



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

October 19, 2010

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United States Department of Energy



SECA Mission



- *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)

≥ 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.

SECA Program Structure



Industry Input

Program Management



Project Management

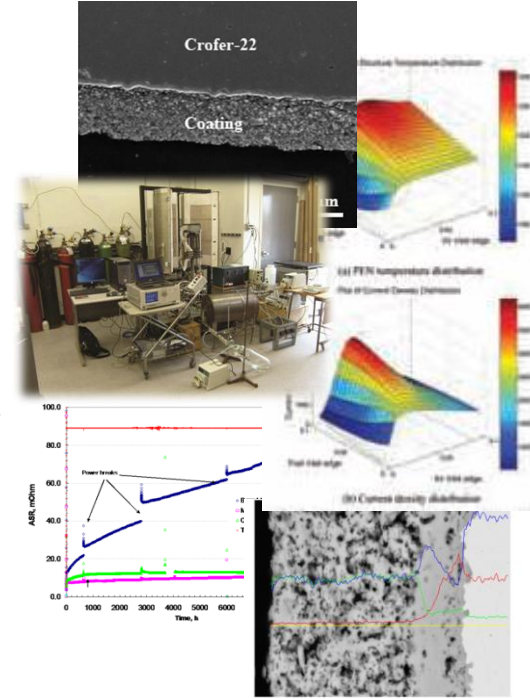
Needs

Research Topics



Industry Teams

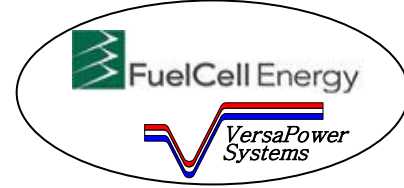
Core Technology Program



Technology Transfer

Intellectual Property Cornerstone of the Alliance

Industry Teams Develop Proprietary Technologies



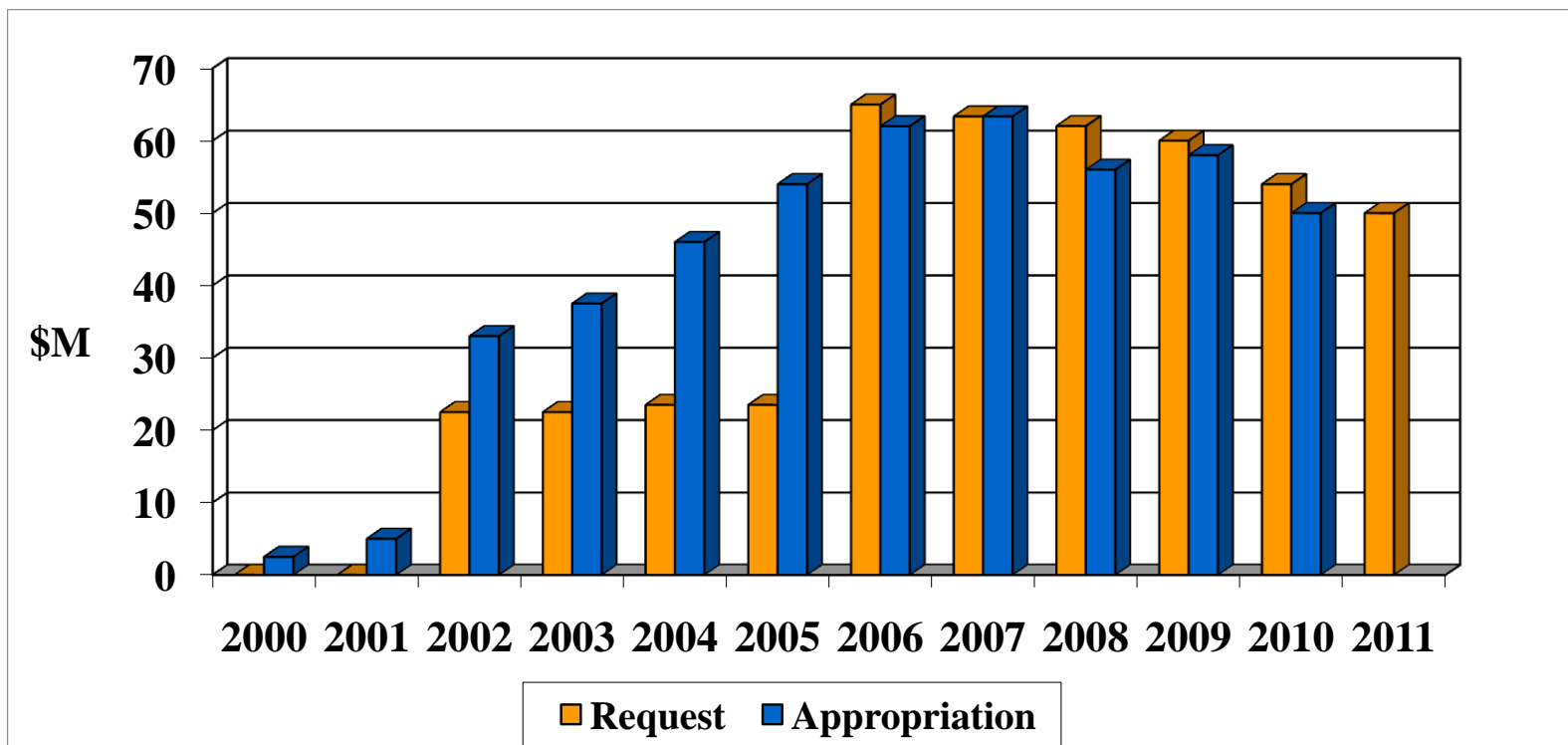
Non-Exclusive Licenses
Exceptional Circumstance to Bayh-Dole Act

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

SECA Core Technology R&D

The graph shows ASR (mOhm) on the left y-axis (0.0 to 100.0) and Temperature (°C) on the right y-axis (0 to 800) against Time (h) on the x-axis (0 to 9000). A red line for Temperature is constant at approximately 800°C. A blue line for ASR shows a step increase at 1000h labeled 'Power breakin', followed by a gradual increase to about 80 mOhm at 9000h. Other lines for Bland41 (blue), MC441 (magenta), and CeMC441 (green) remain relatively flat near 10 mOhm.

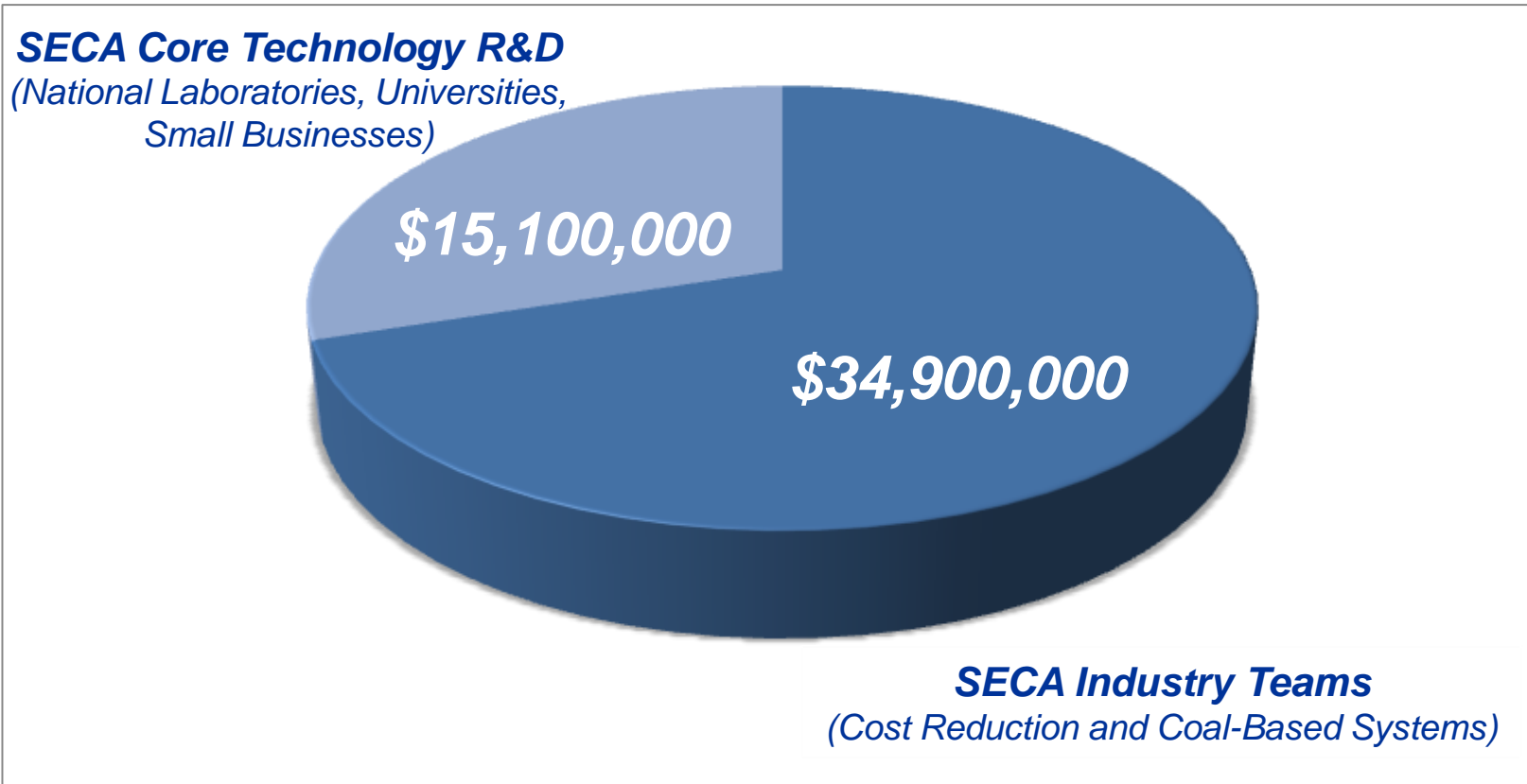
Fossil Energy Fuel Cell Program SECA Budget – History



Fossil Energy Fuel Cell Program

SECA Budget – FY10

\$50MM



Industry Teams & Major Subcontractors

Battelle


Calgary

DELPHI
Driving Tomorrow's Technology

 **United Technologies**

 **FuelCell Energy**

 **WorleyParsons**
resources & energy

 **VersaPower Systems**

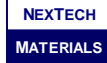
 **Rolls-Royce**

2010 SECA Core Technology & Other Partners



Pacific Northwest National Laboratory
U.S. Department of Energy

MONTANA STATE UNIVERSITY



Alfred University

Carnegie Mellon



Acumentrics
Advanced Power & Energy Technologies



NIST



Georgia Institute of Technology



OAK RIDGE NATIONAL LABORATORY



ceramatec
Advanced Materials & Electrochemical Technologies

Eltron Research & Development

MSRI

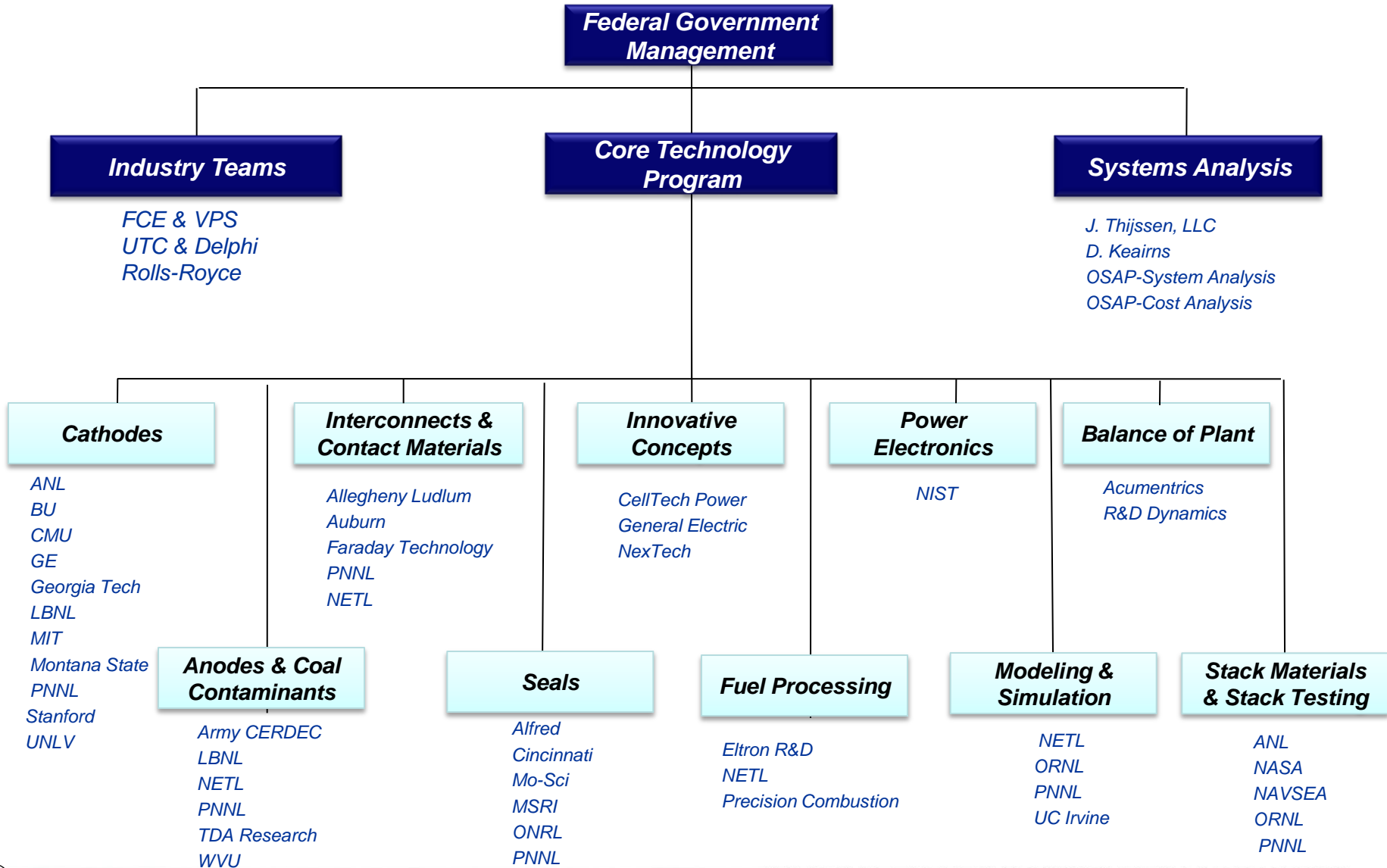
TDA
Research

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

UCIRVINE



Solid State Energy Conversion Alliance



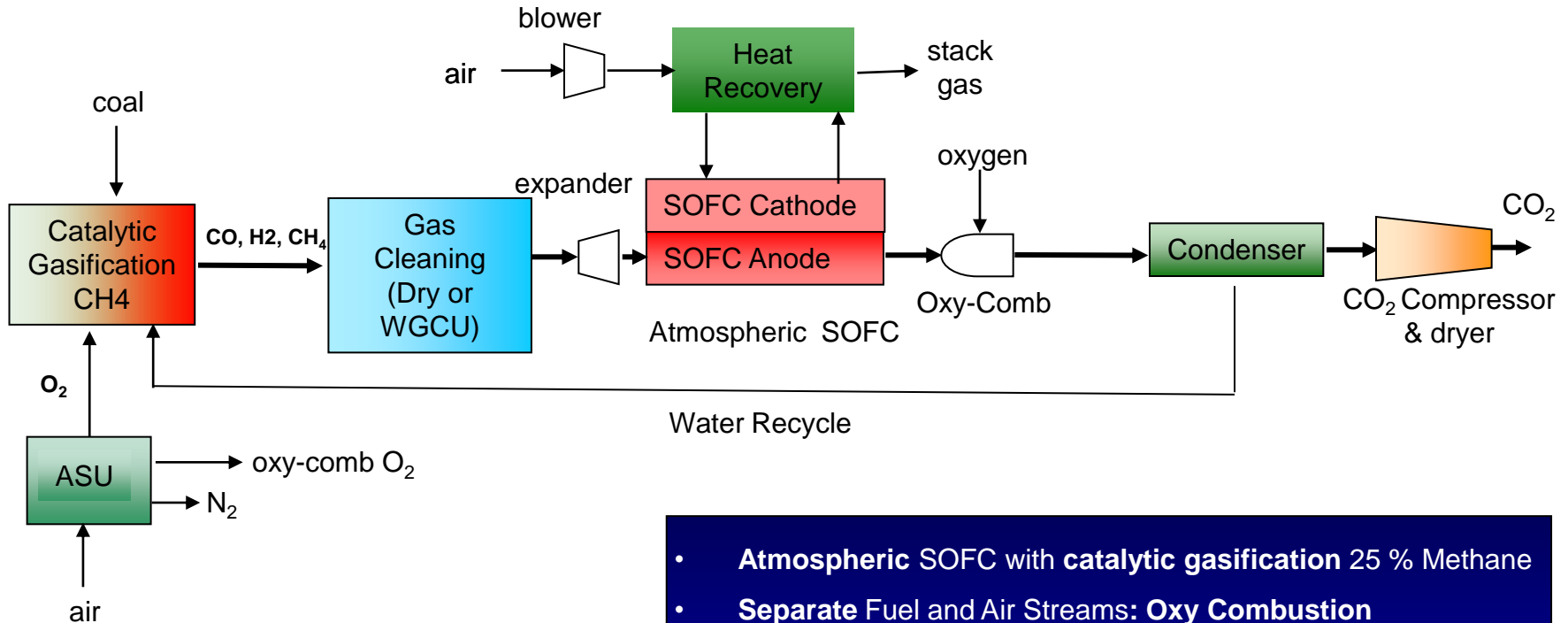
DOE's Office of Fossil Energy

Advanced (Coal) Power Systems Goals

- 2010:
 - 45-47% Efficiency (HHV)
 - 99% SO₂ removal
 - NO_x < 0.01 lb/MM Btu
 - 90% Hg removal
- 2015:
 - 90% CO₂ capture
 - <10% increase in COE with carbon sequestration
 - Multi-product capability (e.g, power + H₂)
 - 60% efficiency (measured without carbon capture)

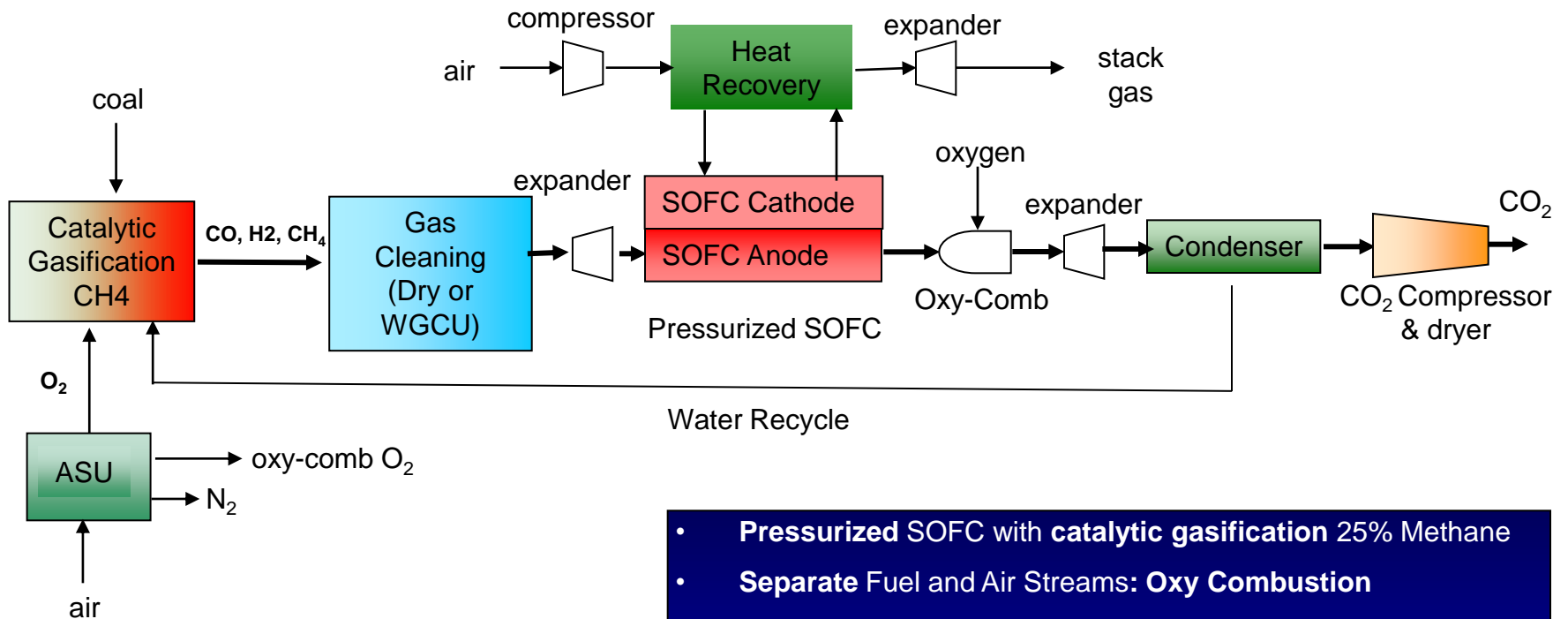


SECA Coal-Based Systems Atmospheric IGFC near-zero water requirement (99% carbon capture, 54% efficiency)



- **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

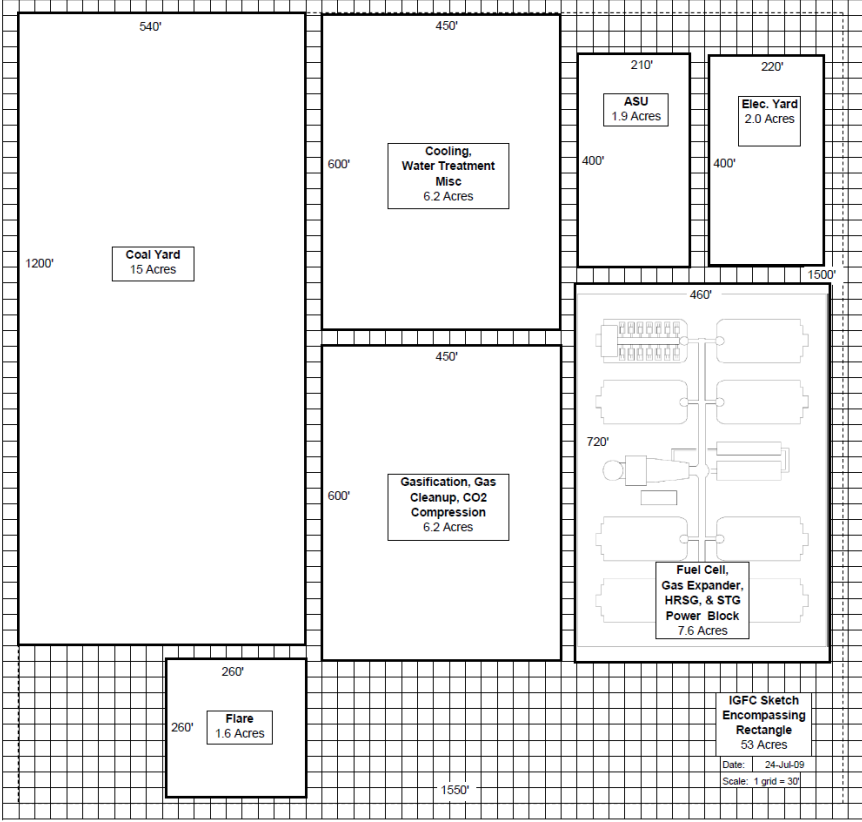
Advanced Power Systems With CO₂ Capture, Compression and Storage

| | 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 |

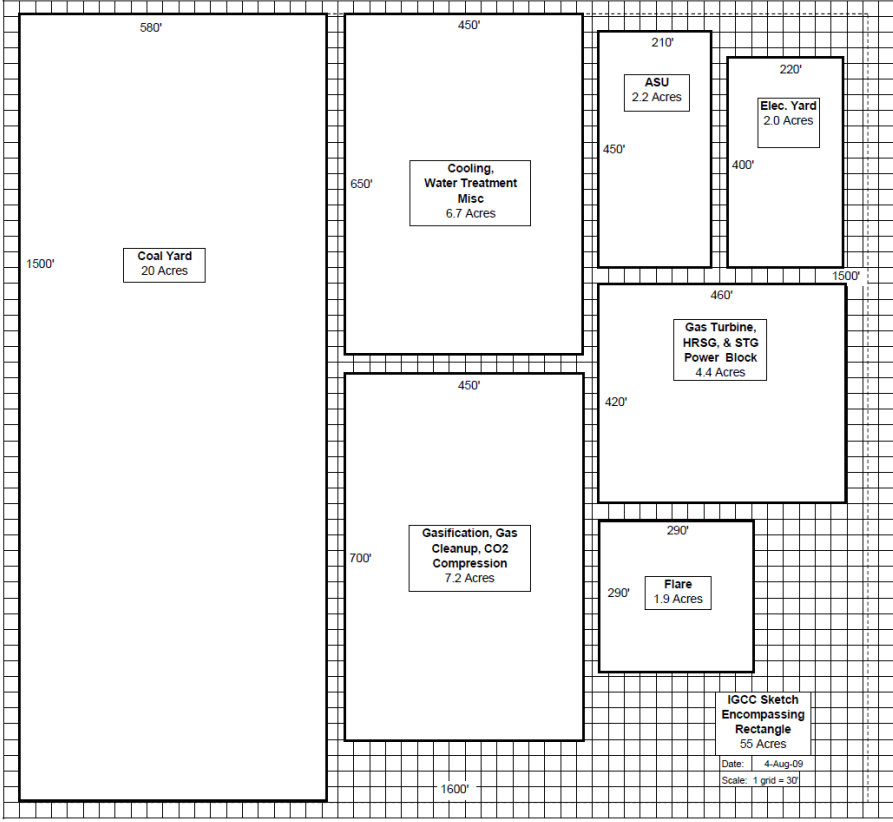
Sources: Cost and Performance Baseline for Fossil Energy Plants, Volume 1, Revision 2 DRAFT, 2010 Anticipated Release
Analysis of Integrated Gasification Fuel Cell Plant Configurations, DRAFT, 2010 Anticipated Release

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:



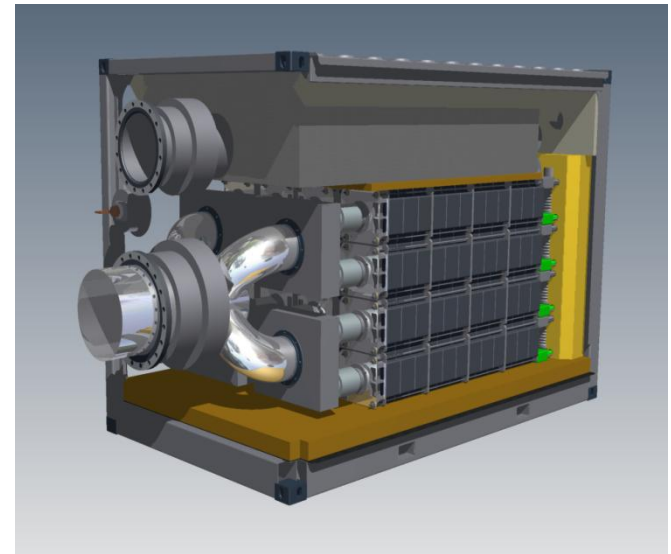
WorleyParsons

resources & energy

SECA Program Milestones – 2010

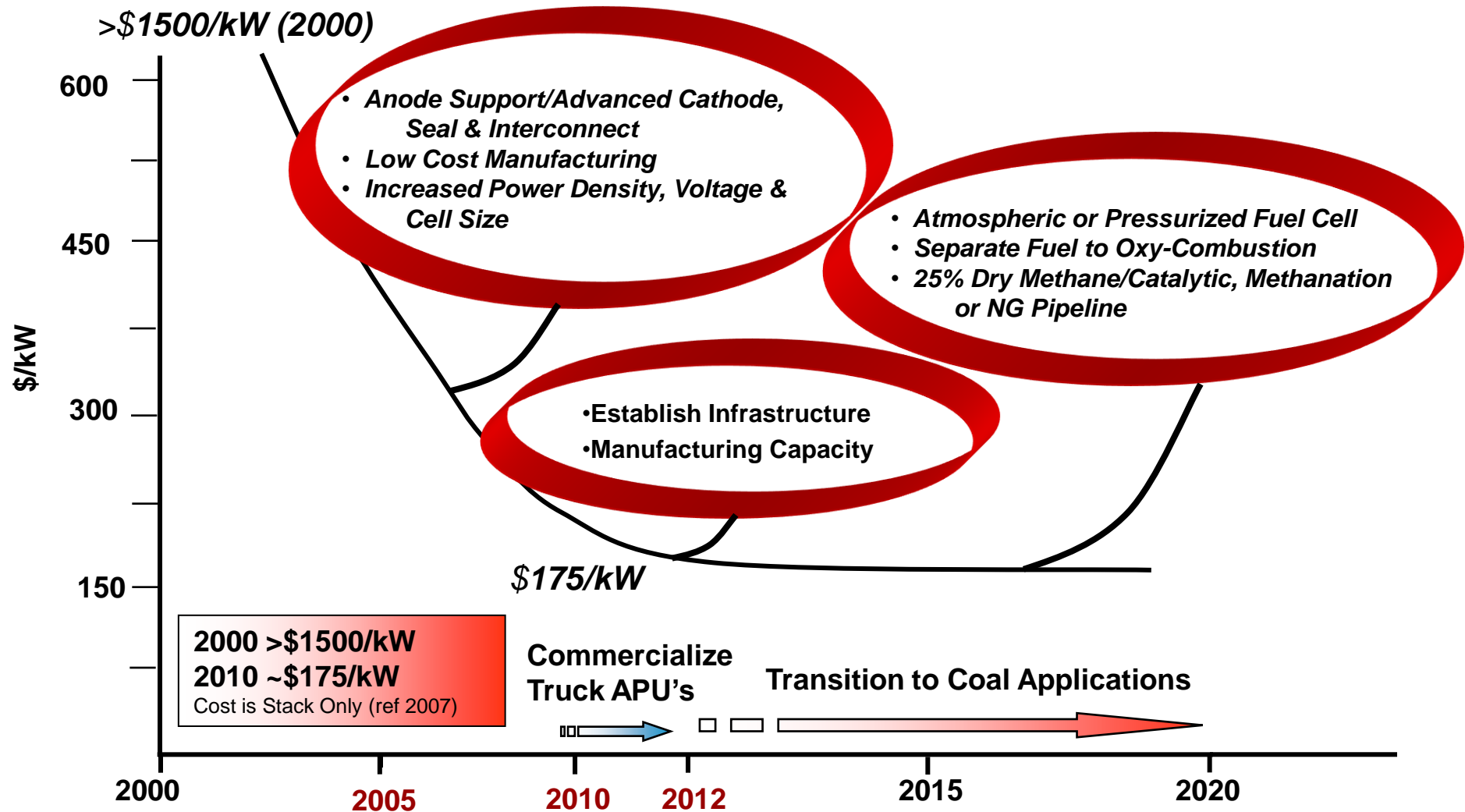
(OMB Performance Assessment Rating Tool)

- **Stack Cost - \$175/kW**
 - 2007 Dollar Basis
- **Power Block - \$700/kW**
- **Maintain Power Density with Increased Scale ~ 300mW/cm²**

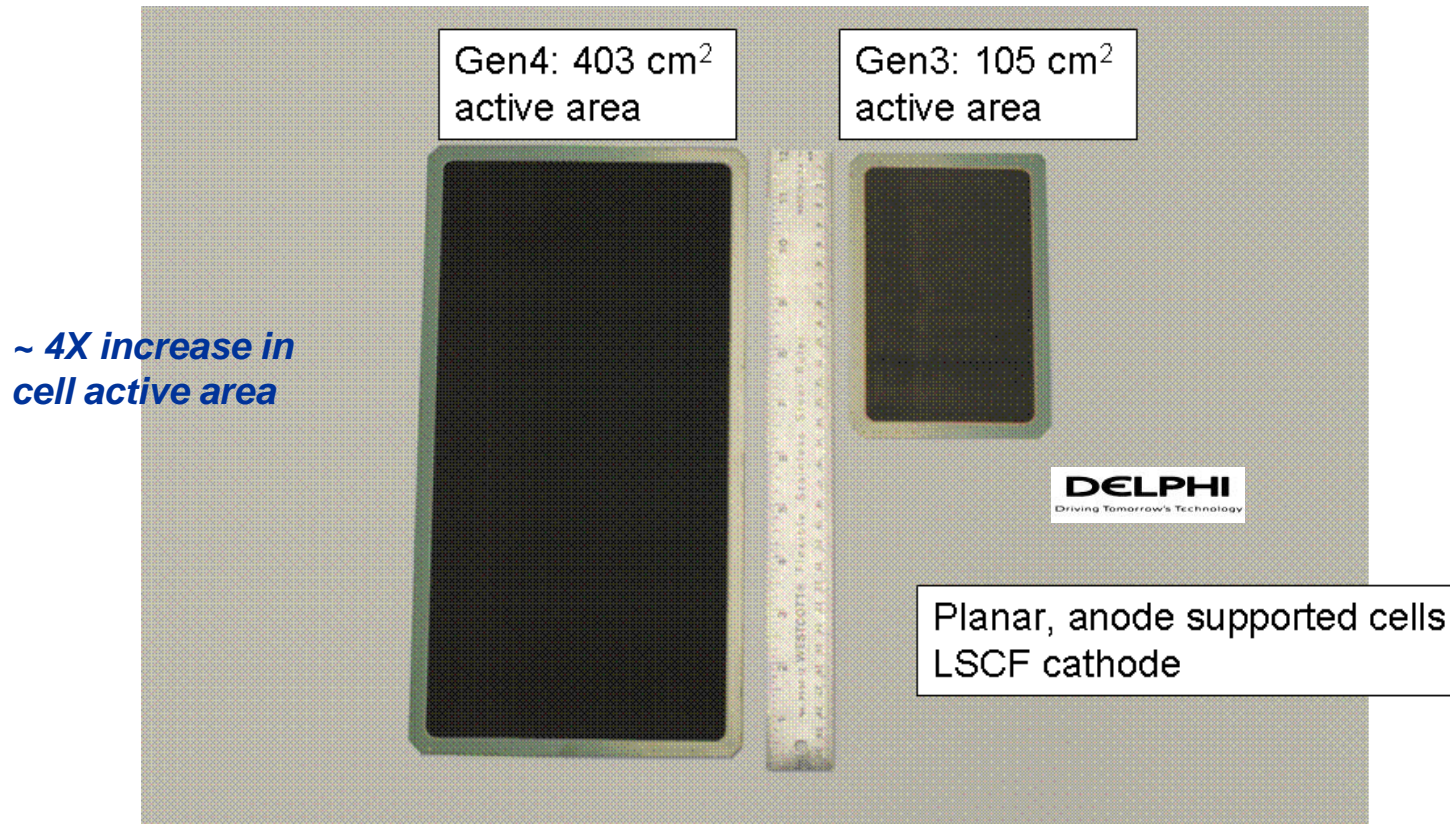


Driving Down Costs For Fuels Cells

(Order of Magnitude Cost Reduction)



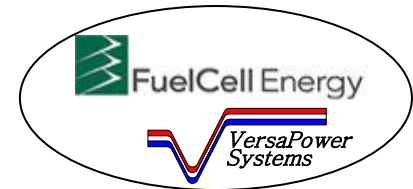
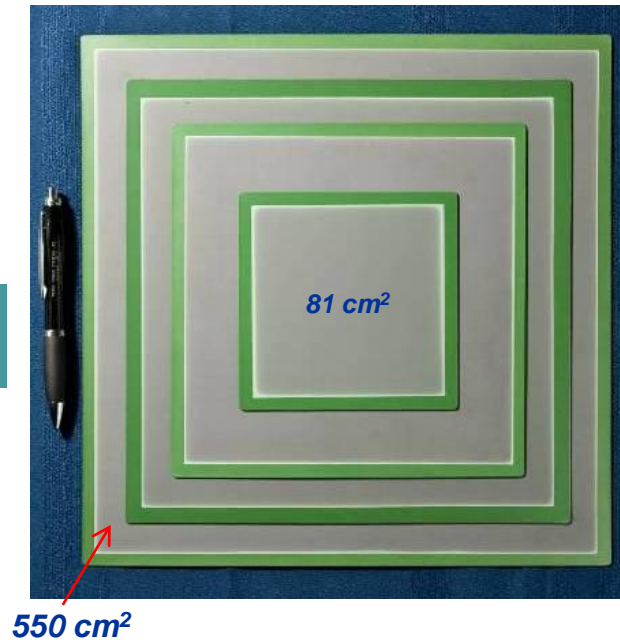
Increase in Cell Size (Active Area)



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

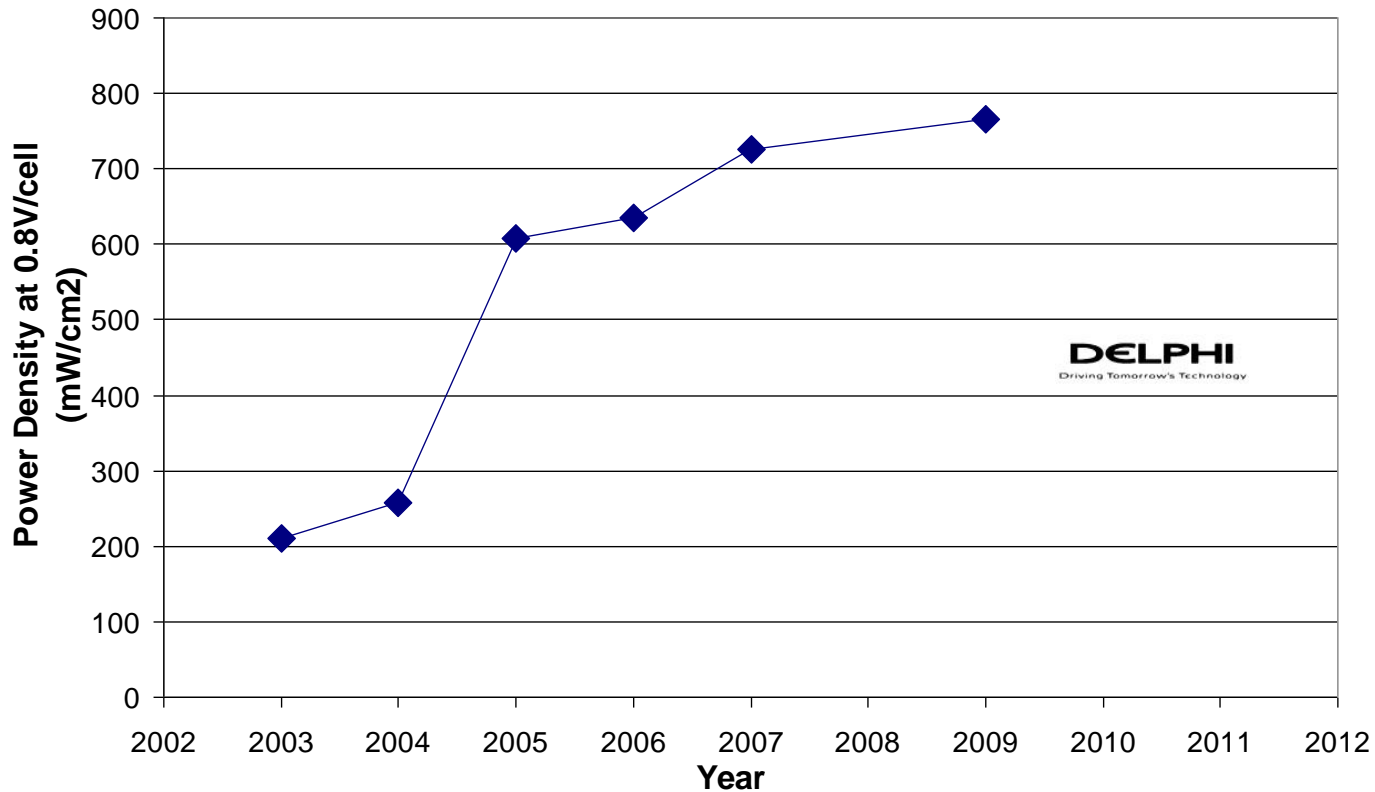
Increase in Cell Size (Active Area)

*~ 7X increase in
cell active area*



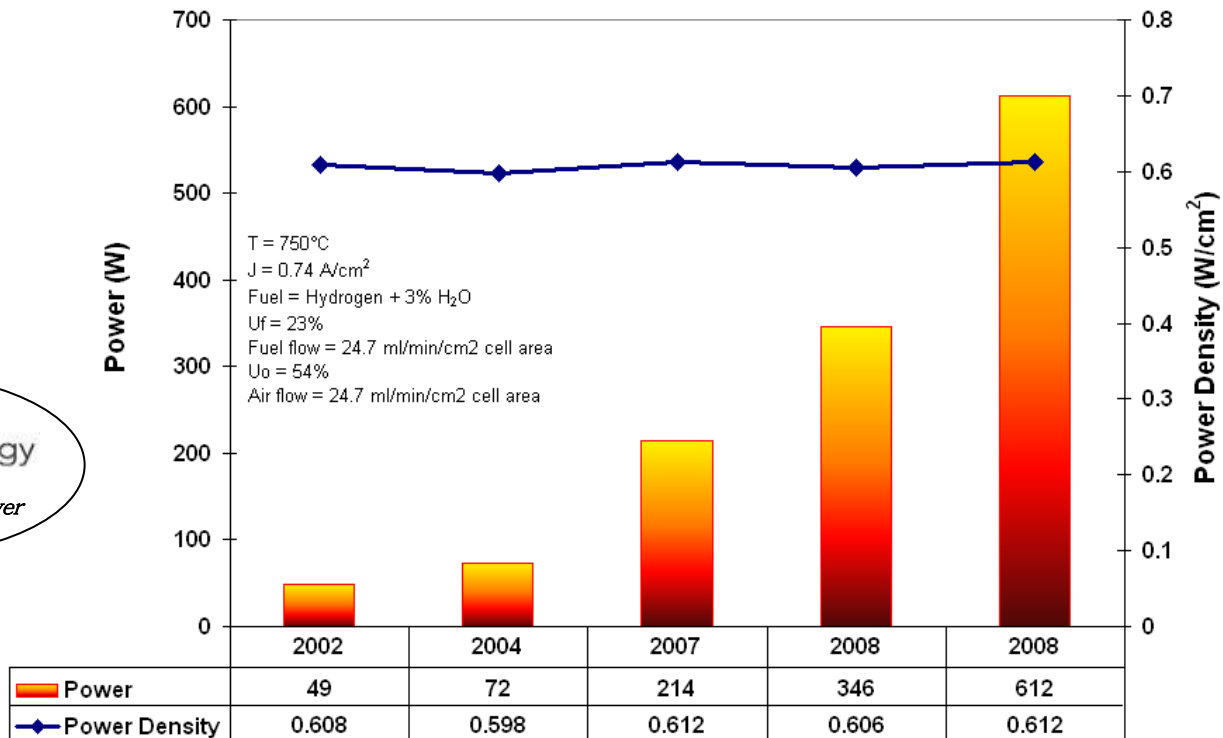
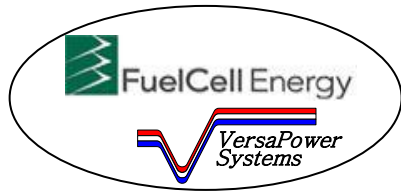
- Higher active area leads to higher power per cell
- Less number of cells per system
- Low parts count

Increase in Cell Power Density



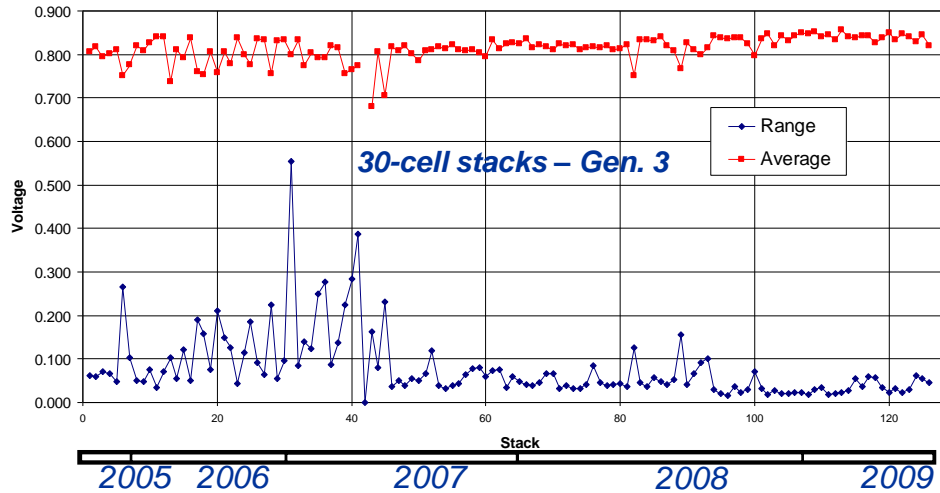
- ~ 4 X increase in cell power density
- Power density independent of cell size

Increase in Cell Power Density

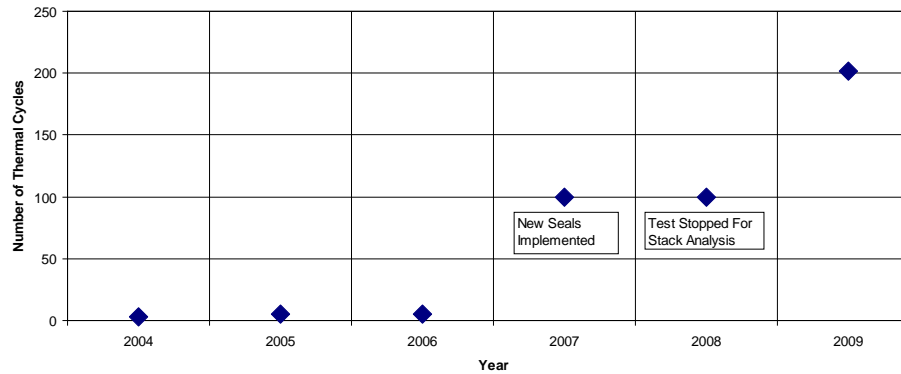


- ~ 4 X increase in cell power density
- Power density independent of cell size

Cell/Stack Reliability

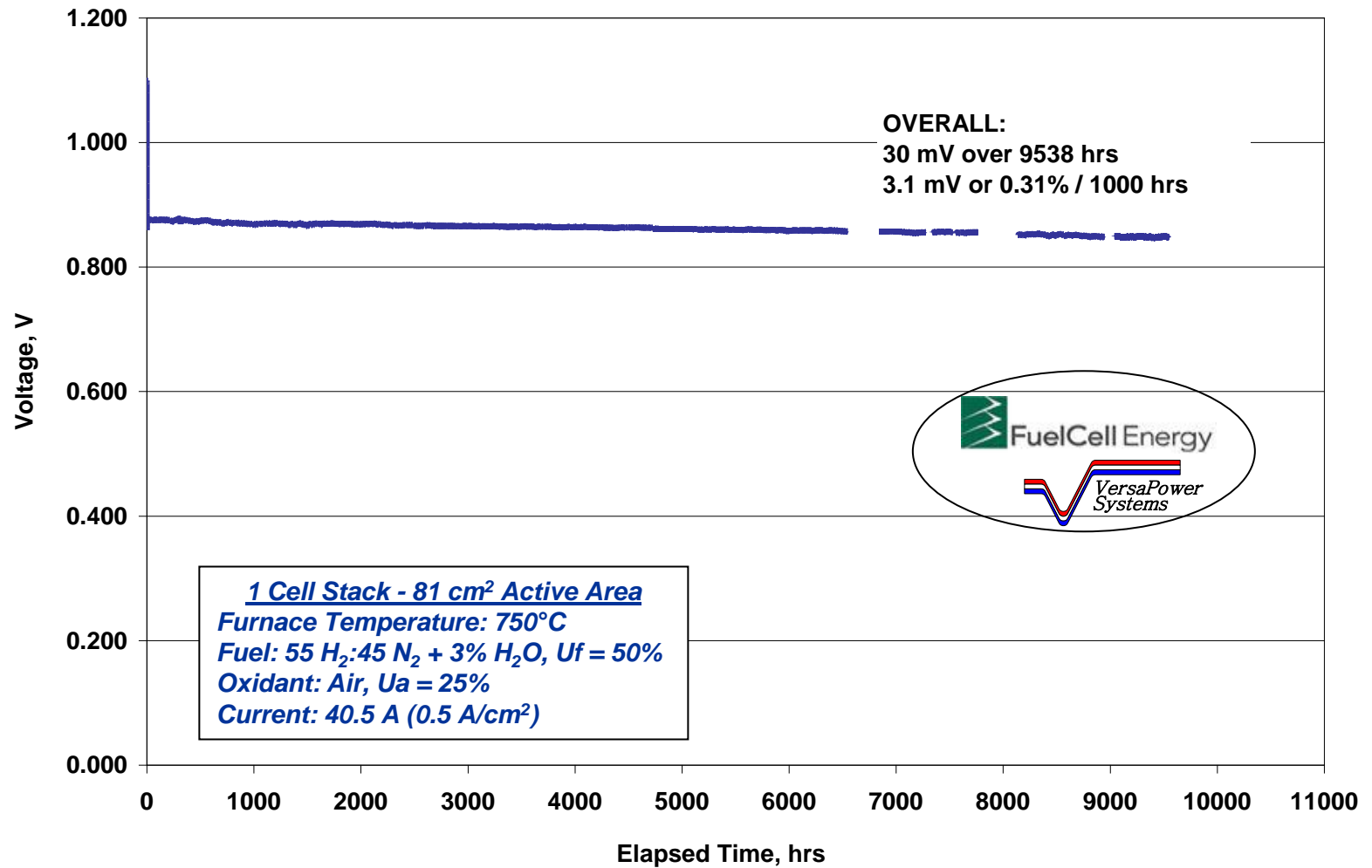


Stack Thermal Cycle Progress



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

Cell/Stack Testing

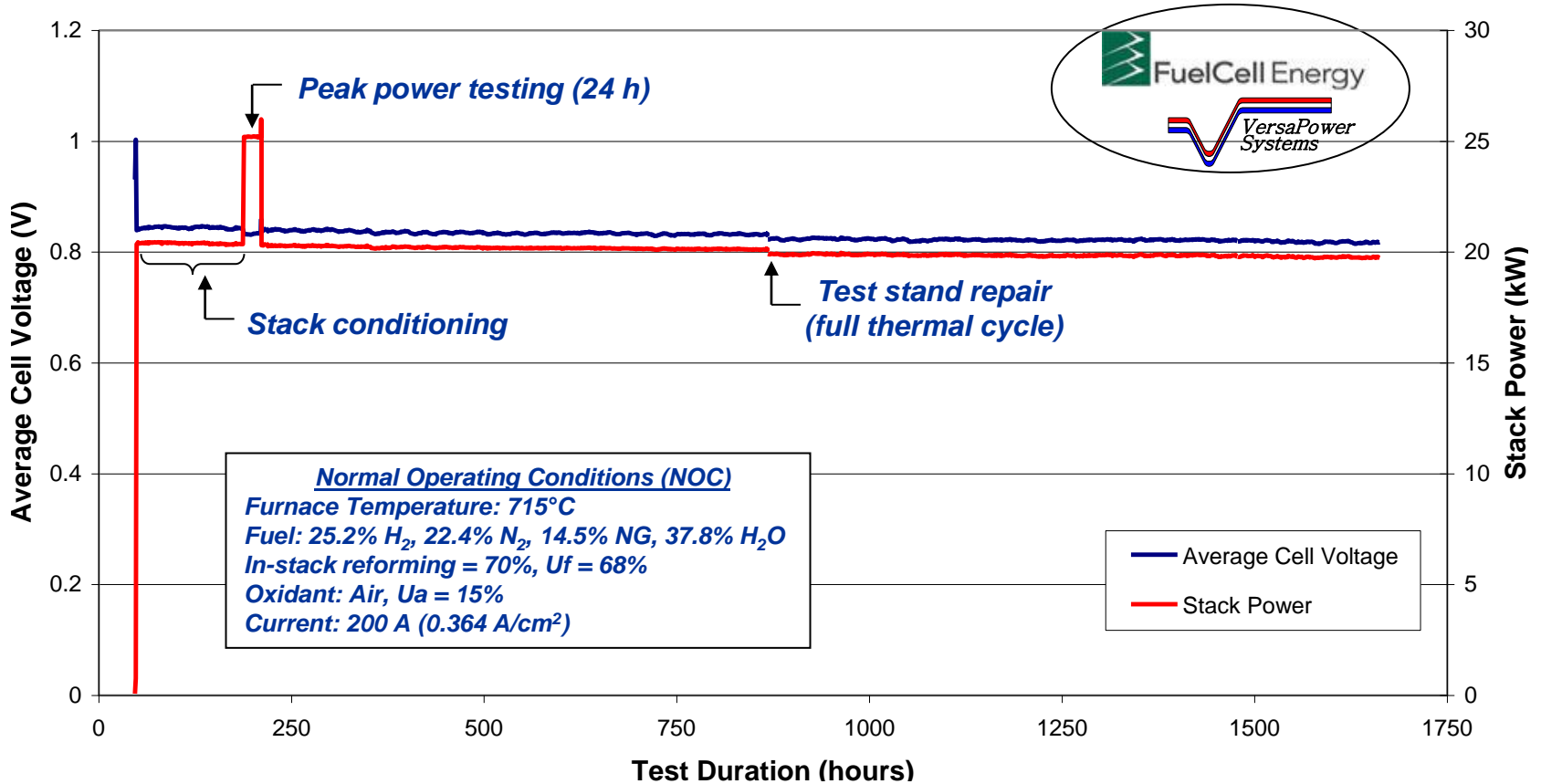


Cell/Stack Testing

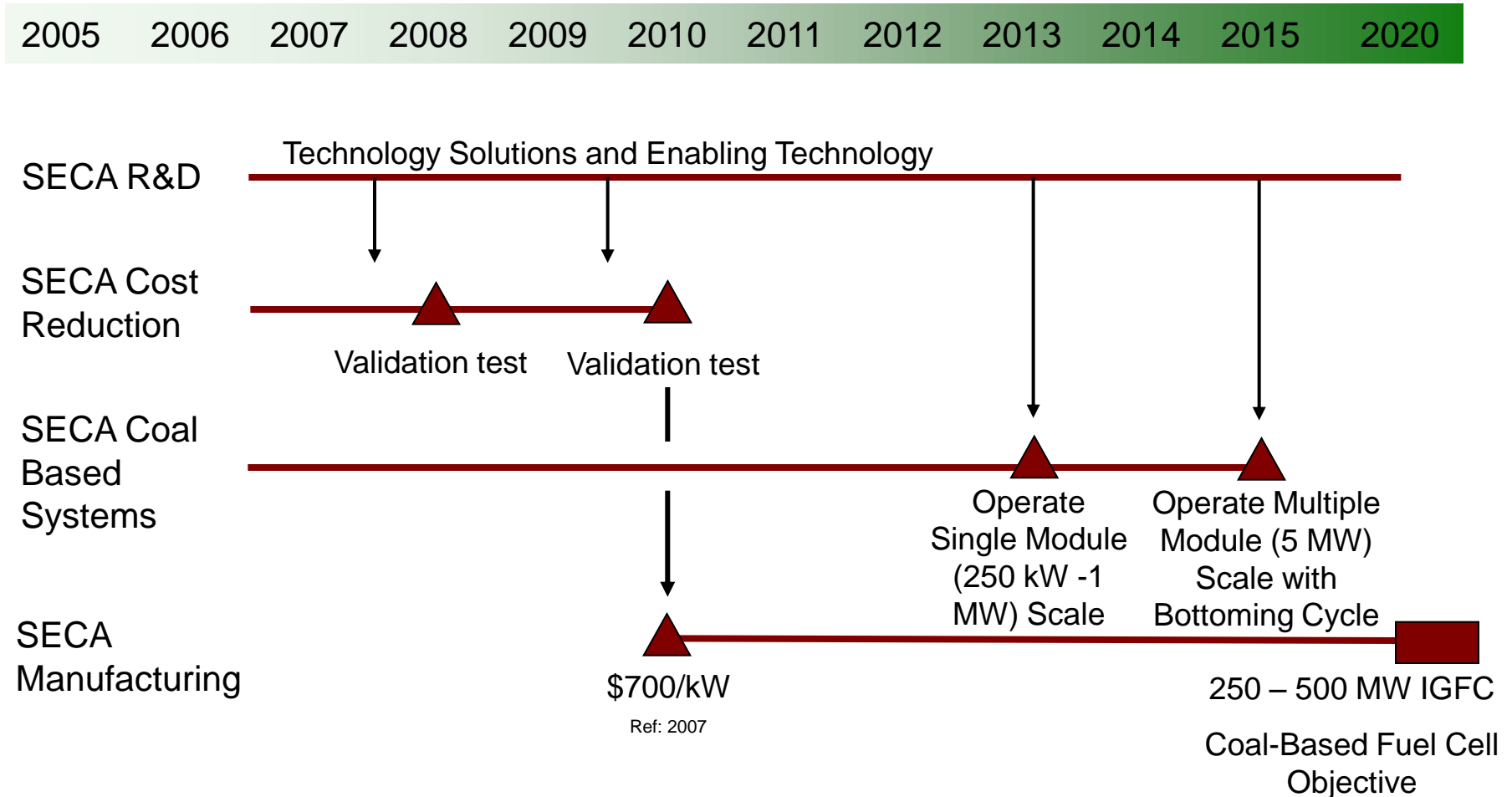
GT058027-0001

120-Cell Stack

Cell Active Area: 550 cm²

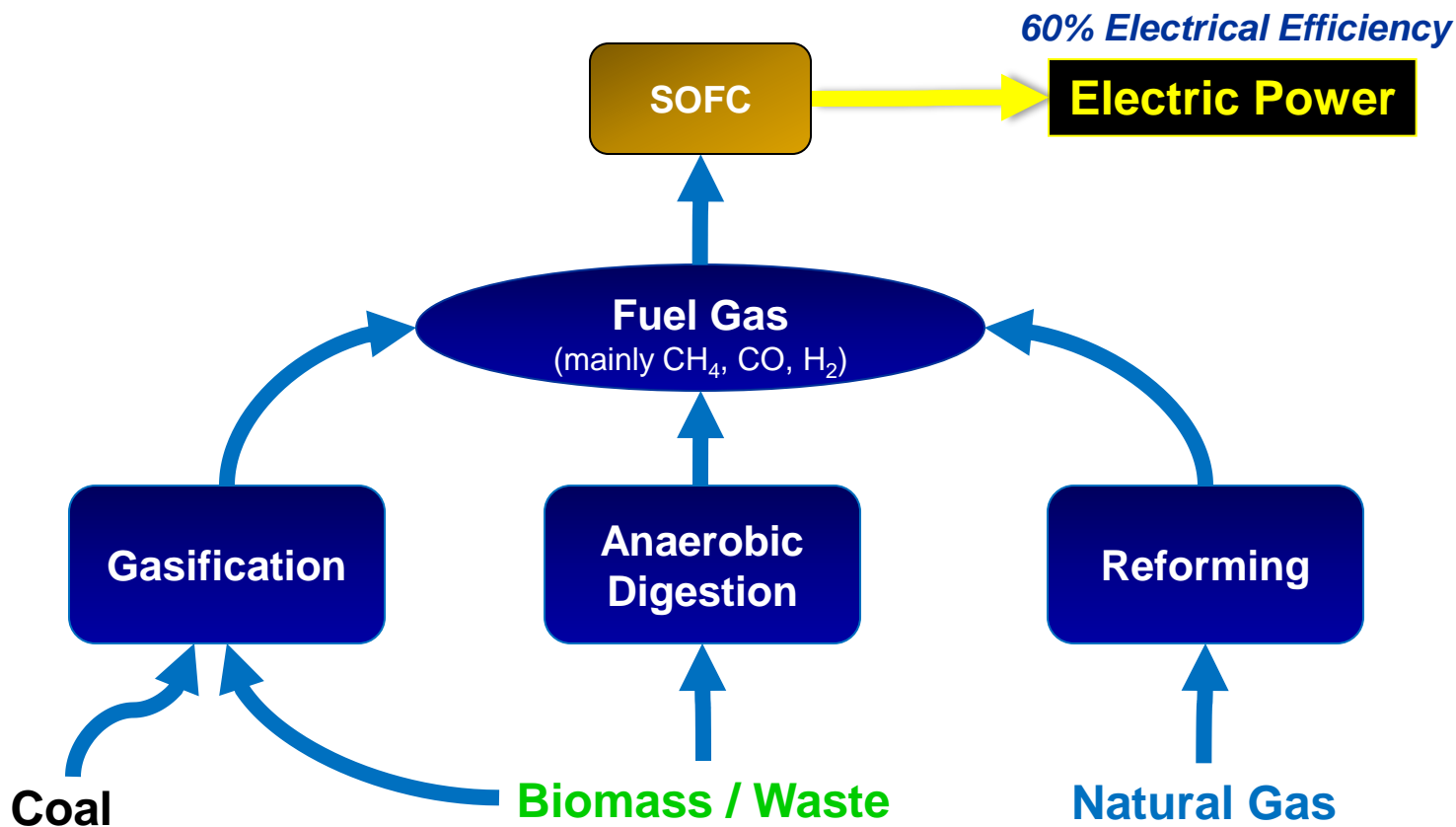


Solid State Energy Conversion Alliance Fuel Cells Technology Timeline



SECA Fuel Flexibility

SOFC Systems can produce power from many fuels



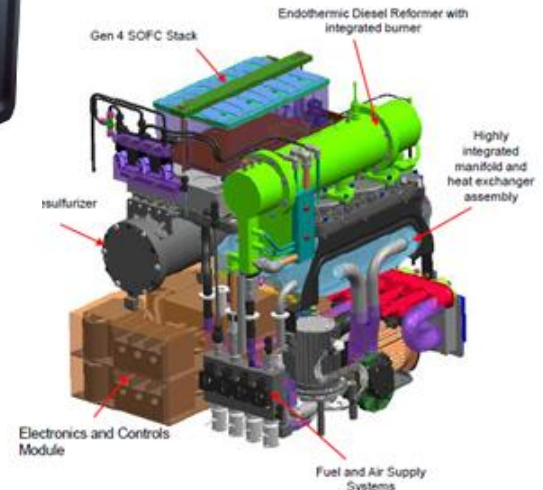
Delphi Auxiliary Power Unit Demos

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 | <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 <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> } <i>Electronic Effect versus Defect Chemistry</i> </div> |
| 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 |

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.)

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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> |
|---|--|---|

“
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