DOE Coordination Meeting

DOE FE DG Program

Dr. Mark C. Williams

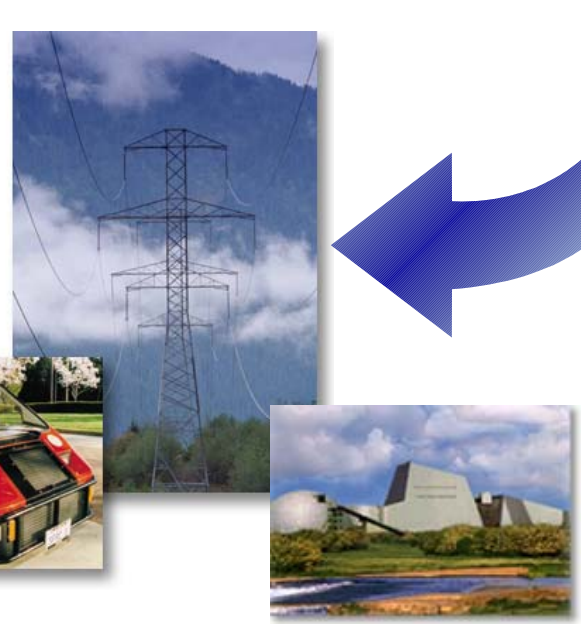
June 3-4, 2003

National Energy Technology Laboratory
Office of Fossil Energy

Fuel Cells Program Mission/Goals

- **Mission: Ensure the widespread deployment of clean distributed generation fuel cells, hybrid and novel generation technology**
  - Lower cost & higher reliability

- **Program Strategic Performance Goals**
  - Fuel Cell 10-fold cost reduction ($400/kW) with 45-50% efficiency
  - Hybrids with 60-70% efficiency adaptable for coal gas



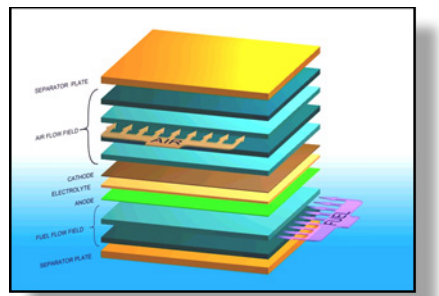
DG Fuel Cell Program Areas

SECA

Molten Carbonate

Tubular SOFC/Vision 21
Hybrids

Advanced Research
(Electrochemical Engineering)



Tubular Solid Oxide Fuel Cells

2002

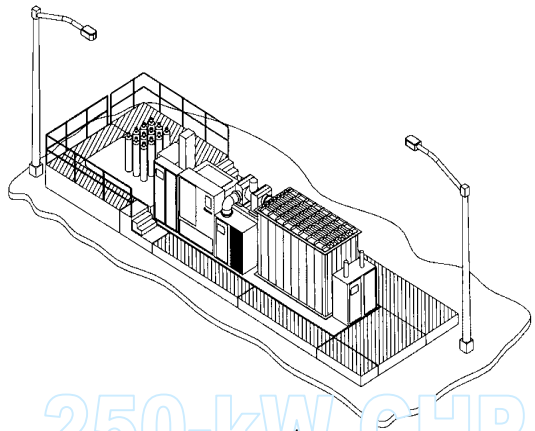
- 47% efficiency
- > $10,000/kW
- 100-220kW
- 20,000 hrs operation at 100-kW

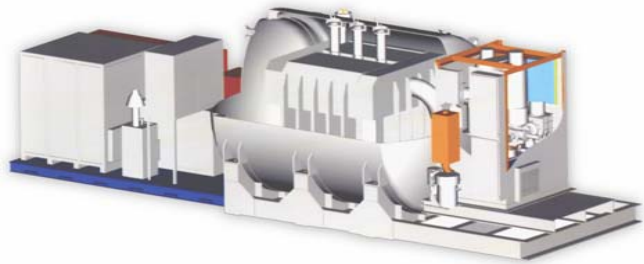
2003-2008

- Near-term DG market
- 47- 63% efficiency
- Munhall, PA 15MW/yr manufacturing facility ($4500/kW)
- 250kW - 550kW
- $1,000-$1,500/kW

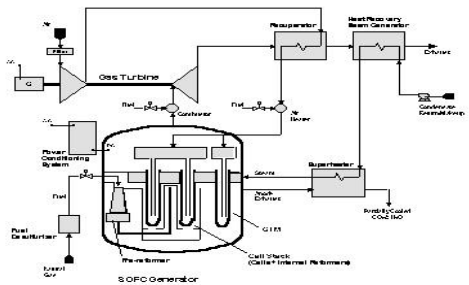
SWPC Demonstration Units

EDB/Elsam





NFCRC/Southern California Edison



150-kW

Carbon Sequistration

Molten Carbonate Fuel Cells

2002

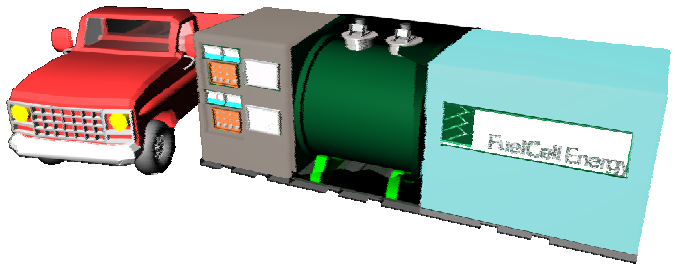
- Demonstration
- 47% efficiency
- $2,500-5,000/kW
- 250kW
- Internal reforming
- Torrington, CT manufacturing facility 50MW/year

2003-2008

- Near-term DG market
- 54% efficiency
- $1,000-1,500/kW
- 250kW-3MW

FCE Direct Fuel Cell Demonstrations

- **250-kw units**
  - Bielefeld, Mercedes, LADWP, Thermie, Rhoen-Klinikum - 12, 250kW's
  - Diesel Bath Maine - 500kW

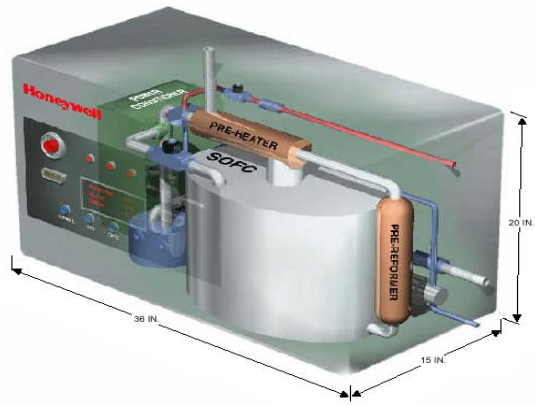


- **1-MW units**
  - King County Digester Gas

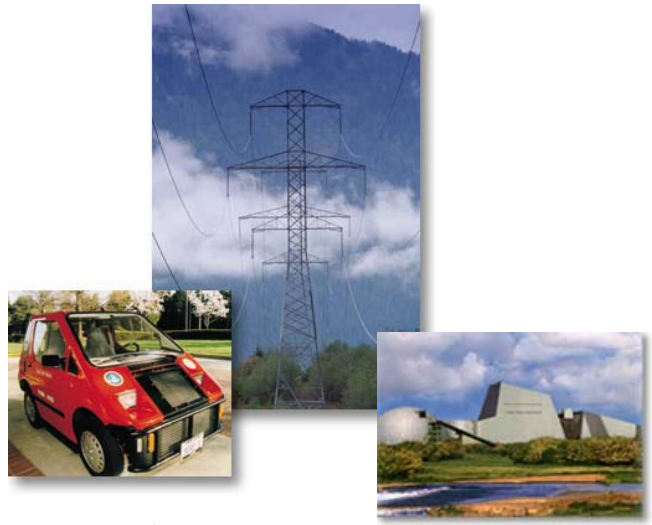
- **2-MW Units**
  - Kentucky Clean Coal

SECA Program Status

- **SECA and SECA Hybrids and Zero Emission Systems major Focus of DOE Fossil Energy Program**
- **Now 6 SOFC SECA Industry Teams**
- **Program in place**
- **Making technical progress**
- **Implementation as planned**
  - **SECA Industry Teams**
    - All doing stack design and testing in FY2003
    - Exploring system design concepts and tradeoffs
    - Six industry teams awarded
    - Coordination with DOD (ARL, TACOM, DARPA, DOD CERL, NAVSEA, ONR), CEC, NASA, NIST, NYSERDA, Ohio Dept. of Dev..
  - **Core Program**
    - In-place at universities and national laboratories
    - Attacking priority mission critical issues within funds provided
    - Tech transfer to industry teams occurring



SECA: A Route to Making Fuels Cells a Reality



2005

- **1st Generation products**
  - Premium power
  - Truck APU's
  - RV's
  - Military

2010

- **$400/kW**
- **Commercial products**
  - Residential, commercial, industrial CHP
  - Transportation APUs

2015

- **$400/kW**
- **Hybrid systems**
  - 60-70% efficient
- **Coal power plants**

SECA INDUSTRIAL TEAMS

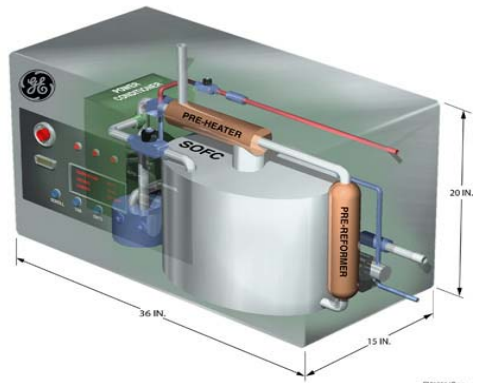
FuelCell Energy

DELPHI Battelle

Driving Tomorrow's Technology

Stacks provided by Global Thermoelectric

General Electric Company



SIEMENS
Westinghouse

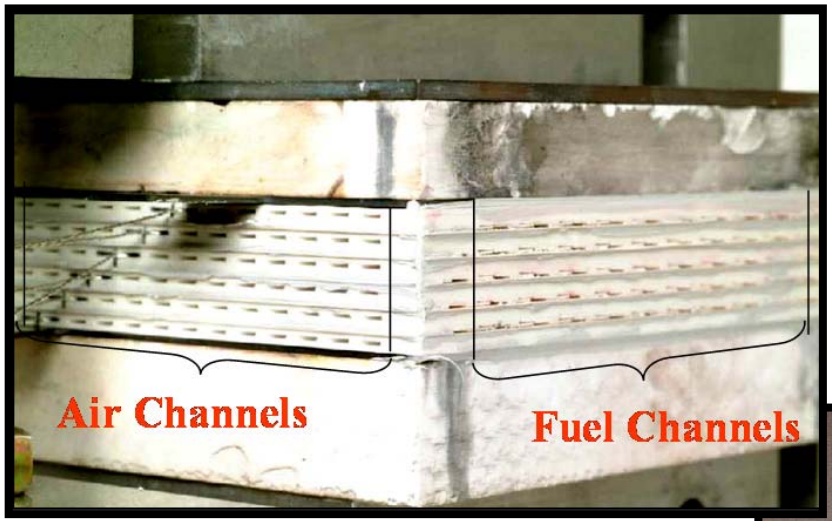
Acumentrics
Advanced Power & Energy Technologies

Cummins Power Generation

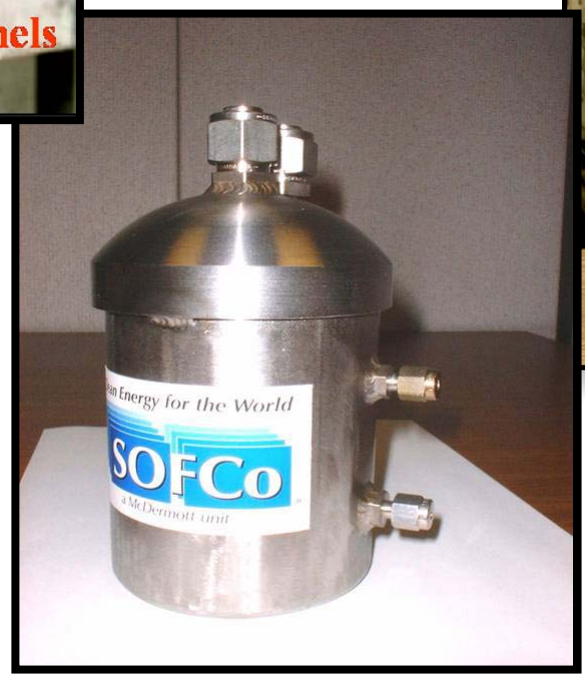
SOFCo EFS Holdings, LLC

NETL

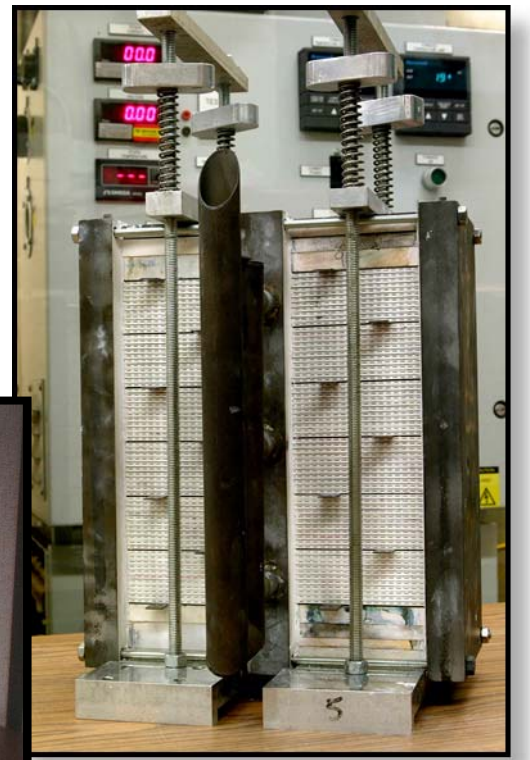
Cummins - SOFCo



5-cell Cross-flow Stack



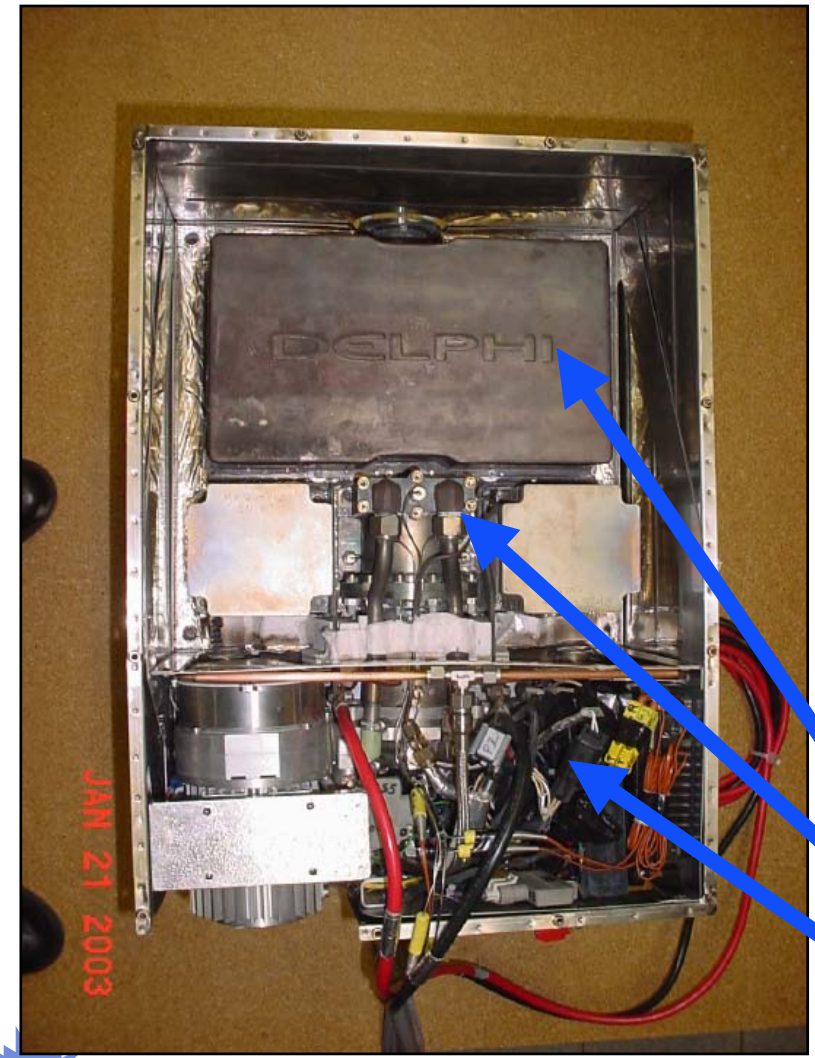
Catalytic Partial Oxidation



Two 60-cell Stacks

Images courtesy of Cummins & SOFCo

Delphi - Battelle



Compact, light, low-cost systems for transportation

Generation 2 APU

Two 15-cell stacks

ReforWER

Balance of Plant

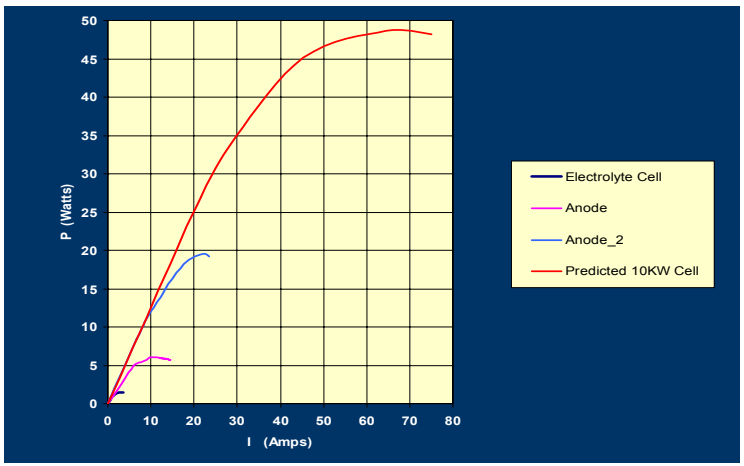
Images courtesy of Delphi

Acumentrics

Anode supported

Tubular SOFC Systems

- 45 minute start-up
- Excellent cycle capability
- Excellent load following
- Low pressure gas feed
- Direct in-cell reforming

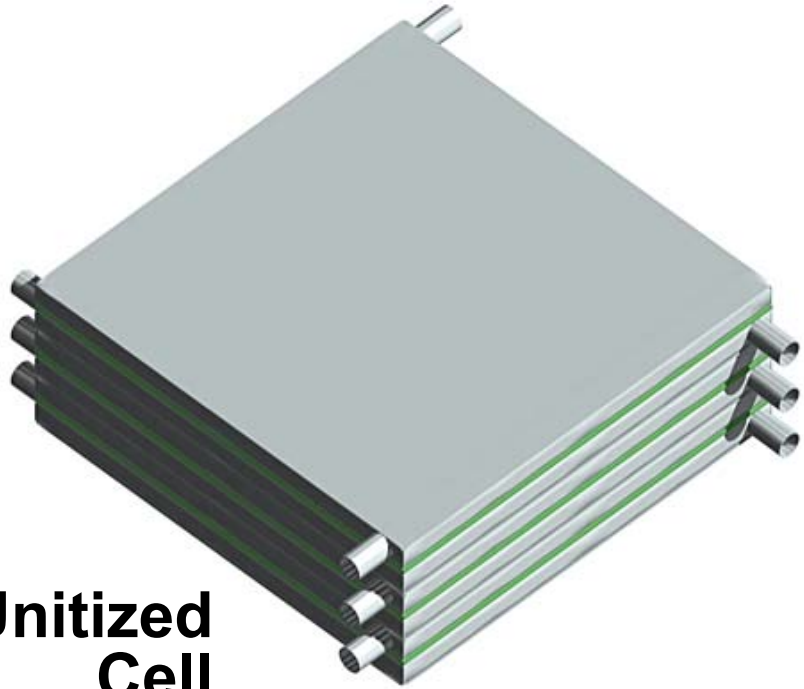


5,000 Watt

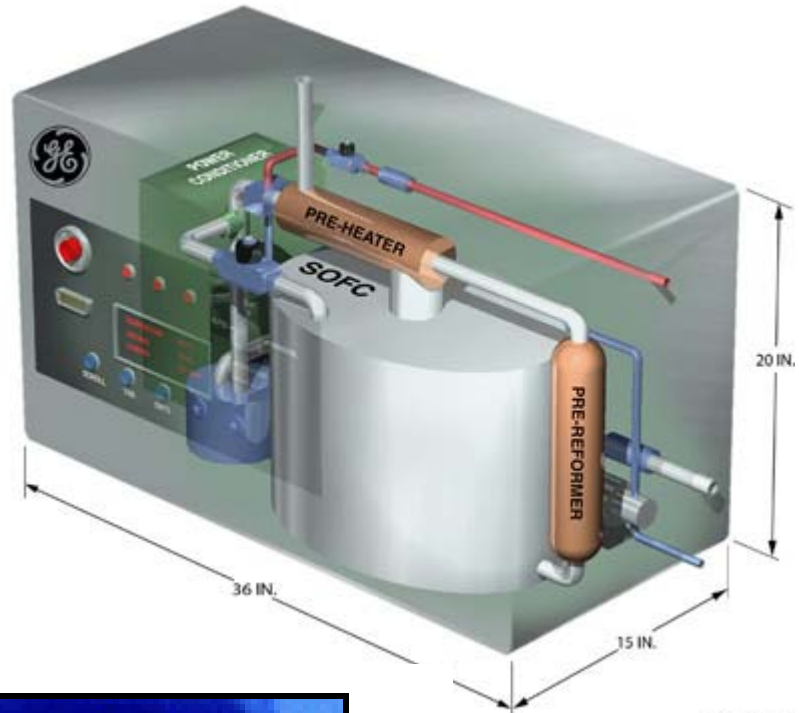
APU Core Module

Q4 - 2002

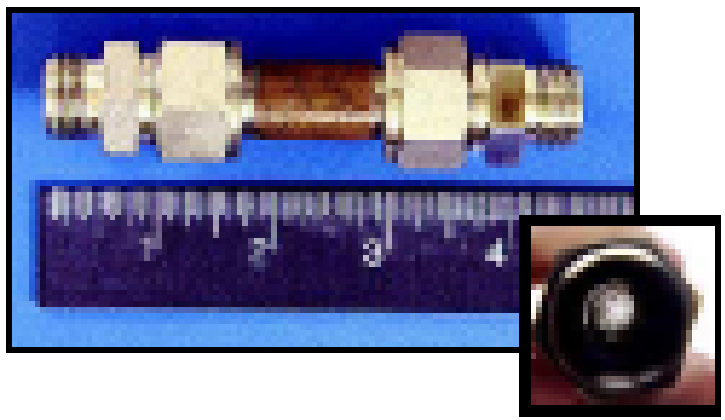
General Electric



Unitized Cell Design



Conceptual Design



1-kW Catalytic Partial Oxidation

Images courtesy of GE

Siemens Westinghouse

5 kW
Prototype

Redesigned Tube

Tubular
cell

Images courtesy of Siemens Westinghouse

FCE-VPS Team Members

VPS is the joint venture between FCE, GTI, EPRI, MSRI and UU

FuelCell Energy
Internal Reforming
Metal Interconnects
Stack Manufacturing
Power Plant Experience

DANA
Gaskets, HEX,
Low Cost Manufacturing

PNNL
Modeling

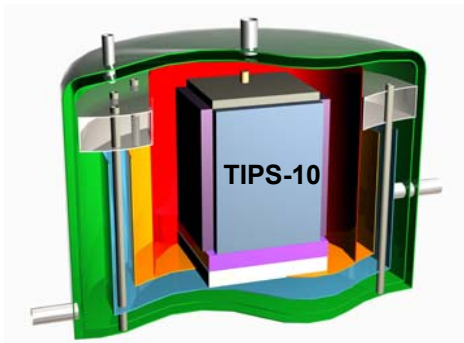
VersaPower Systems
- **TECHNOLOGY**
- **COMMERCIALIZATION**

THE UNIVERSITY OF UTAH
Cell Technology

MSRI
High Power Density Stacks
Advanced Materials

gti
System Design
Fuel Processing
Gas Utility Customers

EPRI
Power Electronics
Utility/Distributed Gen.



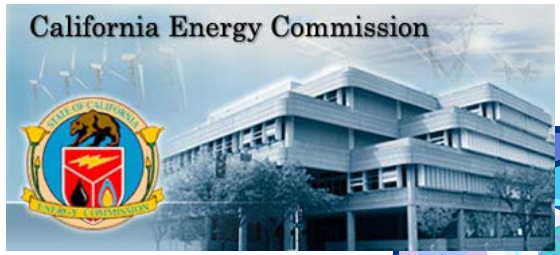
SOFC SYSTEM

MARKET PARTNERS		
Teledyne		Verizon
Alpha	Sempra	Marubeni

MO2710
12/18/01

Other Pathways to High Volume With Help from our Friends

Ohio Department of Development



NASA NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

U.S. Department of Energy
Energy Efficiency and Renewable Energy

National Institute of Standards and Technology NIST
...working with industry to develop and apply technology, measurements and standards

ONR Office of Naval Research

DARPA

TACOM

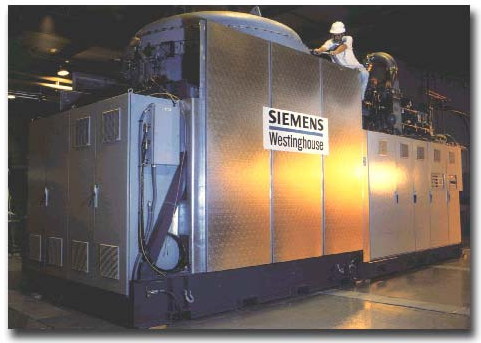
Army Materiel Command
Army Research Laboratory

NETL

Vision 21 Hybrids

Siemens Westinghouse

- Operated > 2,000 hours at sub-MW scale
- 52% efficiency



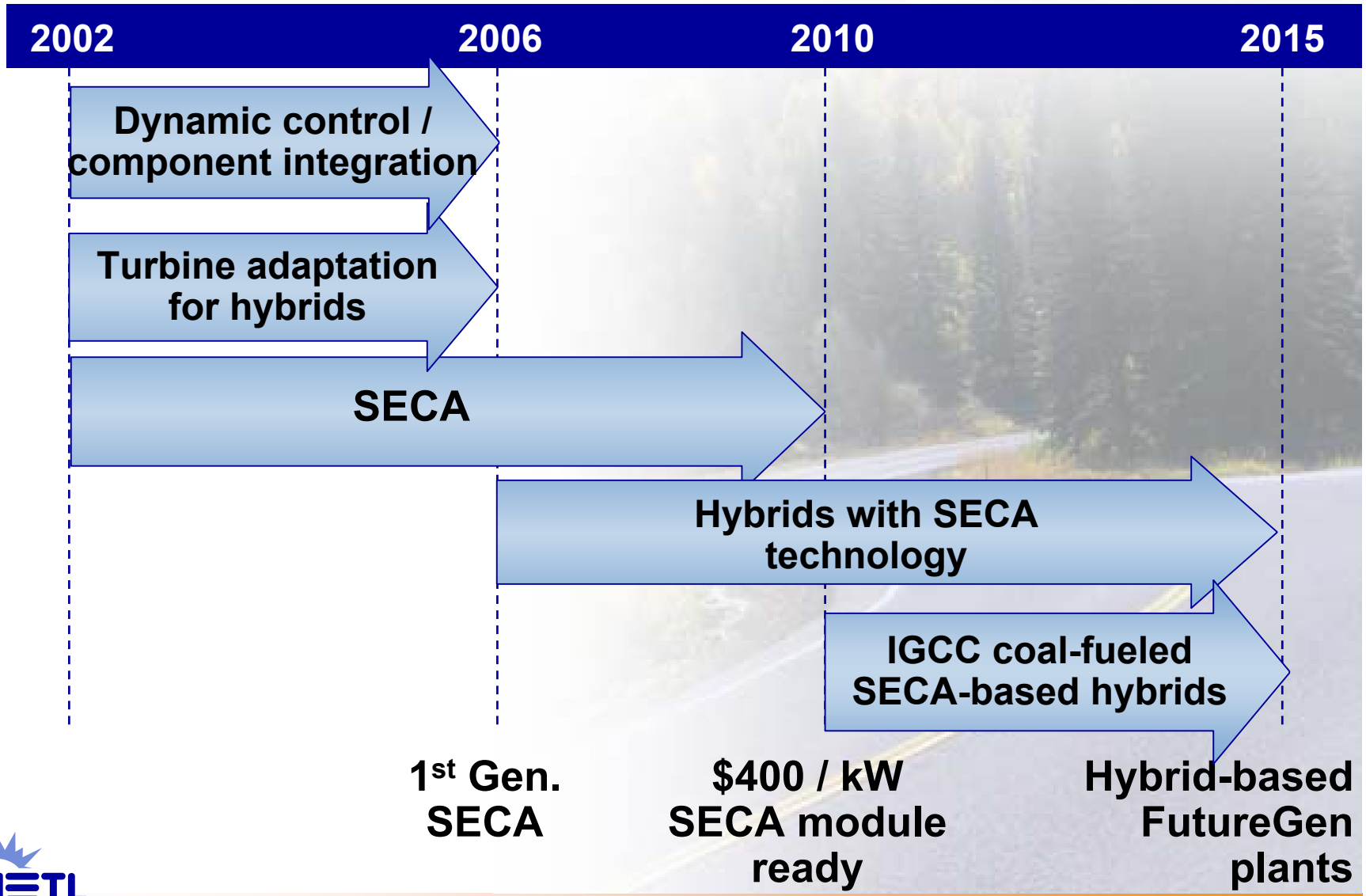
FuelCell Energy

- Operated >6,700 hours at sub-MW scale
- 52% efficiency
- Design of 40 MW plant

General Electric

- Estimated efficiency 67%

SECA: Key Part of Larger Fossil Energy Program



A Vision for 2015

Putting the Pieces Together

SECA

SECA-Based Hybrids

FutureGen Power Plants

Carbon Sequestration

Gasification with Cleanup Separation

Optimized Turbines

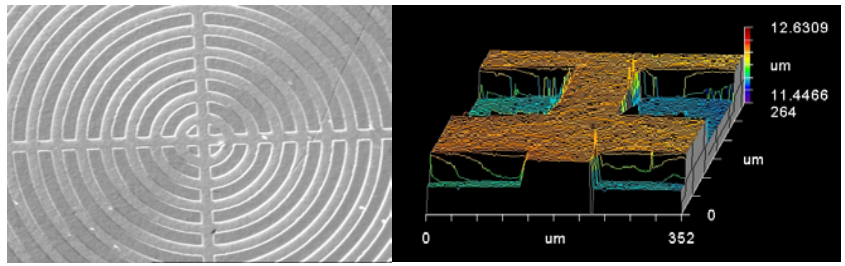
System Integration

NETL

High Temperature Electrochemistry Center

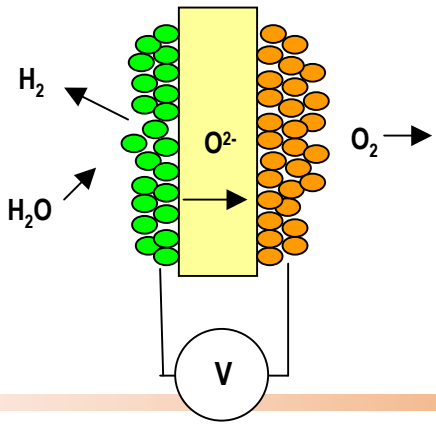
Purpose

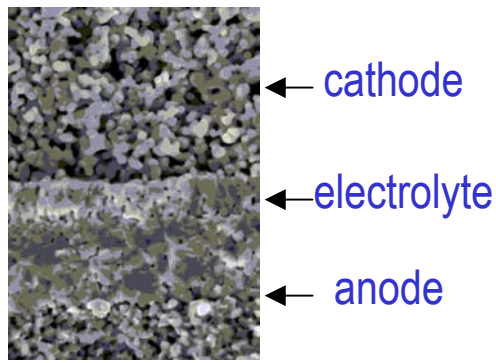
- Conduct fundamental studies of processes in high temperature electrochemical systems not currently addressed in the SECA program.
- Establish a unique research facility equipped with advanced diagnostics to support fundamental studies.
- Establish collaborative research with universities.



Novel electrode structures allow role of microstructure and catalytic activity to be distinguished.

"Reversible" solid oxide fuel cell could produce hydrogen from water during periods of excess grid capacity, and produce electricity later from the stored hydrogen.





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Advanced Research - Fuel Cell and Electrochemical Energy Conversion Technology at HiTEC

- **Electrochemical energy conversion technology:**
  - Reversible/regenerable fuel cells
  - High temperature electrolysers
  - Electrochemical energy storage
- **HiTEC**
  - PNNL
  - MSU

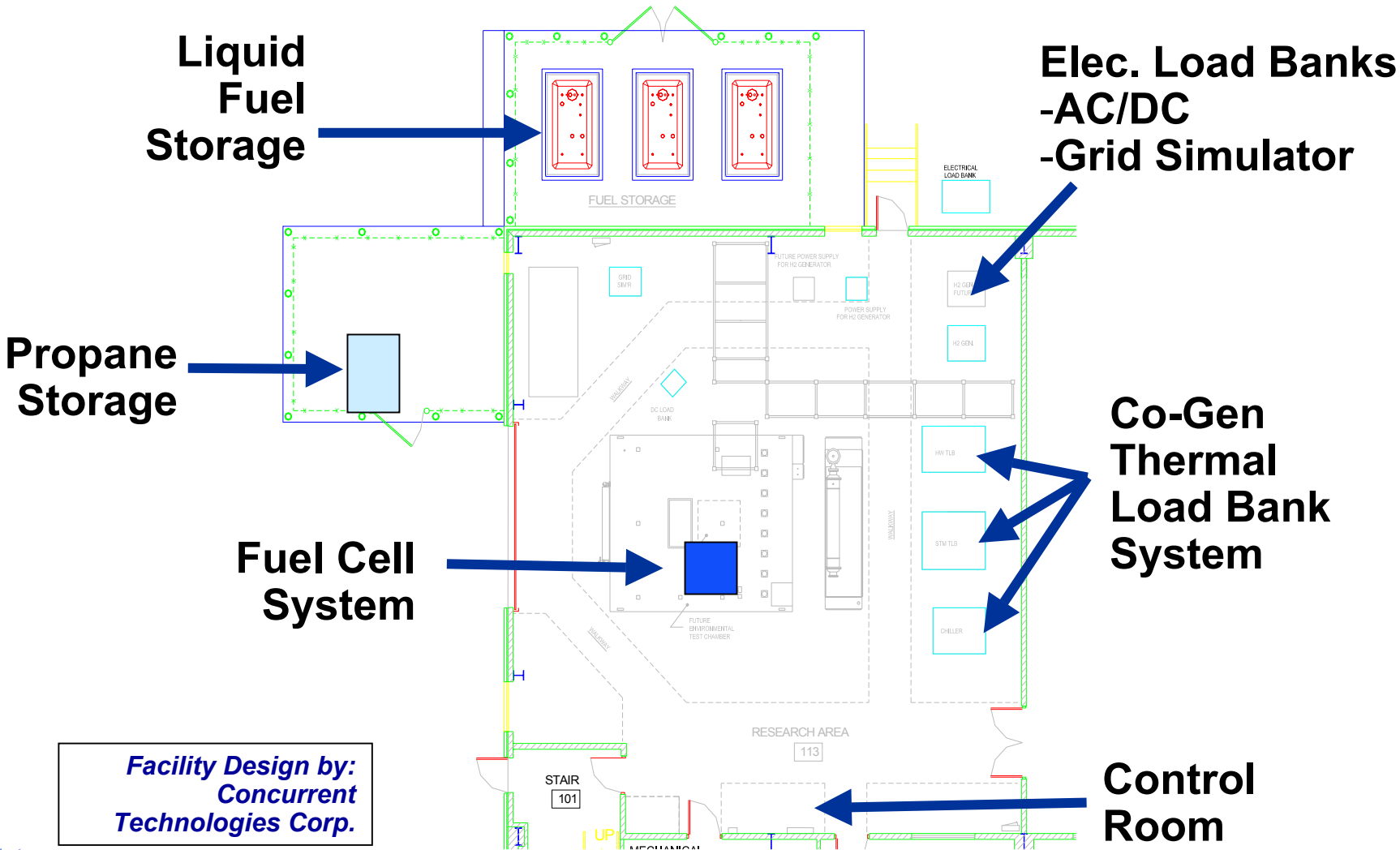
Highlights: *Core Technology Program*

- Glass and mica compressive seal characterization
- Inexpensive Ferritic alloy interconnect characterization
- Fuel cell models available
- Material structural characterization
- Mixed conducting cathodes, LaSrFeOx
- Cathode microstructure optimization
- Cathode mechanism intermediates identified
- Metal oxide anode material–promising S, C,O tolerance
- Low temperature bi-layer and ultra-thin electrolytes
- Efficient DC-DC converter designed
- Developing lower cost consistent materials

Current Priorities: *Core Technology Program*

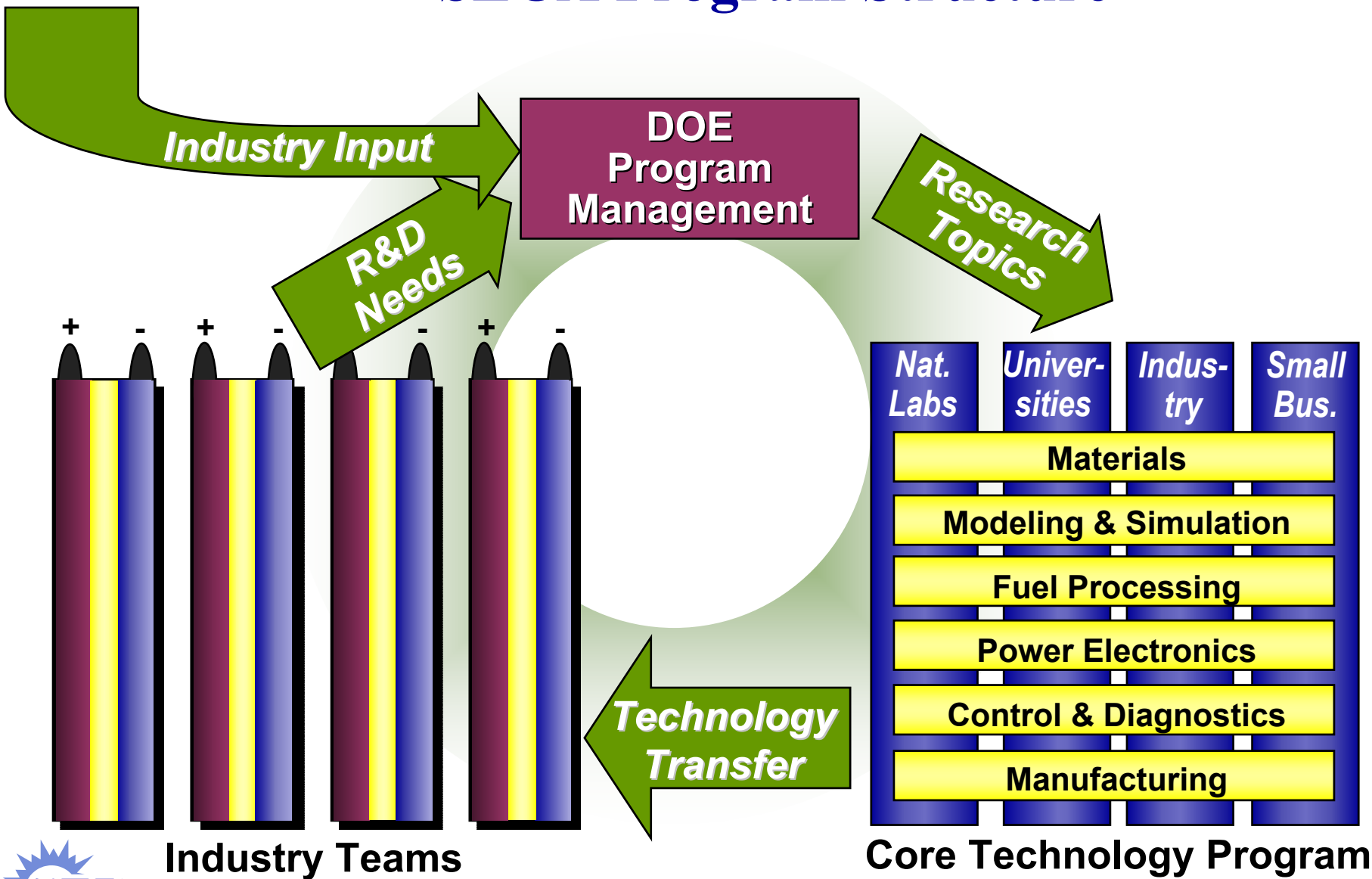
	What	How
1	Gas seals	• Glass and compressive seals
1	Interconnect	• Modifying components in alloys • Coatings
2	Modeling	• Models with electrochemistry • Structural characterization
2	Cathode performance	• Micro structure optimization • Mixed conduction • Interface modification
2	Anode/ fuel processing	• Metal oxides with interface modification • Catalyst surface modification • Characterize thermodynamics/kinetics
3	Power electronics	• Direct DC to AC conversion • DC to DC design for fuel cells
4	Material cost	• Lower cost precursor processing • Cost model methodology

NETL's SECA Test Facility



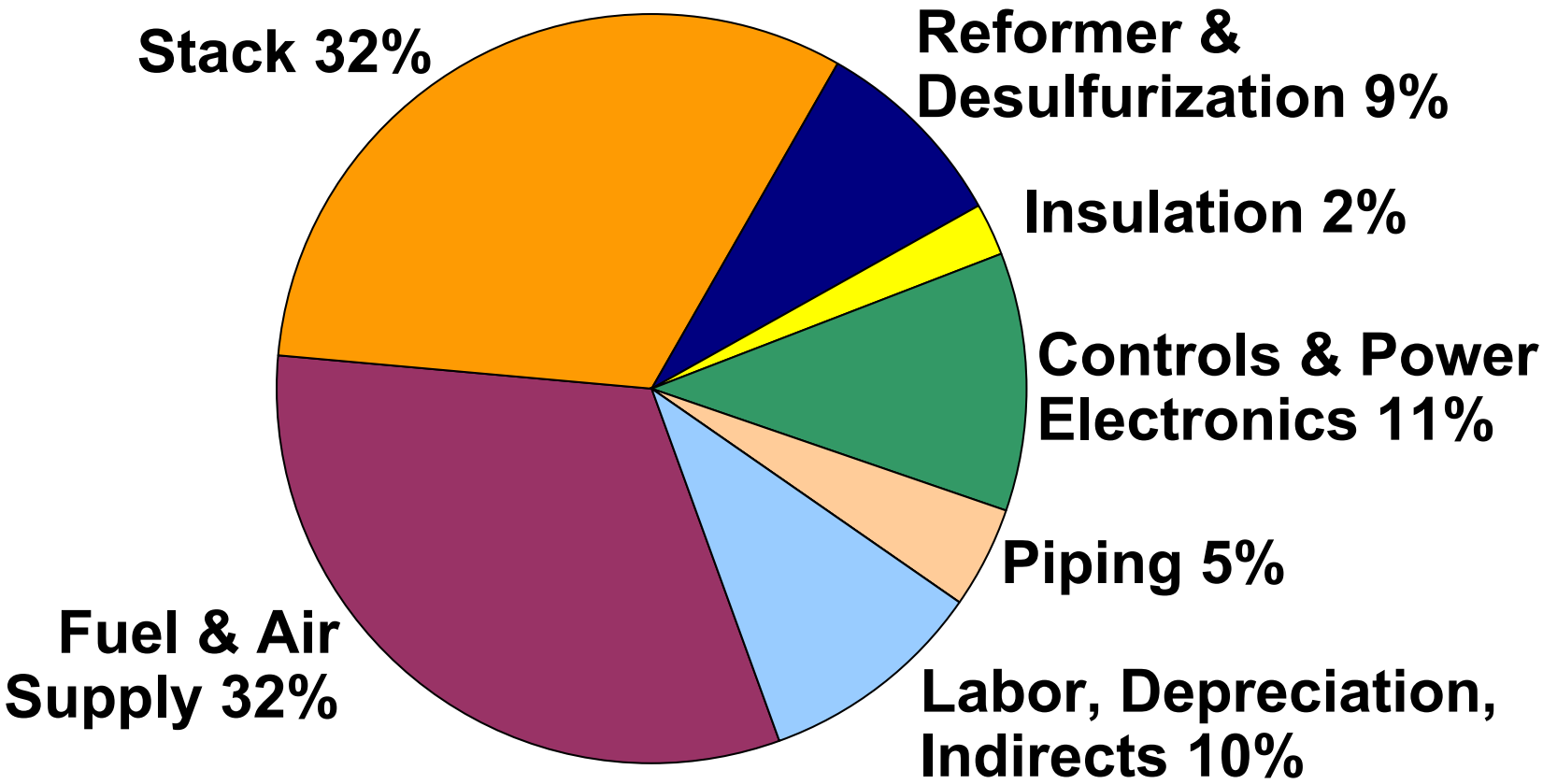
Facility Design by: Concurrent Technologies Corp.

SECA Program Structure



5-kW SOFC Cost Breakdown

Total Cost: $372/kW



Source: Conceptual Design of POx SOFC 5kW net System, Arthur D. Little, Inc., October 12, 2000