The Solid State Energy Conversion Alliance

Power Electronics for Fuel Cells Workshop
Irvine, CA
August 8-9, 2002

Donald W. Collins

National Energy Technology Laboratory

National Benefits

Energy Security

- **Multi-fuel capability allows use of available fuels or currently cost-effective fuels including hydrogen and coal.**
- **In many applications doubles the efficiency of producing power from fossil fuels compared to current technologies.**
  - **Reduced CO_2 emissions**
  - **Reduced dependence on imported fuels**
- **Rapid response to local energy shortages. Eliminates long-lead time and economic uncert**
  plants.

National Benefits

Environment and Health Benefits

- Important health benefits due to the negligible emission of environmental pollutants using fossil fuels.

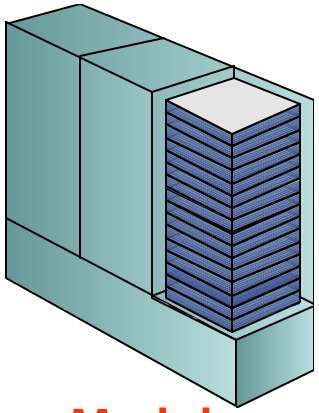
Economic Choices

- Provides a grid independent, environmentally friendly power source for use in the undisturbed, natural areas of the nation.
- Provides more power choices for residences and businesses. The high efficiencies of a combined heat and power (CHP) system along with a choice of fuel, power quality, grid integration or grid independence will provide citizens with choices and will significantly assist de-regulation efforts throughout the nation.

A High Power Density, Low Cost Core Module for Multiple Applications

Stationary

Transportation



Core Module

Military

Common Module Challenges for Power Electronic

SECA Goals and Applications

2005

- **Early Markets**
  - Long-haul trucks
  - RVs
  - Military
  - Premium power

2010

- **$400/kW**
  - Residential & industrial CHP
  - Transportation auxiliary power

2015

- **Vision 21 power plants**
  - 75% efficient
- **Hybrid systems**
  - 60–70% efficient

Fuel Cell/Turbine Hybrids

2001

- > $10,000/kW
- 57-59% efficiency
- 220kW

2004-2015

- DG market
- $1,000-1,200/kW
- 70% efficiency
- 1-20MW
- Vision 21

SECA Program Structure

Industry Input

Program Management

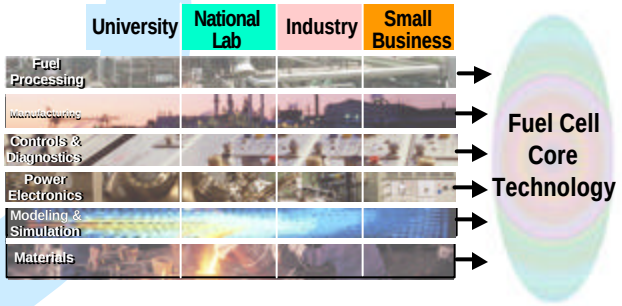
Project Management

Needs

Research Topics

Industry Integration Teams

Technology Transfer



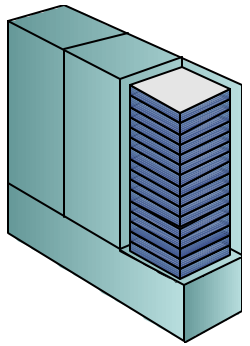
Core Technology Program

Industry Integration Teams
The Manufacturing Base

- **Four teams competitively selected**
  - General Electric (was Honeywell)
  - Delphi Automotive Systems & Battelle
  - Cummins Power Generation & McDermott Technology, Inc.
  - Seimens Westinghouse Power Corp., Fuel Cell Technologies

- **Prototype within four years of award ~ Sept/Oct 2005**

- **20% cost share in Phase I 50% in Phase II and III**

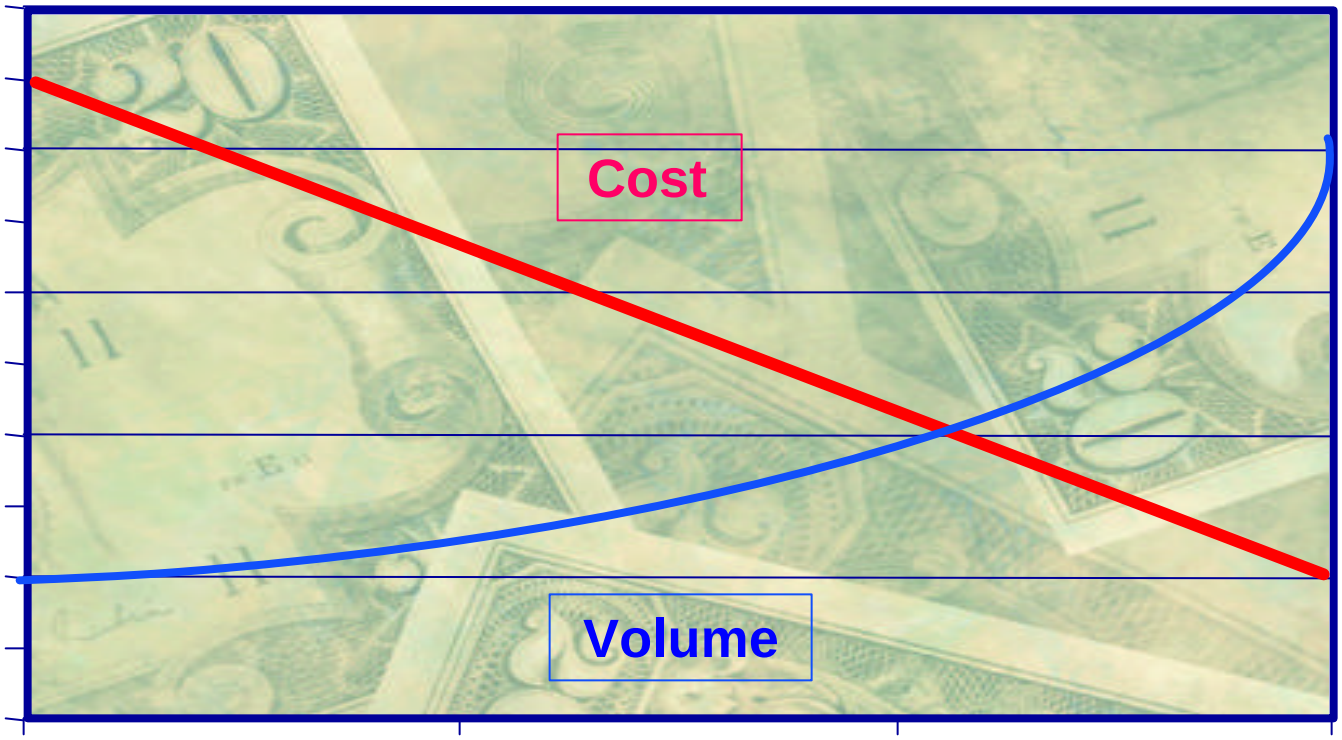


Mass Customization of Building Block Modules

Technical Requirements

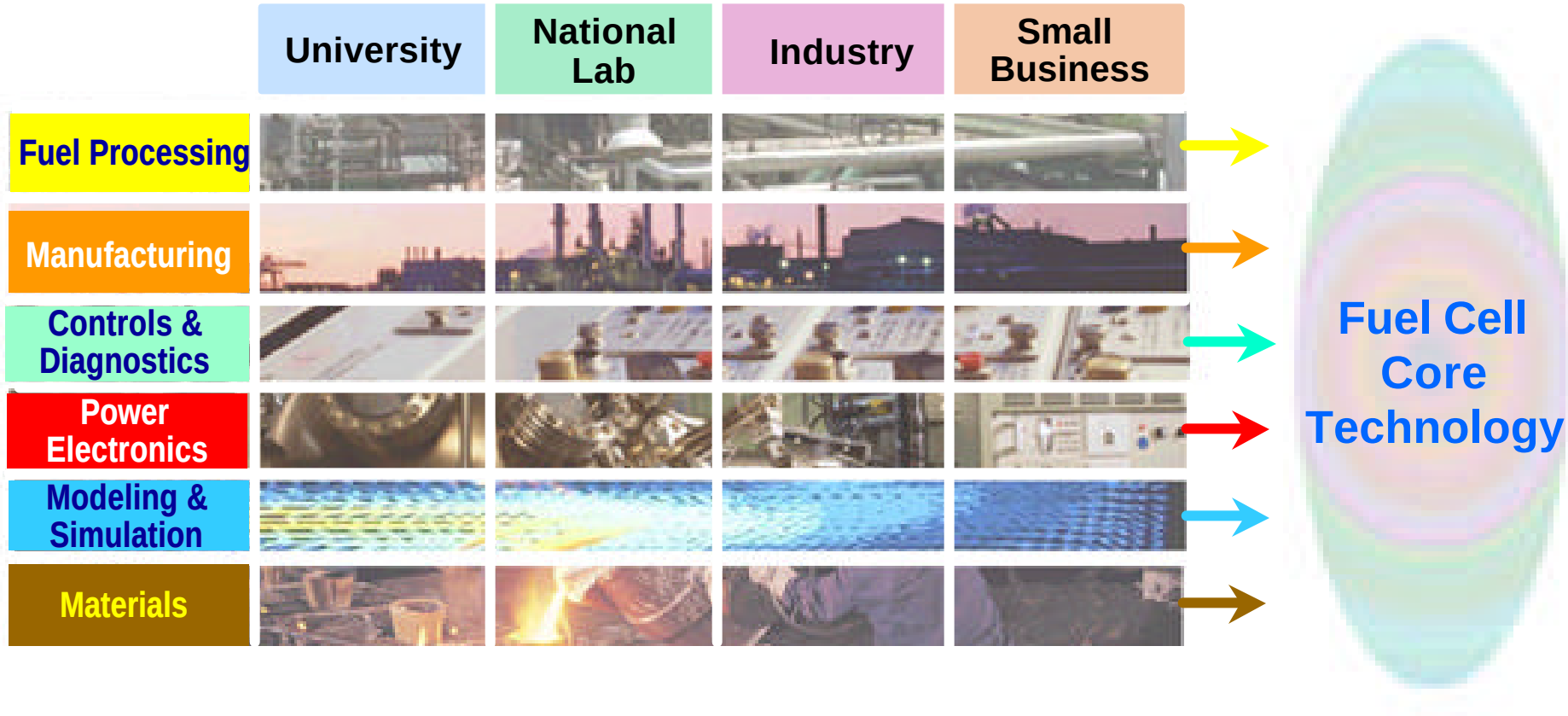
Cost	**$400 / kW**
Power Rating Net	**3-10 kW**
Efficiency (AC or DC/LHV)	**30 - 50% [APU]** **40 - 60% [Stationary]**
Fuels (Current infrastructure)	**Natural Gas** **Gasoline** **Diesel**
Design Lifetime	**5,000 Hours [APU]** **40,000 Hours [Stationary]**
Maintenance Interval	**> 1,000 Hours**

The Vision: *Fuel Cells in 2010*



Low Cost/High Volume
$400/kW/ > 50,000 units/yr

Core Technology Program
The Technology Base



Core Technology Program (CTP)

Raising the Technology Baseline

- **CTP developments can benefit all SECA Industrial Teams**
- **A mix of short (1-2 year) projects address needs of multiple Industrial Teams and a few longer term projects add significant value to all**
- **Semi-annual meeting of CTP participants, Industrial Teams, Project Management Team**
- **19 Awards from FY02 Solicitation**

Intellectual Property
Cornerstone of the Alliance

- **Non-Exclusive License** **CTP ➡ Industry Teams**
  - **Open for 1 year after issue of a U.S. patent**
  - **Ready market of potential licensees**
  - **Best designs vs. highest bidder**
- **Promotes Collaboration - Limits Redundancy**
- **Pilot program; reevaluate after 2 years**

Power Electronics

- **Unique Issues for SOFCs**
  - Power Conversion & Load Interaction **(e.g., Feedback & Ripple)**
  - DC-to-DC Converters **-is SOFC voltage low enough to be unique?**
- **Stationary Applications**
- **Grid Connection Requirements**
- **Transportation Requirements**
- **Architecture Options**
  - Multiple Fuel Cell Modules
  - Hybrid Systems
- **COST! COST! COST!**

SECA & Power Electronics

4.1 Interaction Between Fuel Cell, Power Conditioning Systems & Application Loads

- fully characterize the phenomena of electrical feedback to solid-oxide fuel cell (SOFC) stacks and the effect on SOFC operating performance and service life longevity

- analytical tool development

4.2 DC-to-DC Converters for Solid-Oxide Fuel Cells

- innovative and cost-effective DC-to-DC regulator/converter architectures and topologies for SOFC power generation systems

- $\leq$ 3% energy loss for conversion

Interaction Between Fuel Cell, Power Conditioning Systems and Application Loads

- **University of Illinois** "An Investigation to Resolve the Interaction Between Fuel Cell,Power, Conditioning System and Application Loads"
  - Modeling of application load and fuel cell dynamics
  - Modification of existing models for PEM systems
  - SABER simulation software environment is compatible with PNNL approach
  - Diverse Team of Experts
    - GA Tech
    - VA Tech
    - Ceramatec
    - Avant! Systems

DC-to-DC Converters For Solid-Oxide Fuel Cells

- **Texas Engineering Experiment Station**

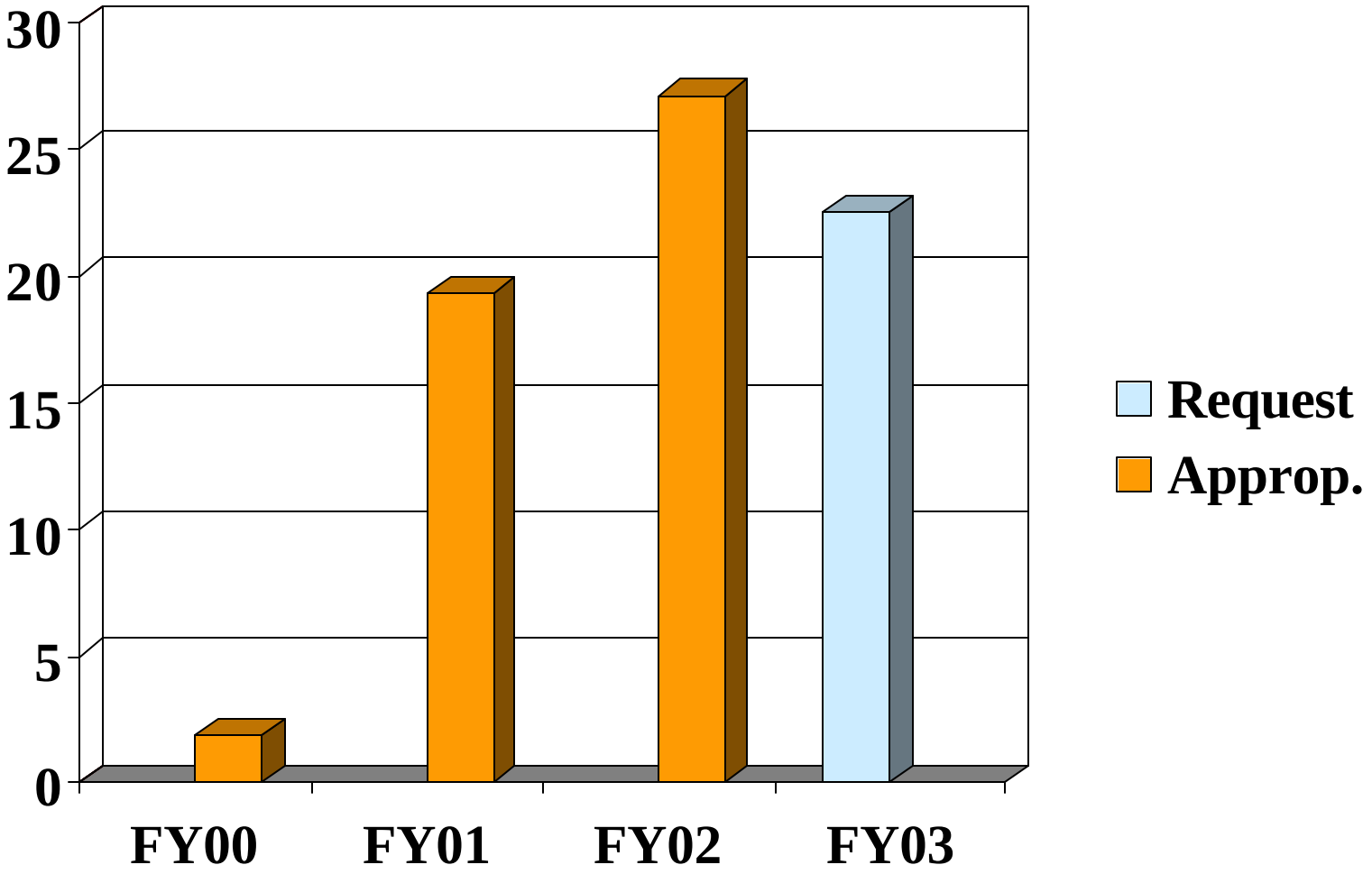
  (a.k.a. Texas A&M University) "Development of a New Class of Low Cost, High Frequency Link Direct DC to AC Converters for Solid Oxide Fuel Cells (SOFC)"

  - Direct DC to AC power electronics
  - Innovative digital signal processor control
  - circuit resonance control

- **Virginia Polytechnic Institute and State University** "A Low-Cost Soft-Switched DC/DC Converter for Solid-Oxide Fuel Cells"

  - Computer modeling and simulation
  - Optimize design of high-frequency, high-power transformers
  - System integration with circuit design and a hardware prototype
  - Tested & evaluation with available active and passive loads
  - EPRI PEAC Corp

SECA Budget
($ - millions)



INDUSTRIAL TEAMS

Honeywell (GE)	Demonstrated a unique unitized sealess radial design. Single cell performance at 700 C is near Goals
Delphi/ Battelle	Demonstrated automotive APU. Design developed by Battelle will use unique seals, anode, and cathode.
Cummins/ McDermott	McDermott has demonstrated a unique design and cost effective multi-layer manufacturing using techniques developed in the semi-conductor industry.
Siemens-Westinghouse	Siemens-Westinghouse has redesigned their technically successful tubular design to reduce stack cost.

SECA Timeline

• Industry Team Solicitation Issued	November 3, 2000
• Proposals Due	*January 3, 2003*
• SECA Core Technology Program Workshop	February 14 & 15, 2000
• 2nd Annual SECA Workshop	March 29 & 30,2001
• 2001 Industrial Teams Selected	August 2001
• Core Technology Program Review	November 2001
• Core Technology Program Solicitation Issued	January 2002
• Core Technology Program Review	June 18 & 19, 2002
• Core Solicitation Awards	August 6, 2002
• Core Technology Program Review	*February 2003*

www.netl.doe.gov/scng
www.seca.doe.gov

Tubular Solid Oxide Fuel Cells

2001

- 47% efficiency
- > $10,000/kW
- 100-220kW
- 16,000 hr operation at 100-kW

2003-2008

- Near-term DG market
- 47- 63% efficiency
- Homestead, PA 15MW/yr Manufacturing facility 2003 ($4500/kW initially)
- 250kW - 550kW
- $1,000-1,500/kW

FUTURE NEEDS