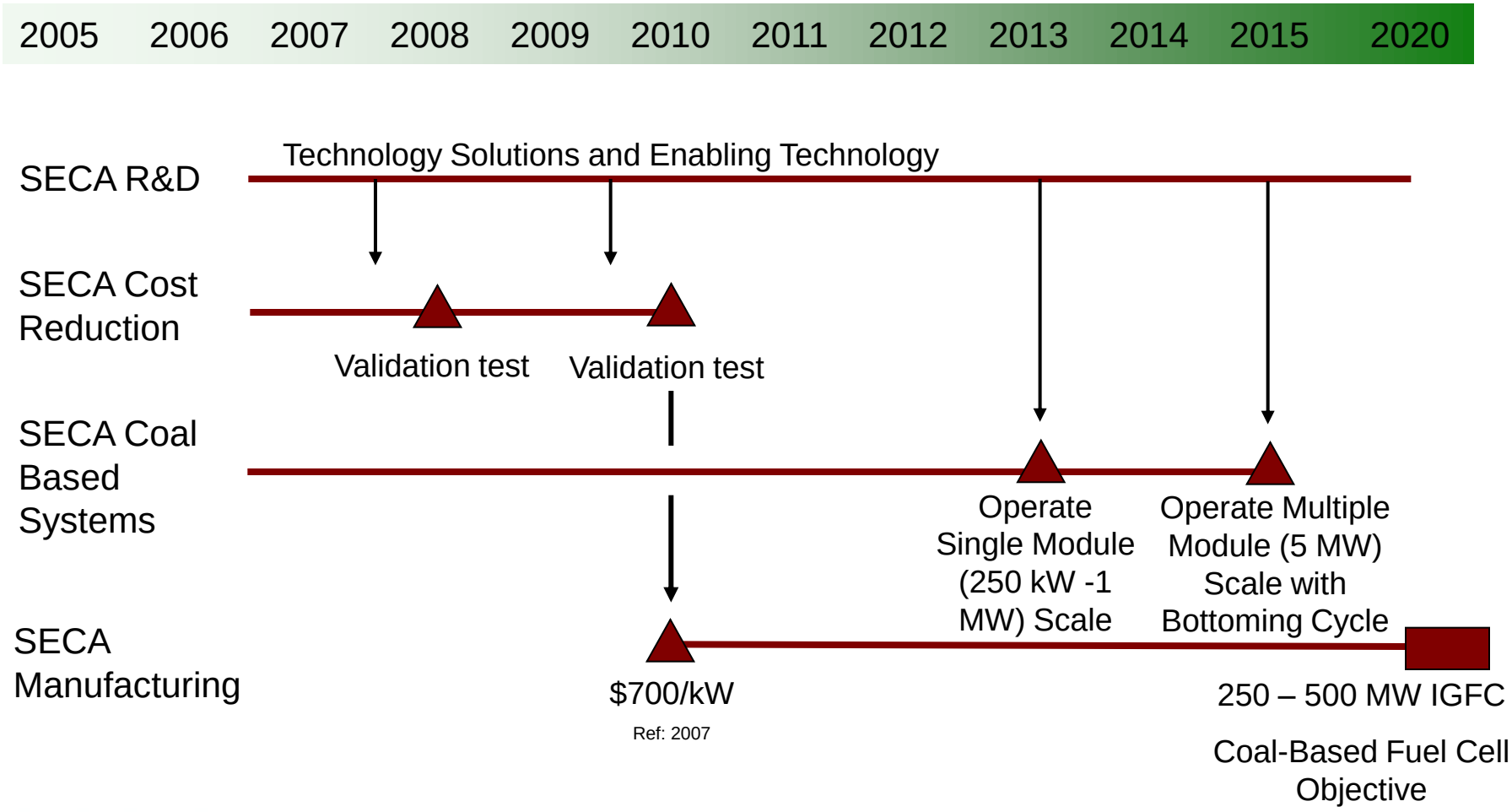
Cell/Stack Testing



Cell/Stack Testing

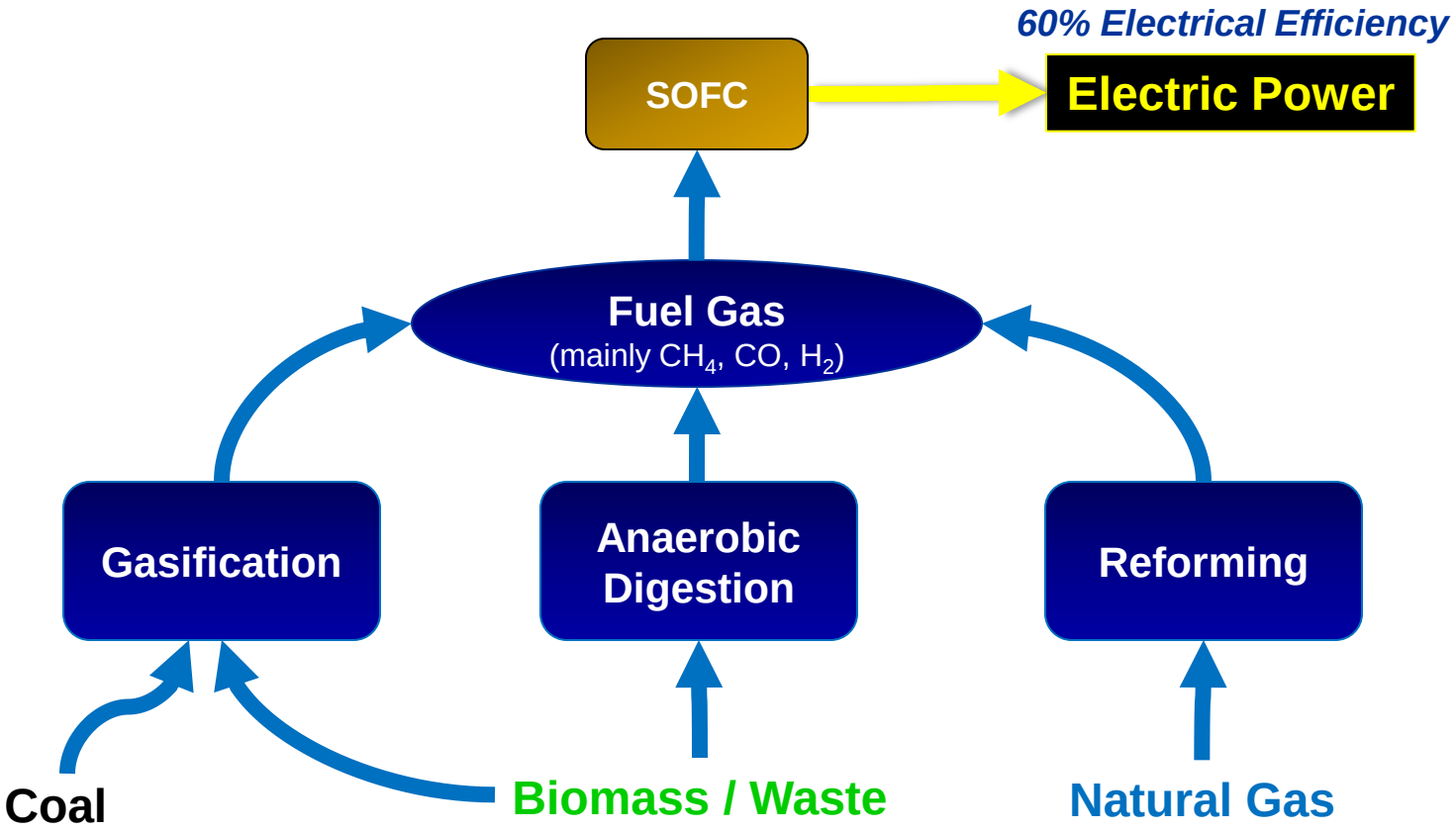


Solid State Energy Conversion Alliance
Fuel Cells Technology Timeline



SECA Fuel Flexibility

SOFC Systems can produce power from many fuels

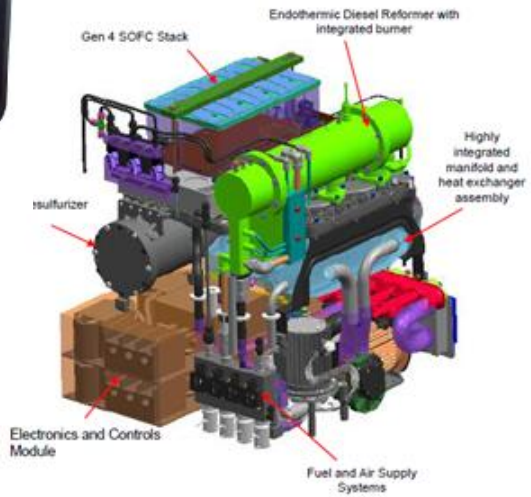


Delphi Auxiliary Power Unit Demos

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, (NUWCDIVNPT) 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 Core Technology Research Areas

Gas Seals	▪ Glass and Compressive Seals ▪ Compliant Seals ▪ Self-healing Materials ▪ High Temperature Refractive Seal
Failure Analysis	▪ Models with Electrochemistry & EMF ▪ Define Operating Window (Not possible experimentally) ▪ Structural Failure Analysis & Design Criteria (ASME)

Cathode performance	▪ Understand Mechanism
	  ▪ Ad-atom Modification of Surfaces
	  ▪ Modification through Infiltration
	Electronic Effect versus Defect Chemistry

Interconnect	▪ Coatings ▪ Electrode to Interconnect Interface - Contact Material
Anode / fuel processing	▪ Establish Fuel Specification ▪ Characterize Thermodynamics/Kinetics/ Contaminants
Heat Exchangers/ High Temperature Blowers	▪ Cost and Reliability ▪ Design Guidelines

For More Information on SECA…

Websites:

www.netl.doe.gov
www.fe.doe.gov
www.grants.gov

CDs available from the website

- **11th 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