Solid State Energy Conversion Alliance

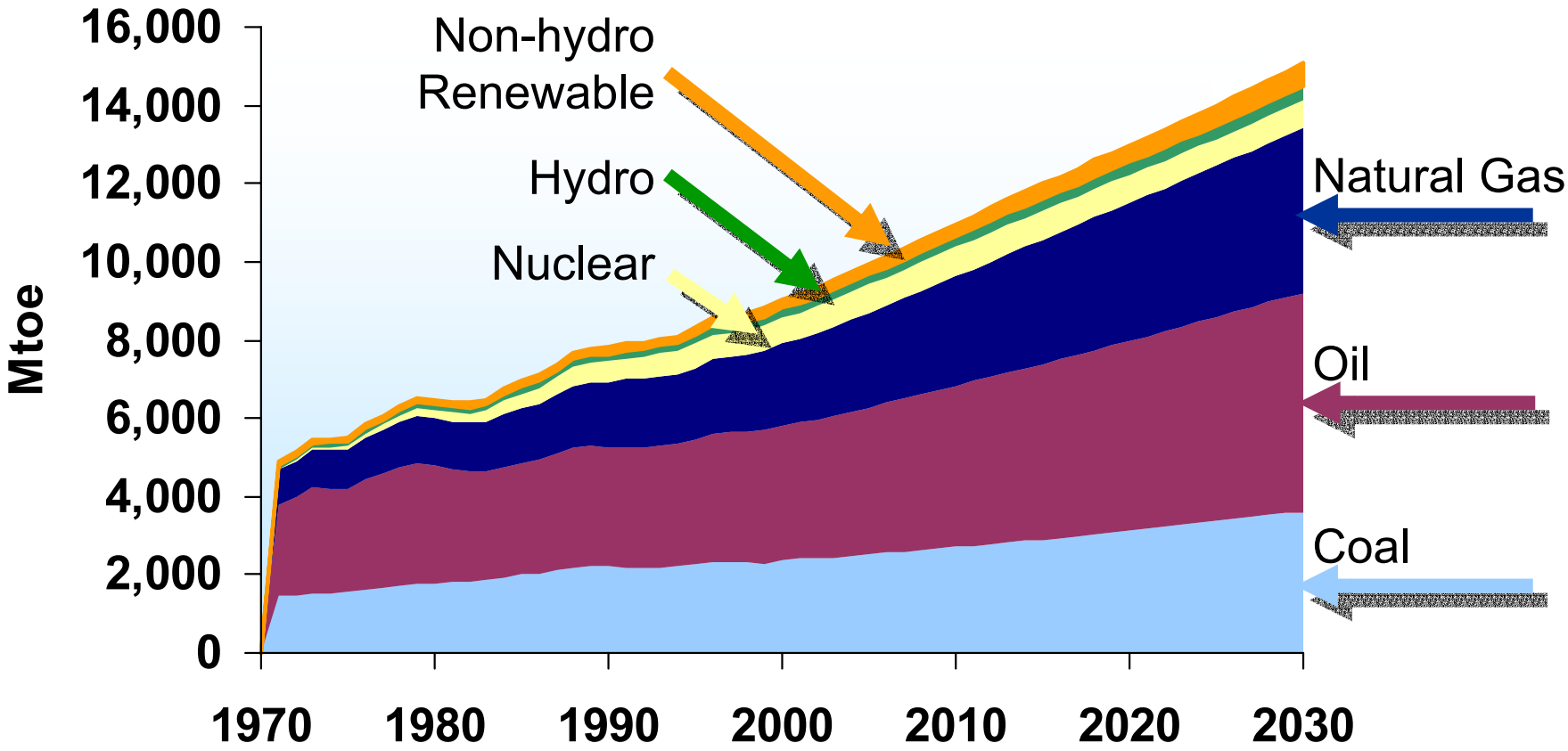
SECA and the Office of Fossil Energy's Program Strategy

4th Annual SECA Meeting
Rita A. Bajura, Director
April 15, 2003

National Energy Technology Laboratory
Office of Fossil Energy

World Primary Energy Demand

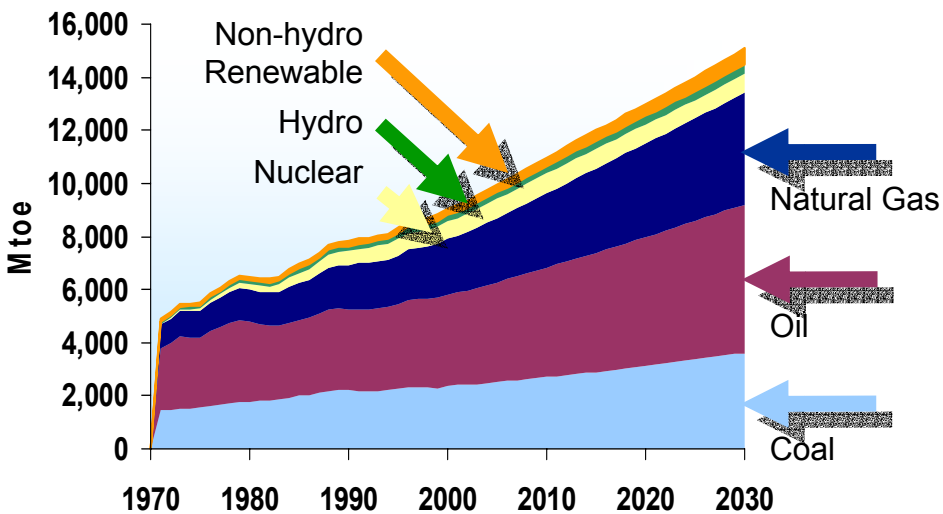
Projected to Grow 66% by 2030



World Energy Outlook 2002. IEA

The Challenge

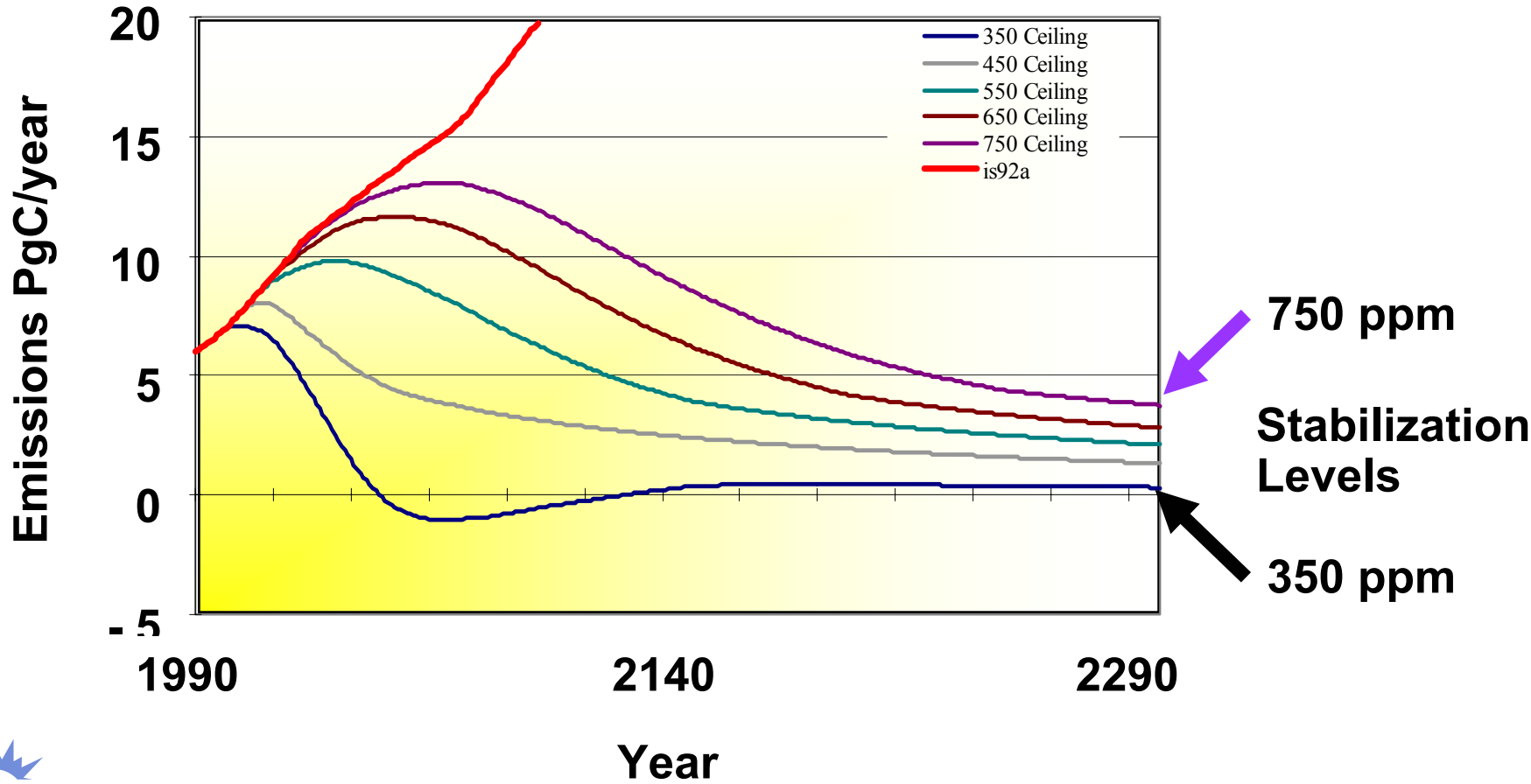
Defining a Path to World Energy Future



Future

- **Energy security**
- **Economic development**
- **Environmental protection**
- **Social welfare**

Ultimately, Net Global GHG Emissions Must Sharply Decline and Even Approach Zero to Achieve Stabilization

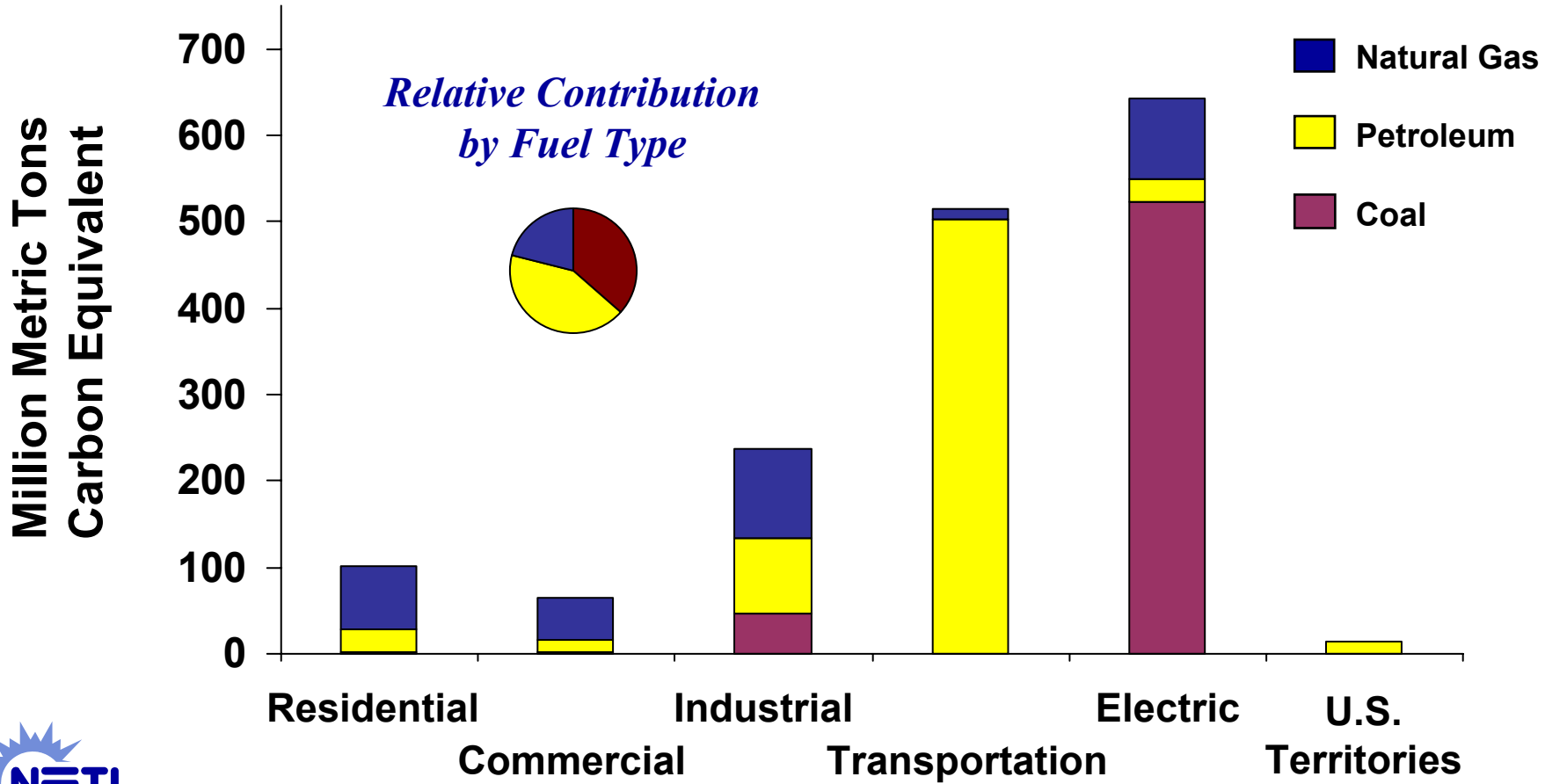


Source: PNNL

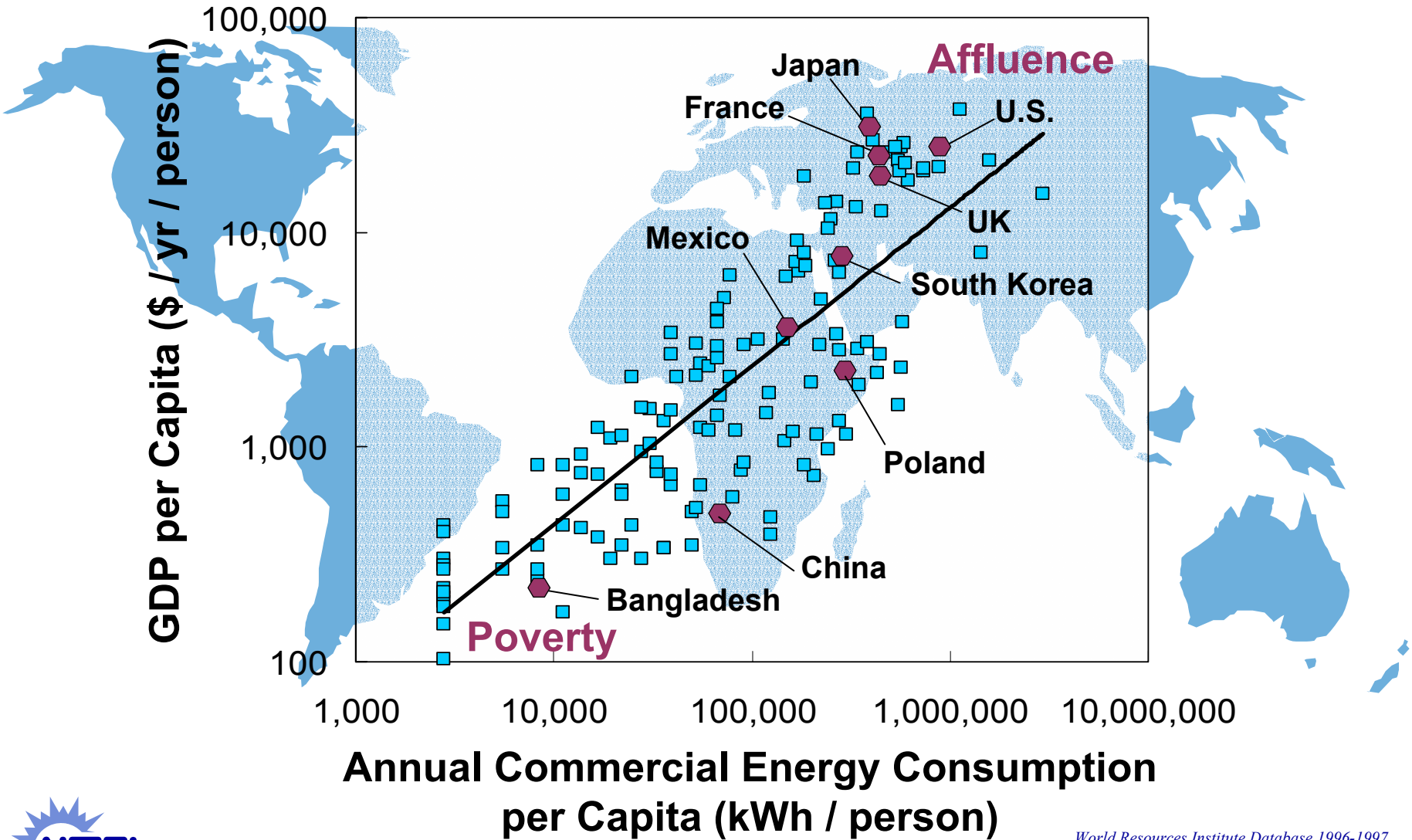
All Sectors and All Fossil Fuels Contribute to Carbon Emissions

CO_2 Emissions from Fossil Fuel Combustion

Year 2000 Emissions by Sector and Fuel Type



The World Needs Affordable Energy



World Resources Institute Database 1996-1997

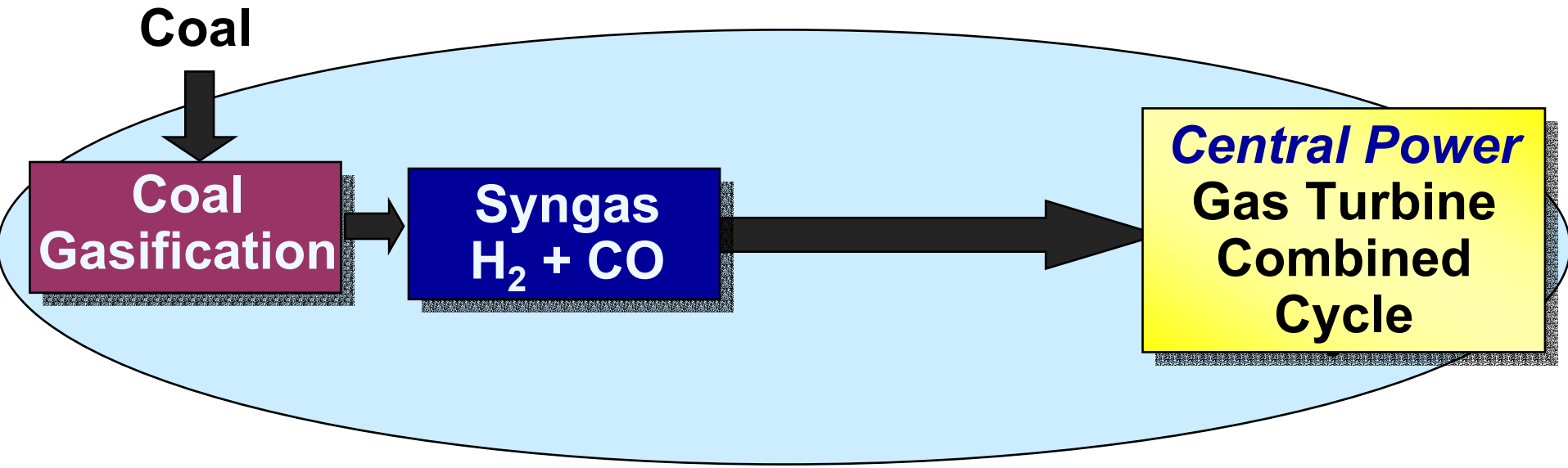
FutureGen: A Presidential Initiative

One billion dollar, 10-year demonstration project to create world's first, coal-based, zero-emission electricity and hydrogen plant

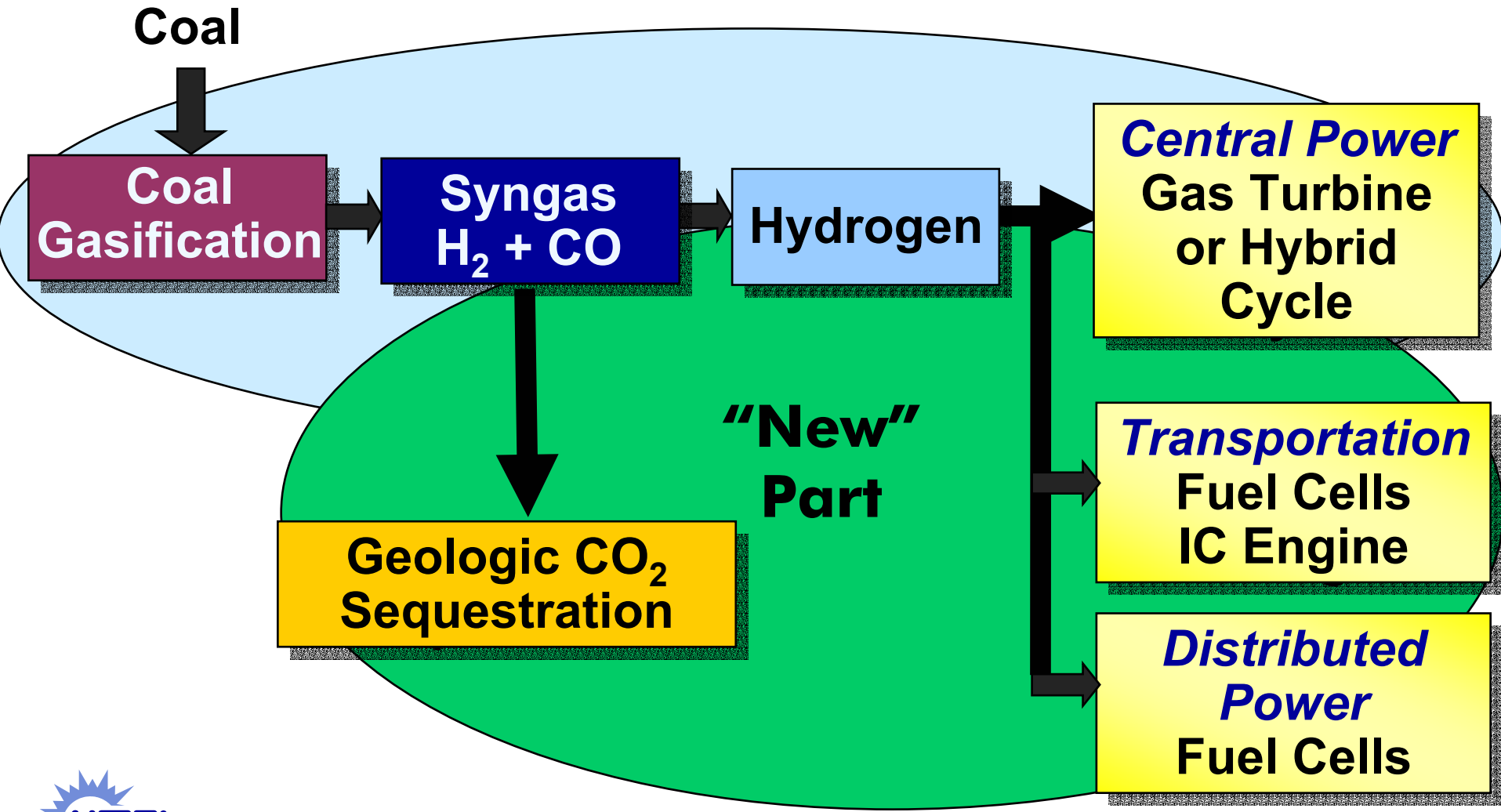
President Bush, February 27, 2003

- **Produce electricity and hydrogen from coal using advanced technology**
- **Emit virtually no air pollutants**
- **Capture and permanently sequester CO_2**

"Traditional" Integrated Gasification Combined Cycle

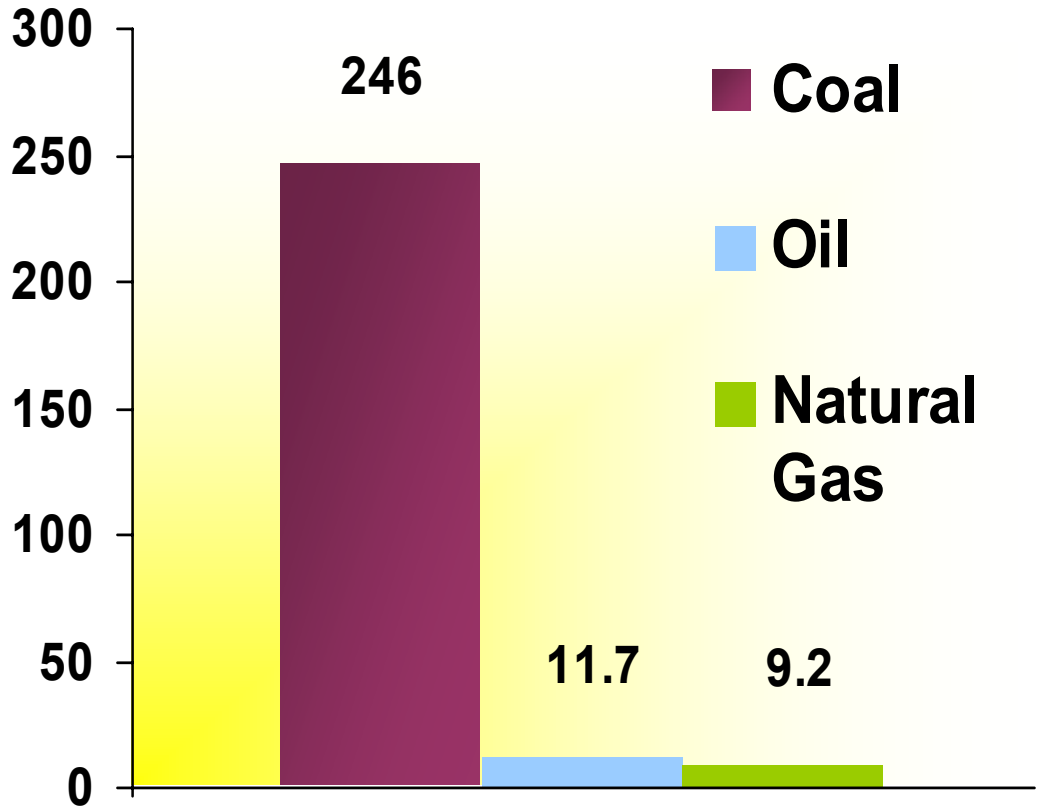


IGCC in FutureGen



Why Coal?

- **Abundant reserves**
- **Low and stable prices**
- **Technology improvements**
  - Could enable near-zero emissions of air pollutants/GHGs



U.S. Fossil Fuels Reserves/Production Ratio

Shows Years Supply at Current Production

EIA- U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves: 2001 Annual Report, November 2002;
Coal: BP Statistical Review, June 2002, World Energy Council

Why Sequestration?

- Compatible with existing energy infrastructures
- May prove to be lowest cost option

Options for Electricity & Hydrogen Production

Fossil/Sequestration
FutureGen

Nuclear

Dream Source
- **Fusion**
- **Thermochemical**

Renewable Energy

Conservation / Efficiency Improvement

SECA: A Route to Making Fuels Cells a Reality

2005

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

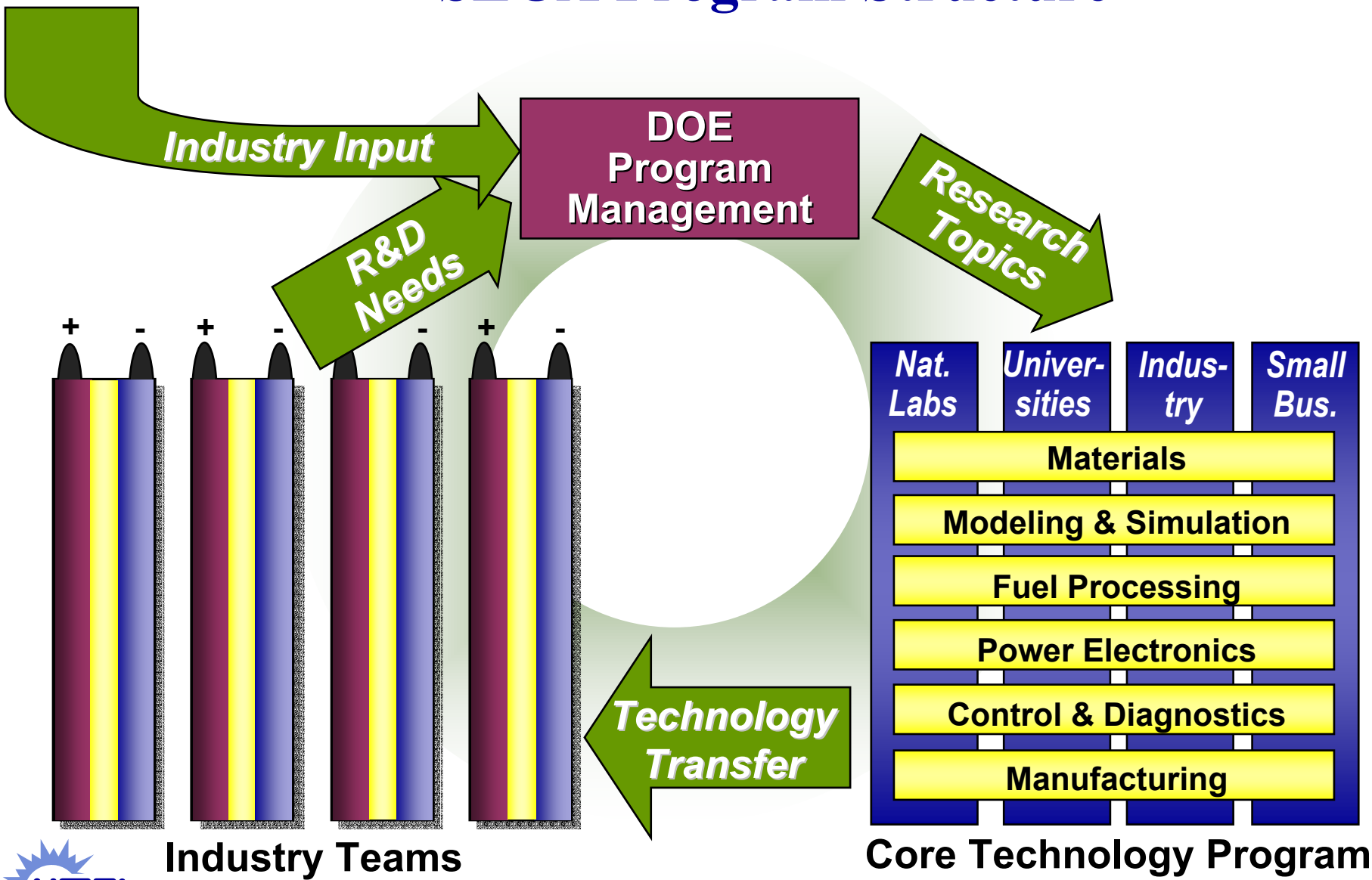
2010

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

2015

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

SECA Program Structure



Four SECA Industry Teams

Cummins Power Generation

SOFCo EFS Holdings, LLC
Solid Oxide Fuel Cells and Fuel Processors

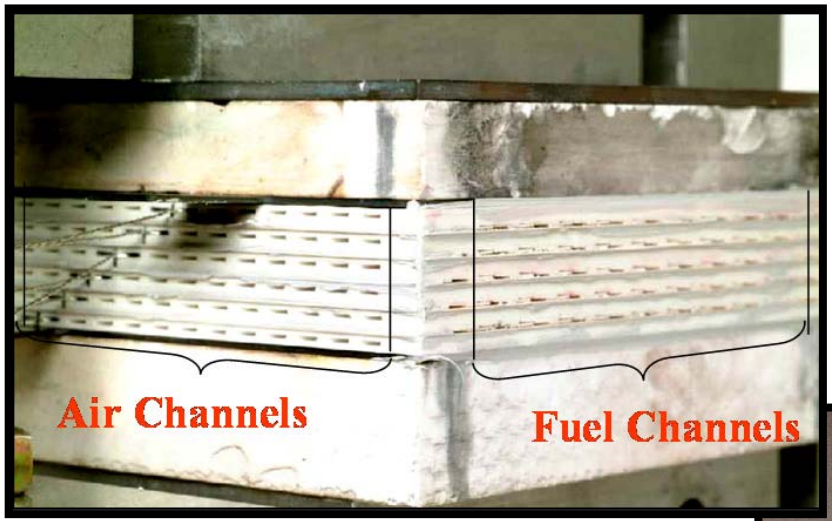
DELPHI
Driving Tomorrow's Technology

Battelle

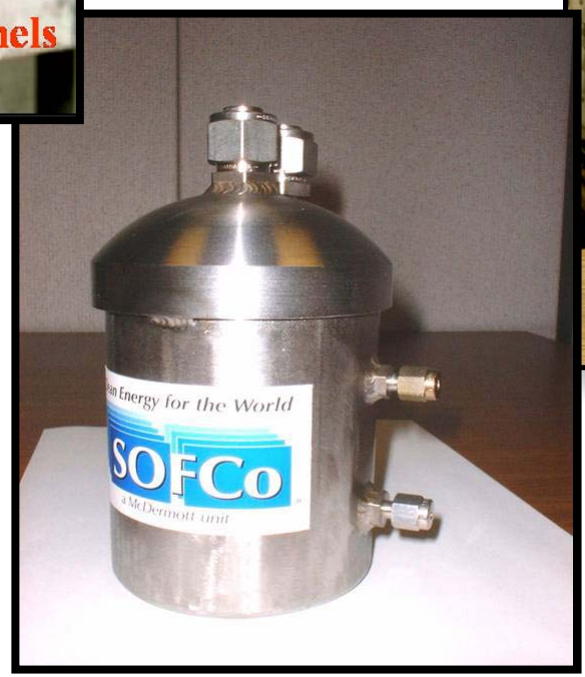
General Electric Company

SIEMENS Westinghouse

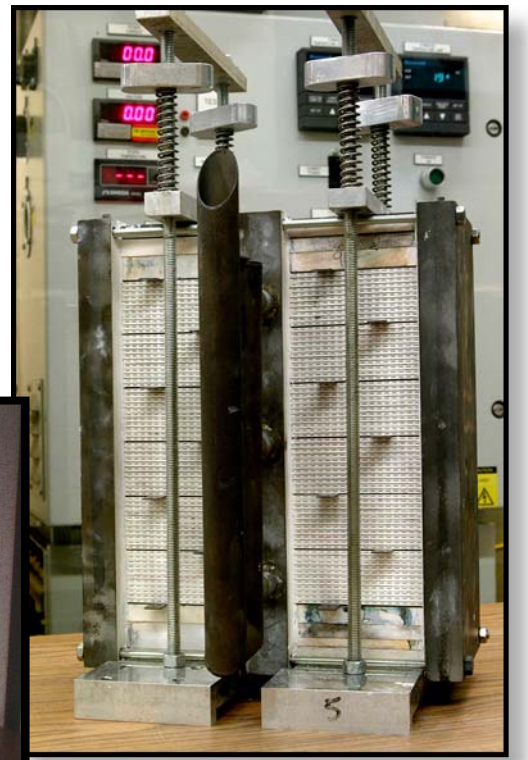
Cummins - SOFCo



5-cell Cross-flow Stack



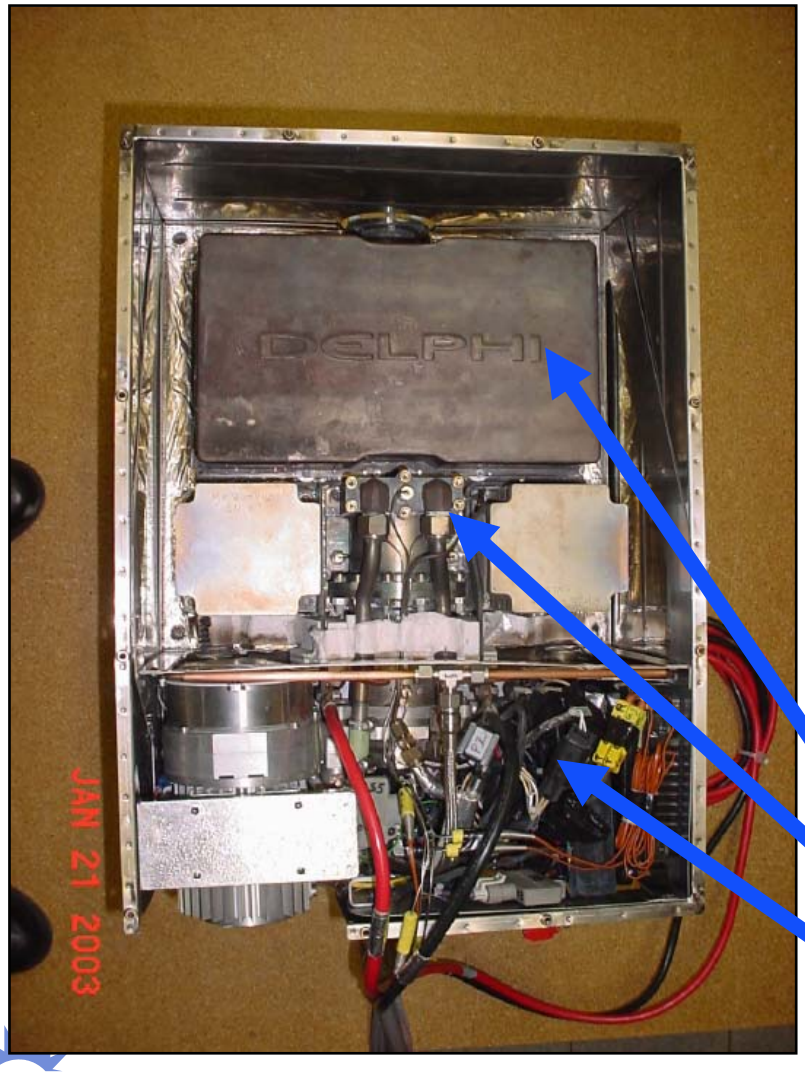
Catalytic Partial Oxidation



Two 60-cell Stacks

Images courtesy of Cummins & SOFCo

Delphi - Battelle



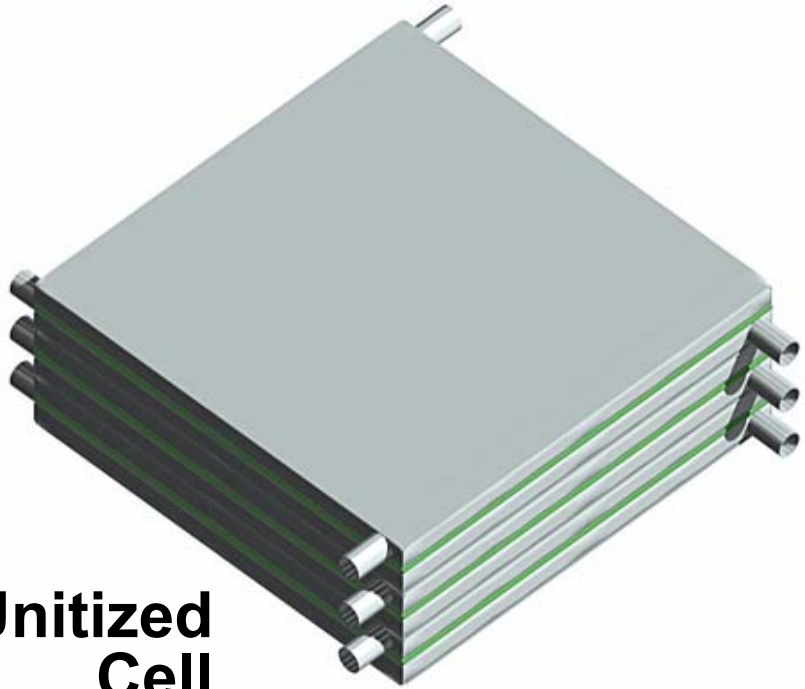
Compact, light, low-cost systems for transportation

Generation 2 APU

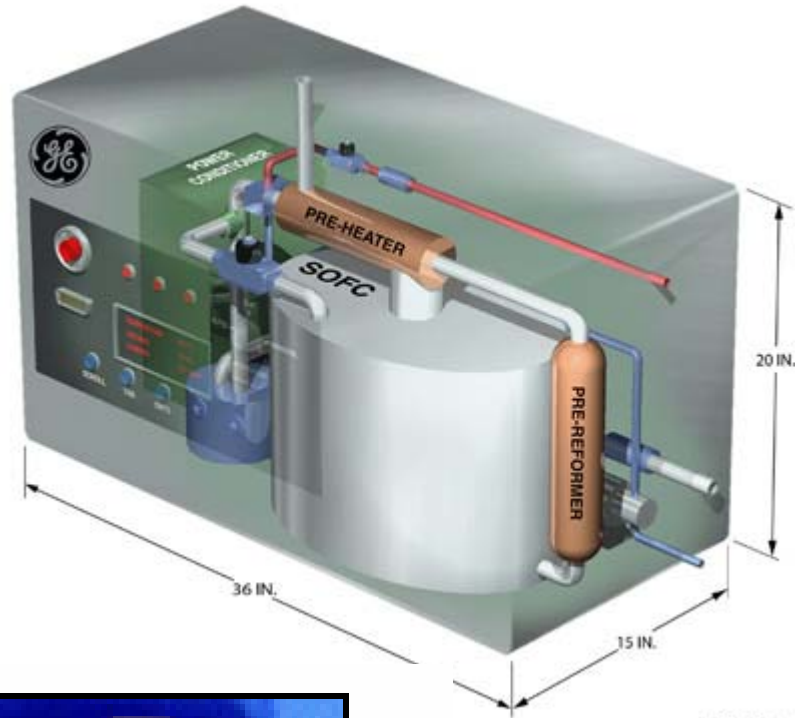
Two 15-cell stacks
ReforWER
Balance of Plant

Images courtesy of Delphi

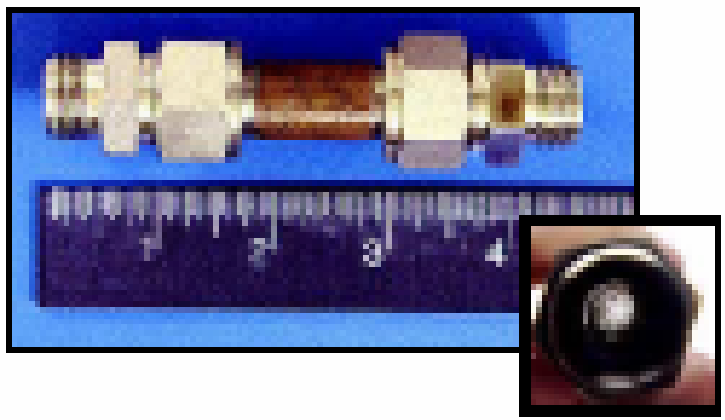
General Electric



Unitized Cell Design



Conceptual Design



1-kW Catalytic Partial Oxidation

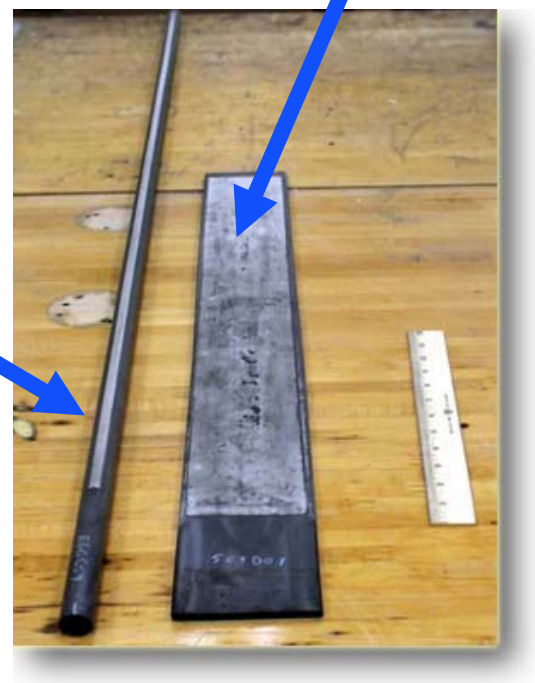
Images courtesy of GE

Siemens Westinghouse

5 kW
Prototype

Redesigned Tube

Tubular
cell

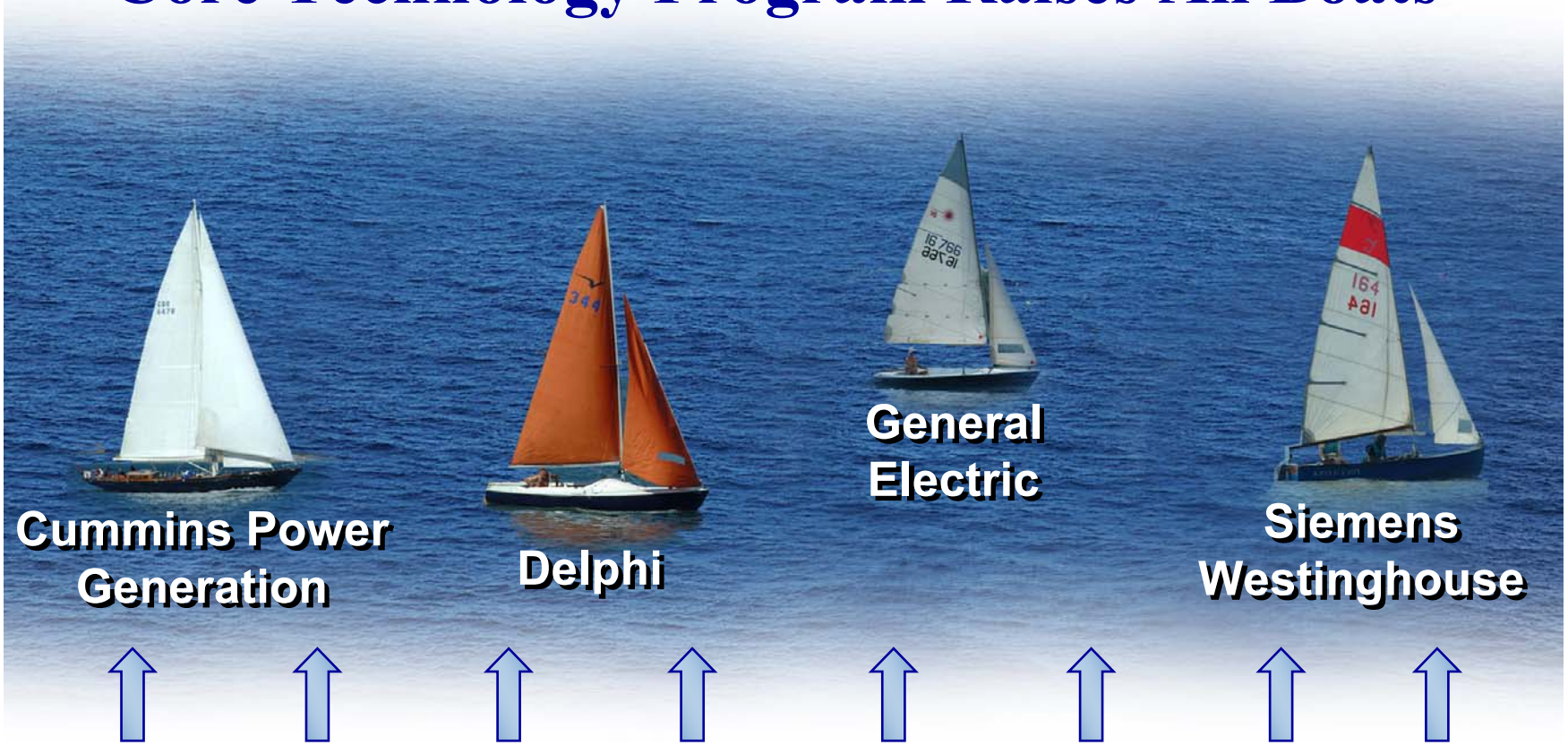


Images courtesy of Siemens Westinghouse

Different Approaches!

Team	Design	Manufacturing
Cummins-SOFCo	• Electrolyte supported • 850 C • Thermally matched materials • Seal-less stack	• Tape casting • Screen printing • Co-sintering
Delphi-Battelle	• Anode supported • 750 C • Ultra compact • Rapid transient capability	• Tape casting • Screen printing • 2–stage sintering
General Electric	• Anode supported • 750 C • Hybrid compatible • Internal reforming	• Tape calendering • 2–stage sintering
Siemens Westinghouse	• Cathode supported • 800 C • Redesigned tubular • Seal-less stack	• Stack extrusion • Plasma spray

Core Technology Program Raises All Boats



- Materials
- Modeling and simulation
- Fuel processing
- Power electronics
- Controls and diagnostics
- Manufacturing

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

Cross Cutting Technologies

Seals, Modeling And Analysis, Cathodes, Anodes, Interconnects, Fuel Processing

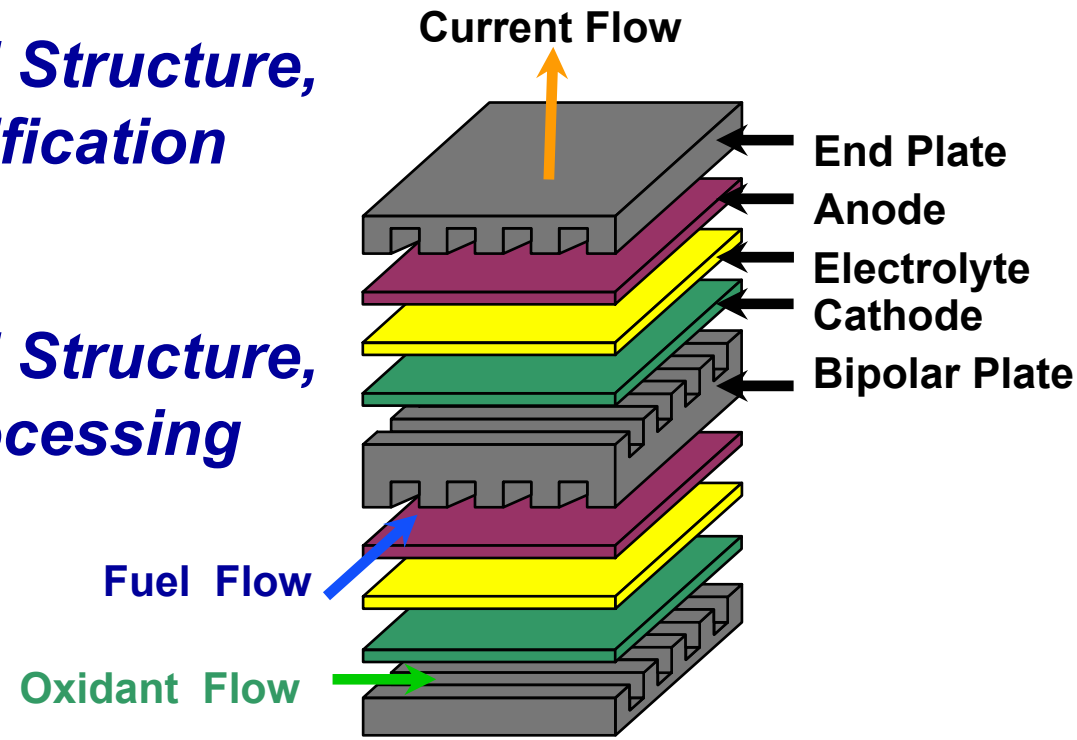
- **PNNL**

Metallic Supported Cell Structure, Cathode Interface Modification

- **LBNL**

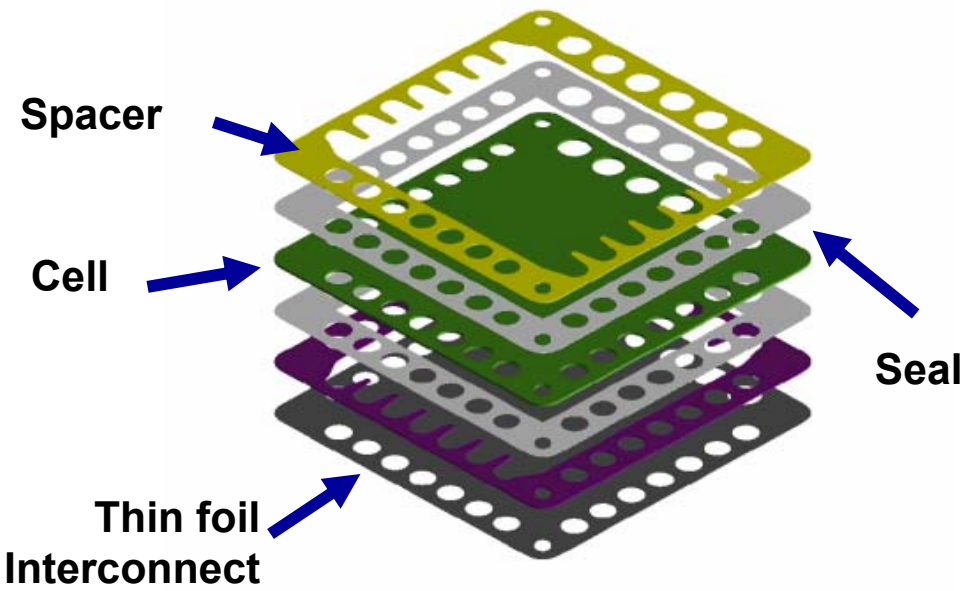
Metallic Supported Cell Structure, Interconnects, Fuel Processing

- **ANL**



Intermediate-temperature Inexpensive Interconnect Materials

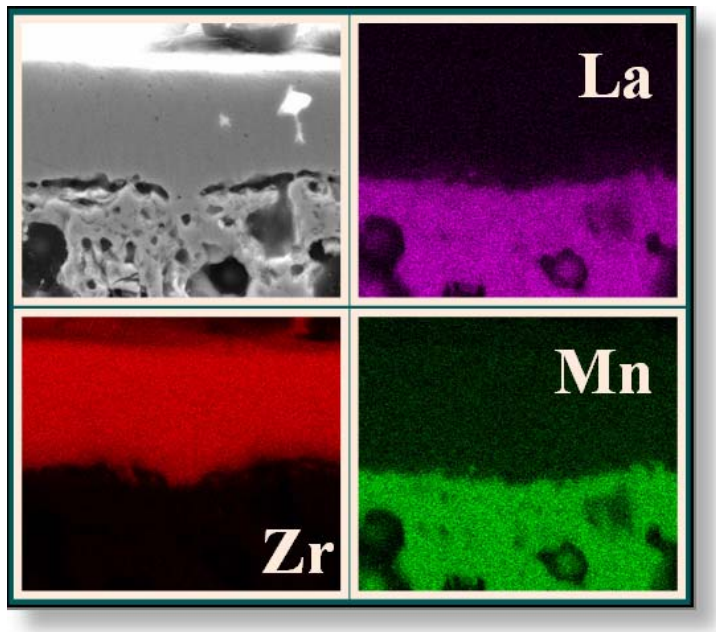
- U. of Pittsburgh
- Ceramatec
- Southwest Research Institute
- PNNL
- ANL



Images courtesy of Delphi

Materials for 2- to 3-fold Improvement in Cathode Performance

- U. of Washington
- U. of Missouri Rolla
- U. of Utah
- Functional Coating, LLC
- Georgia Tech
- PNNL



Images courtesy of NexTech

Structural, Performance, And Optimization Design Tools

- PNNL
- NETL
- ORNL
- U. of Florida
- Georgia Tech
- TIAX

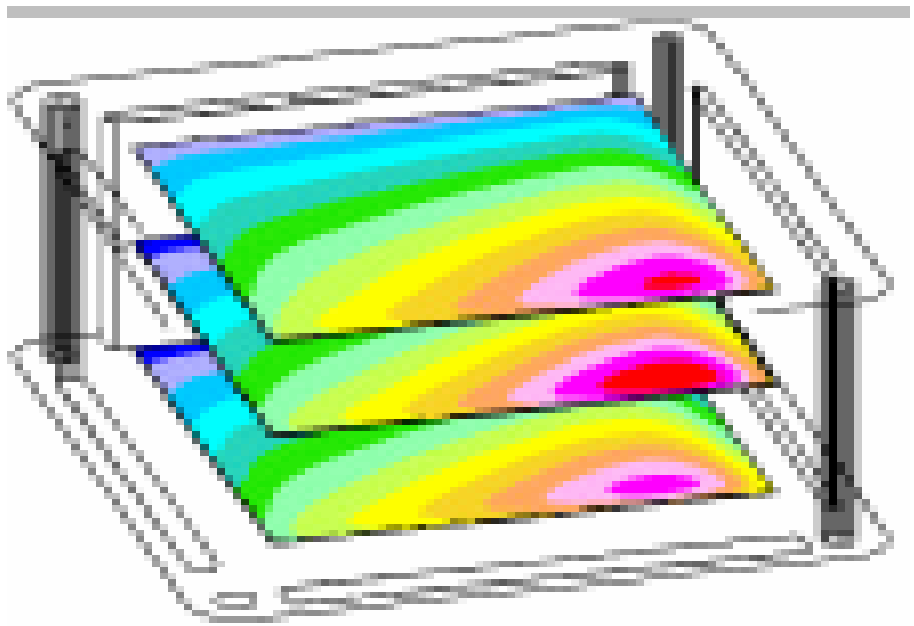


Image courtesy of PNNL

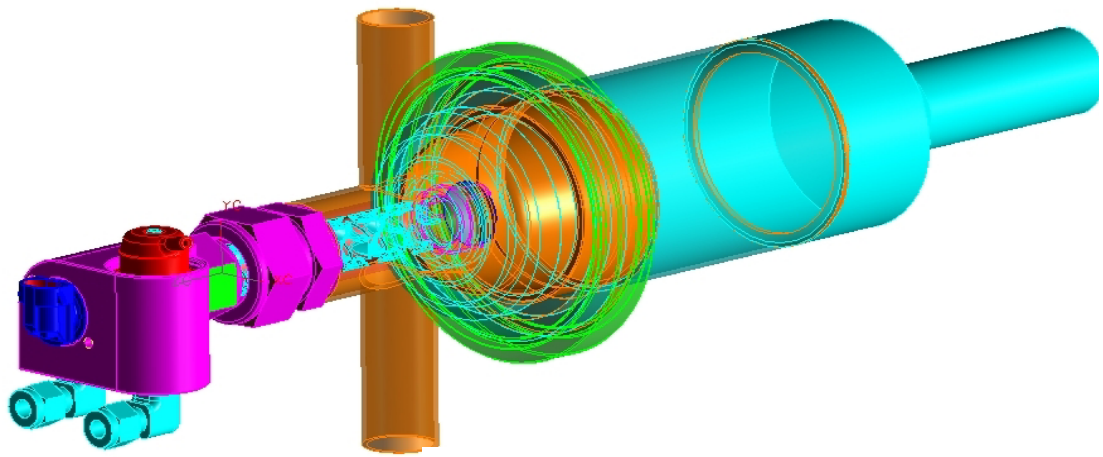
Fuel Processing

Carbon/Sulfur Resistant Anodes

- Northwestern
- GTI

Carbon/Sulfur Resistant Reforming Catalysts

- LANL
- ANL
- NETL



Tubular cPox Reformer

Image courtesy of Delphi

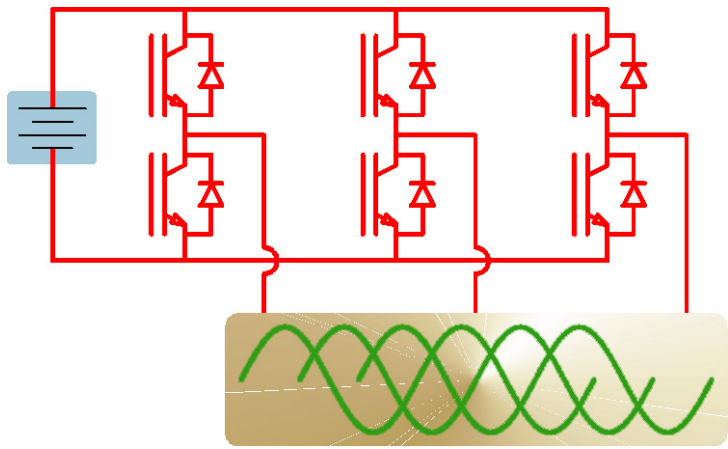
Balance of Plant

Interaction Among Fuel Cell, Power Conditioning, Load

- **U. of Illinois**

DC-DC / DC-AC Converters

- **Texas A&M**
- **VPI**

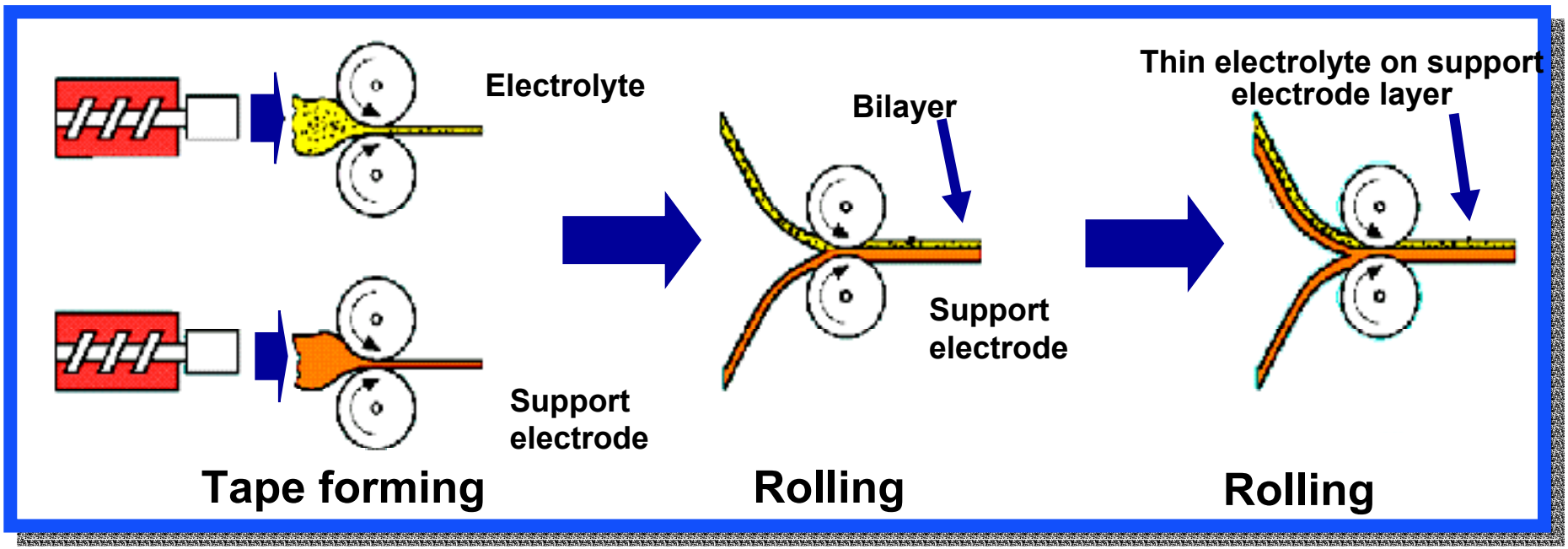


High Temperature Sensors

- **NexTech Materials**

Low Cost / Consistent Precursor Materials

- NexTech Materials
- U. of Utah



Tape Calendering

Image courtesy of Honeywell

Highlights: *Core Technology Program*

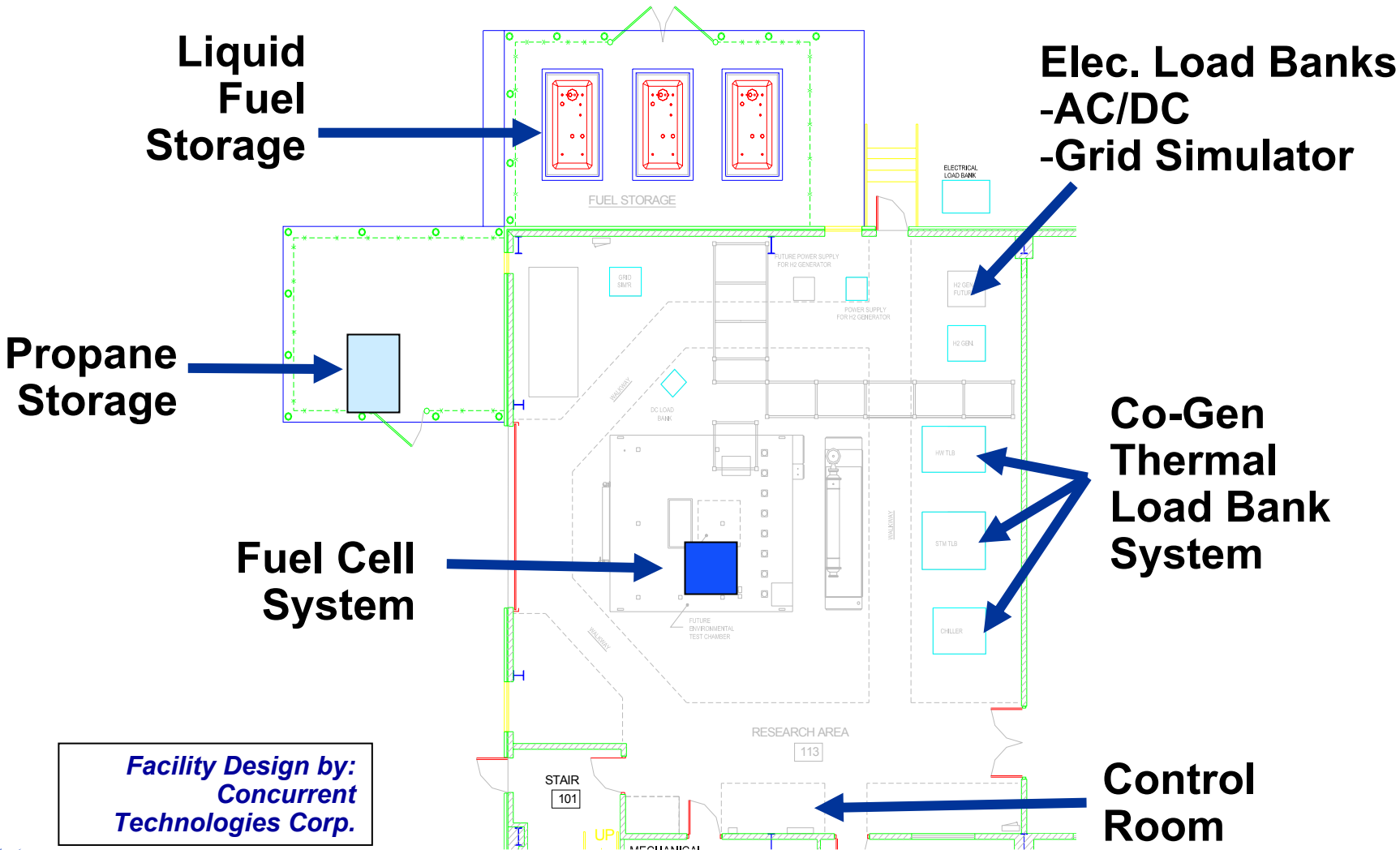
- Glass and mica compressive seal characterization
- Inexpensive Ferritic alloy interconnect characterization
- Fuel cell models available
- Material structural characterization
- Mixed conducting cathodes, LaSrFeOx
- Cathode microstructure optimization
- Cathode mechanism intermediates identified
- 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

SECA Performance Targets
Phase 1 FY2005/06

Cost	$800/ kW, $600/ kW, $400/ kW

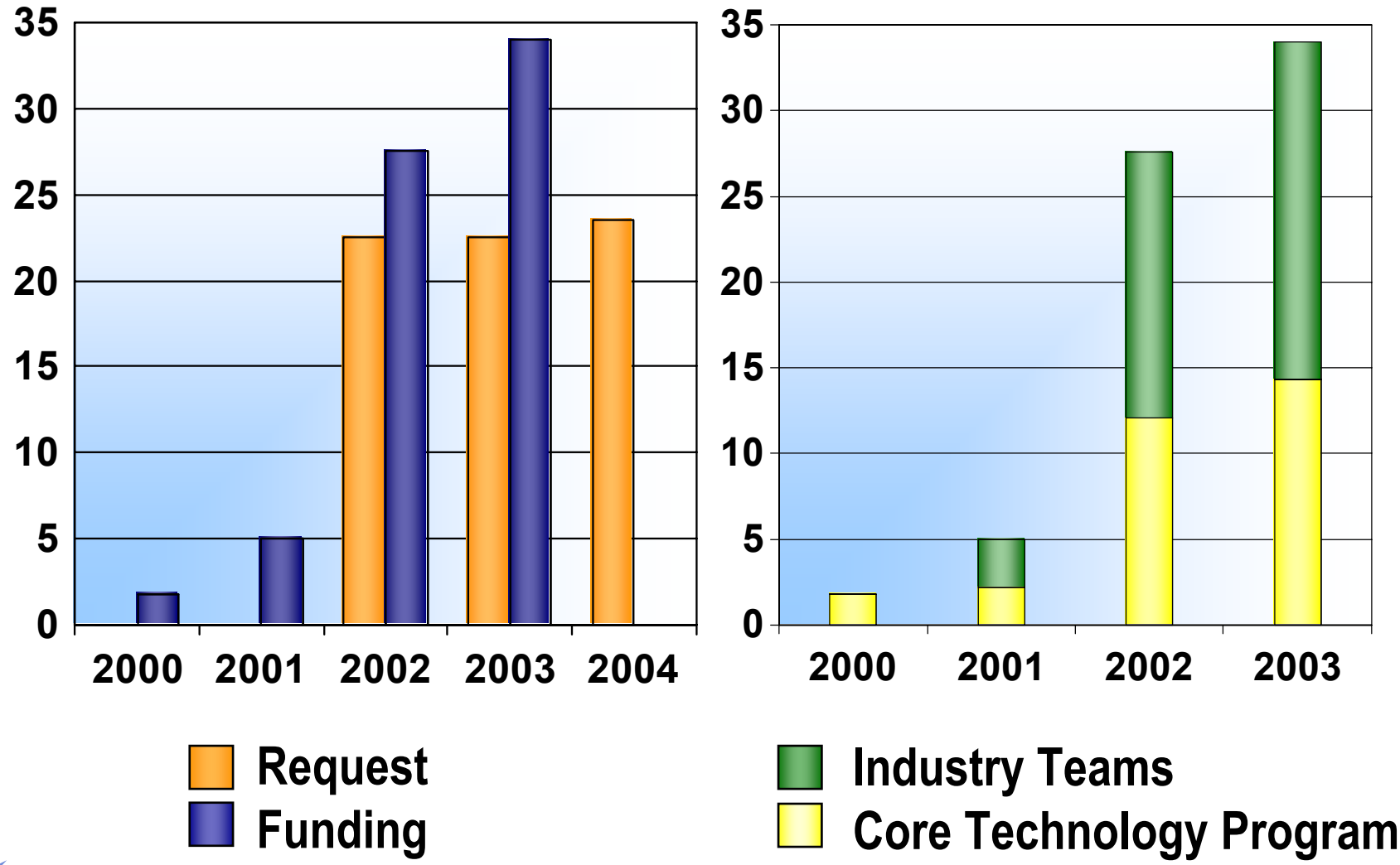
Power rating	3-10 kW (net)
Efficiency (AC or DC/LHV)	Stationary: 40 - 60% APU: 30 - 50%
Fuels (Current infrastructure)	Natural gas Gasoline Diesel
Design lifetime	Stationary: 40,000 hours, 100 cycles APU: 5,000 hours, 1,000 cycles
Maintenance	> 1,000 hour interval

NETL's SECA Test Facility



Facility Design by: Concurrent Technologies Corp.

SECA Budget ($M)

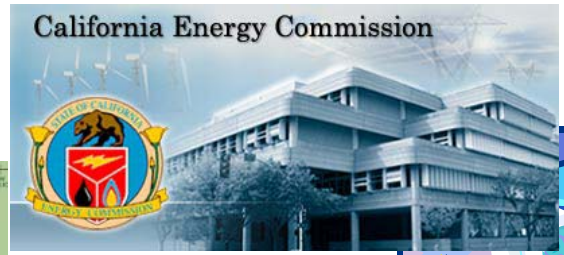


Other Pathways to High Volume

With Help from our Friends

Ohio Department of Development

California Energy Commission



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

Office of Naval Research

DARPA

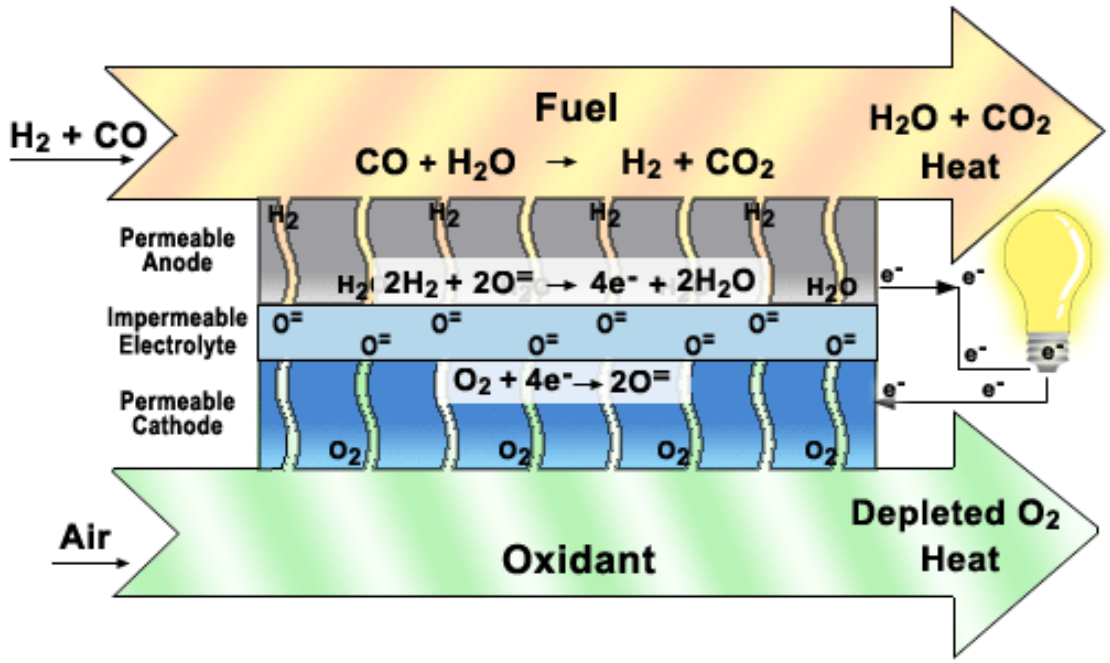
TACOM

Army Research Laboratory

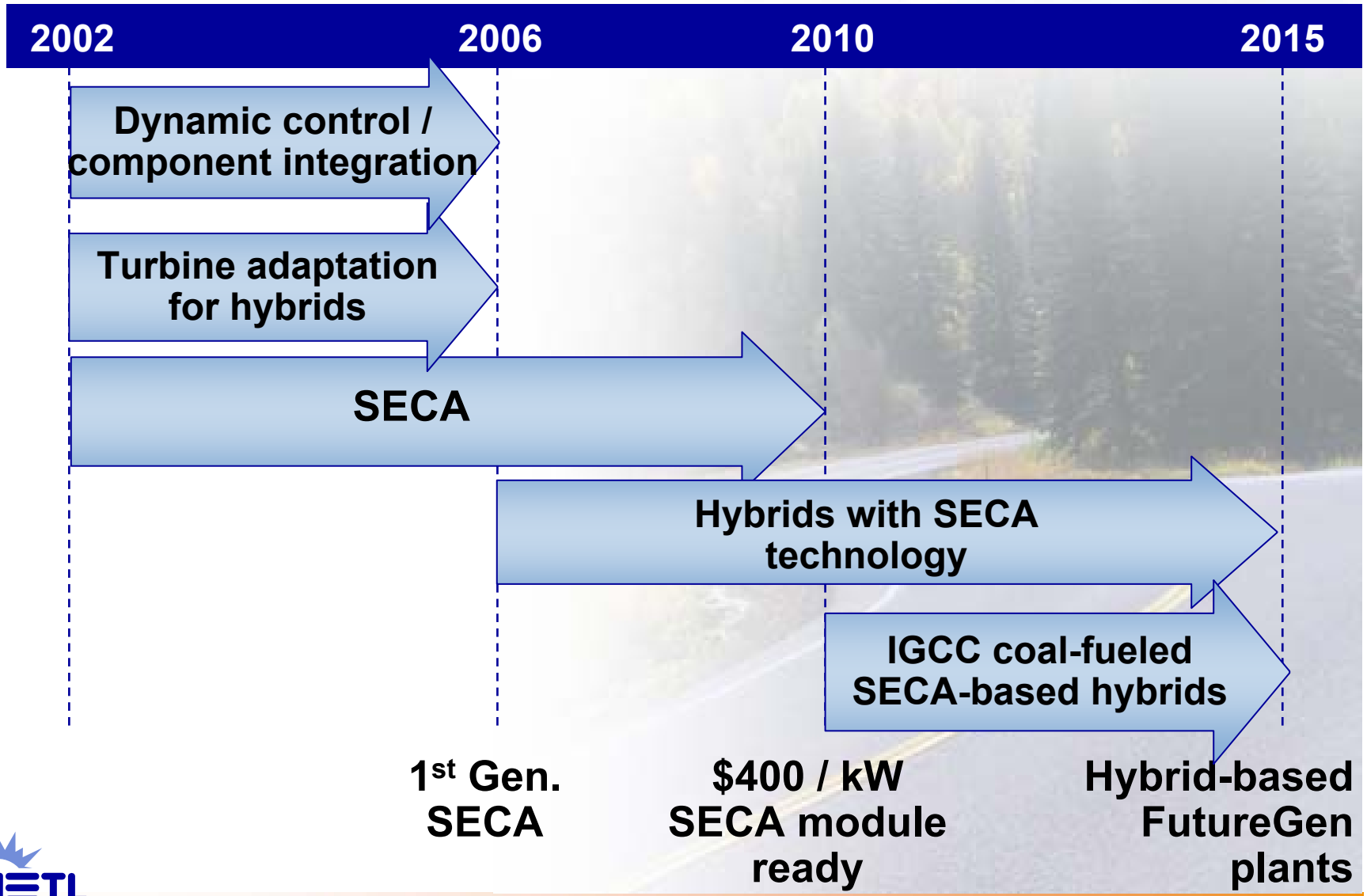
NETL

SECA Program Status

- Program in place
- Making technical progress
- Implementation as planned



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

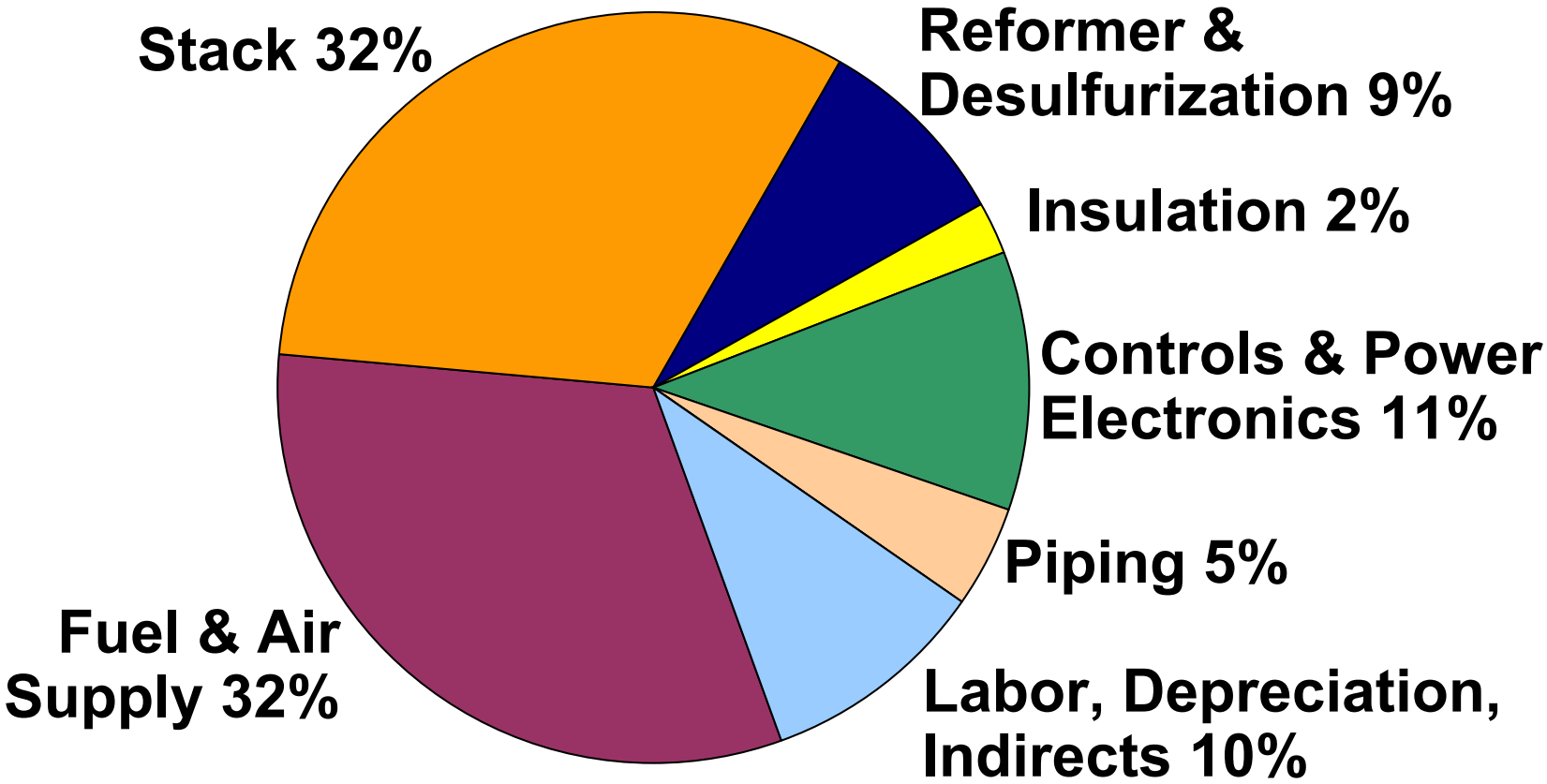
Optimized Turbines

System Integration

NETL

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