The U. S. Department of Energy Fossil Energy Fuel Cell Program
Solid State Energy Conversion Alliance
Goals and Challenges

8th SECA Workshop

Wayne A. Surdoval

Technology Manager, Fuel Cells
National Energy Technology Laboratory
U. S. Department of Energy

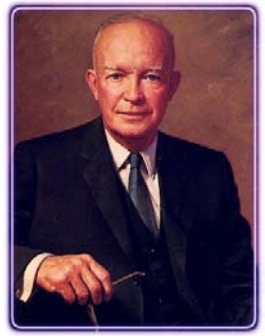
7 August 2007

Atoms for Peace
1953

October 22, 1953: The Atomic Energy Commission announces that an AEC-owned demonstration power plant of 60 MW will be built at Shippingport, PA, jointly by Westinghouse Electric Corporation and Pittsburgh's Duquesne Light Company under the direction of the **U.S. Navy/AEC Naval Reactors Branch.**

The more important responsibility of this atomic energy agency would be to devise methods whereby this fissionable material would be allocated to serve the peaceful pursuits of mankind. Experts would be mobilized to apply atomic energy to the needs of agriculture, medicine and other peaceful activities. A special purpose would be to provide abundant electrical energy in the power-starved areas of the world.

Dwight D. Eisenhower,
President of the United States of America,
to the 470th Plenary Meeting of the United Nations General Assembly
Tuesday, 8 December 1953



Photograph of the Shippingport Atomic Power Station in Shippingport, Pennsylvania, the first full-scale nuclear power generating station in the United States which began operating in 1957.

Clean Coal Power Initiative

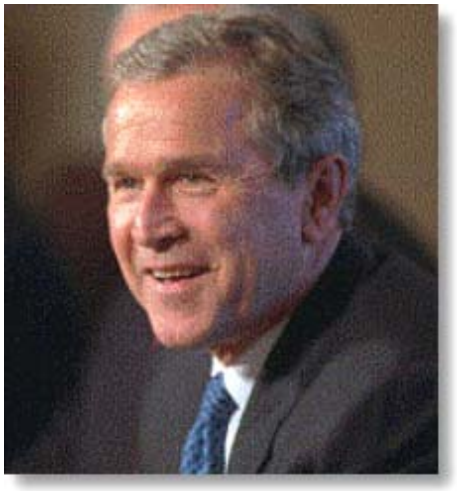
"More than half of the electricity generated in America today comes from coal. If we weren't blessed with this natural resource, we would face even greater [energy] shortages and higher prices today. Yet, coal presents an environmental challenge. So our plan funds research into new, clean coal technologies."

Statement by President George W. Bush
National Energy Policy
May 17, 2001

FutureGen
2003

“Today I am pleased to announce that the United States will sponsor a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant . . . .”

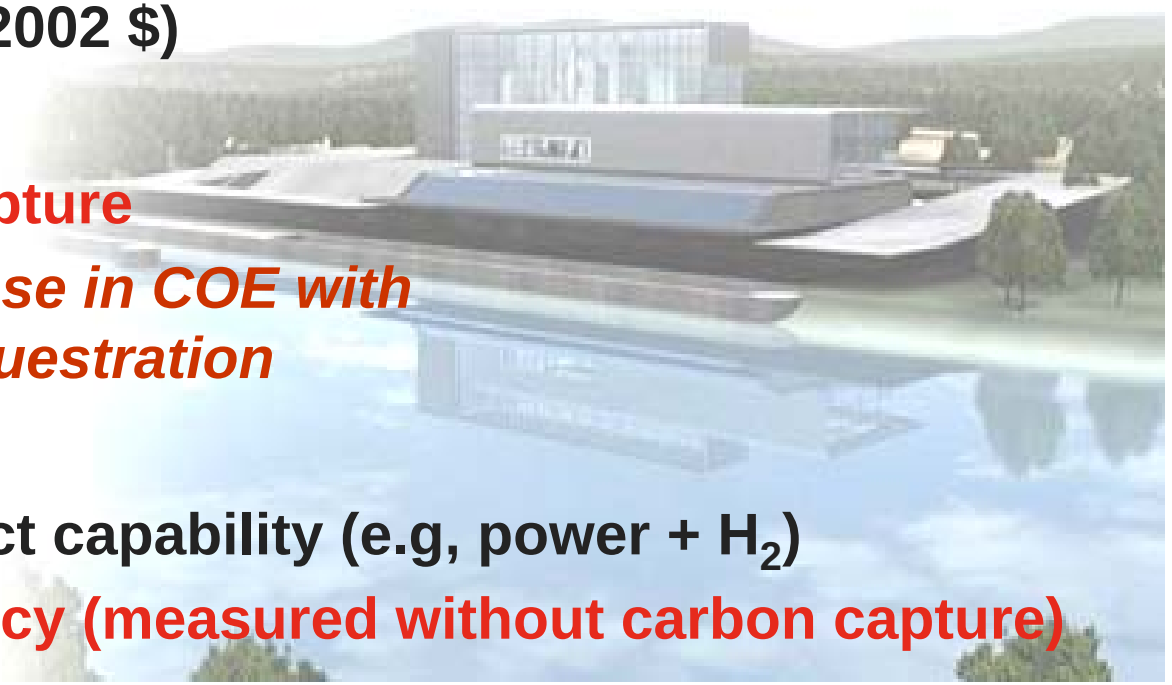
Statement by the President
February 27, 2003



DOE's Office of Fossil Energy

Advanced (Coal) Power Systems Goals

- **2010:**
  - **45-50% Efficiency (HHV)**
  - **99% SO_2 removal**
  - **NOx< 0.01 lb/MM Btu**
  - **90% Hg removal**
  - **$1,000/kW (2002 $)**
- **2012:**
  - **90% CO_2 capture**
  - ***<10% increase in COE with carbon sequestration***
- **2015**
  - **Multi-product capability (e.g, power + H_2)**
  - **60% efficiency (measured without carbon capture)**

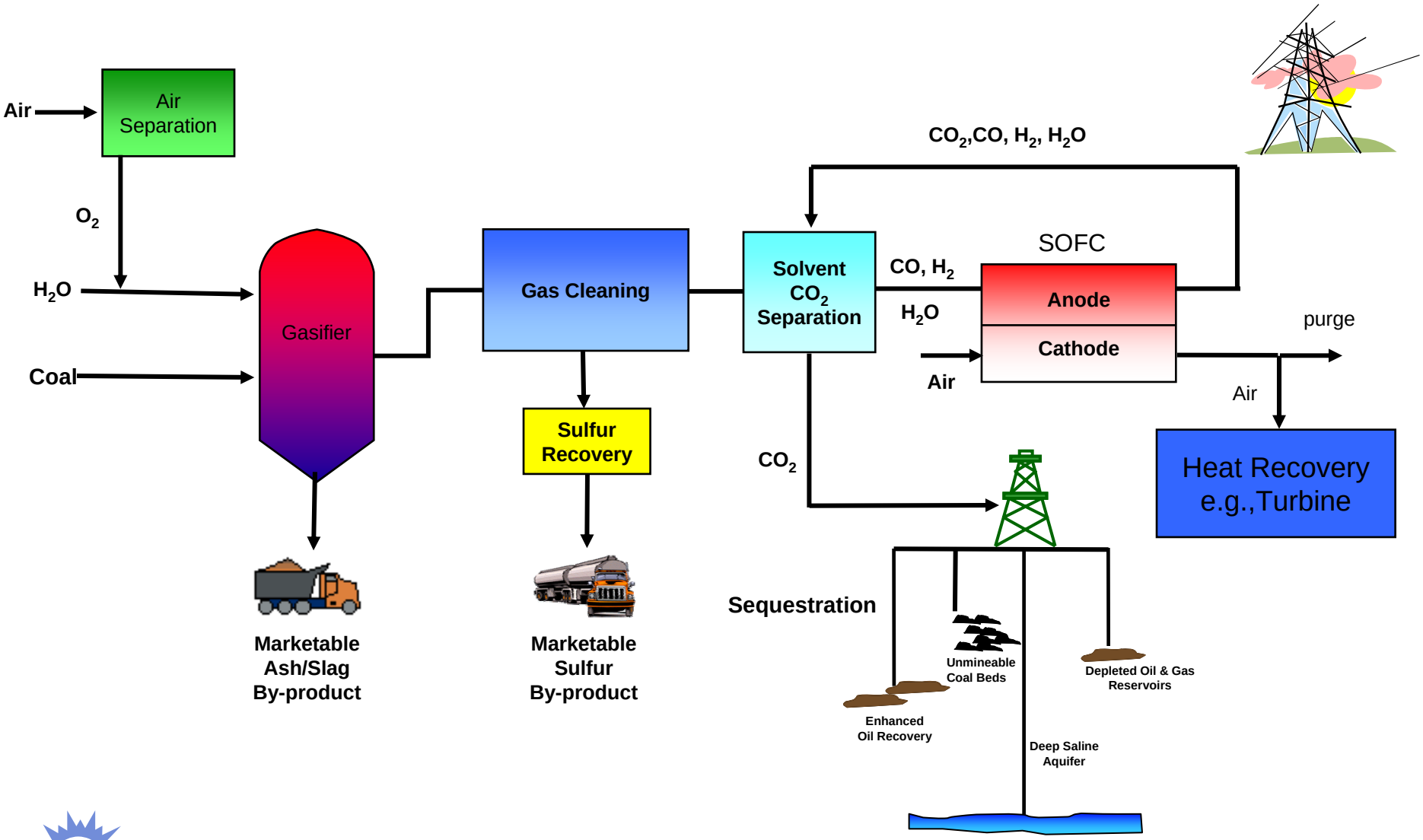


NETL

Why Fuel Cells in a Coal Plant (*FutureGen*)?

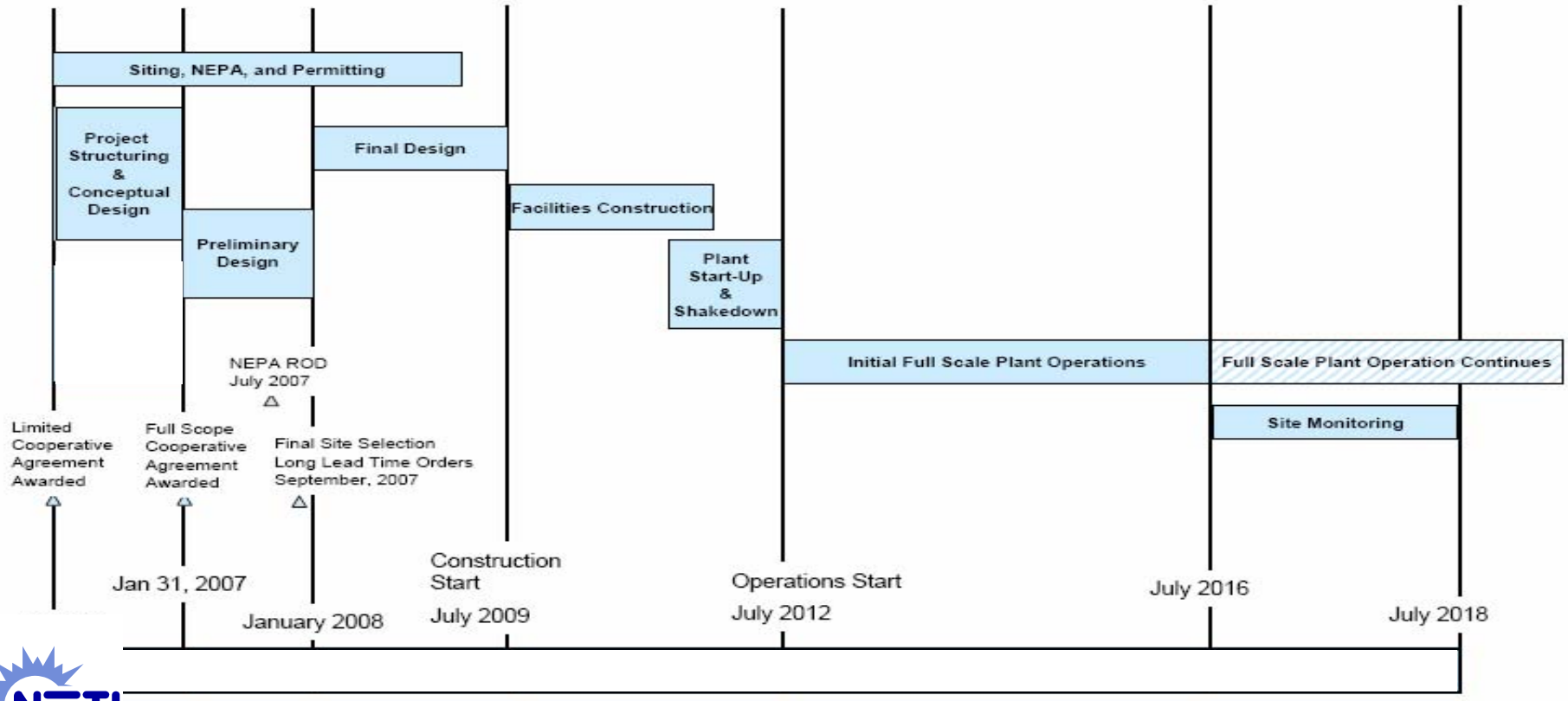
- **Permits high efficiency gasification**
- **Multiple options for Carbon Capture, remove > *90%***
- **High Power Station Efficiency _*60%* HHV?**
- **Near Zero Emissions _ *NOx or < 0.5ppm***
- ***No Impact on Cost of Electricity with SECA goals***
- ***Meet environmental regulations; able to site and produce energy from coal in any state in the U.S.***

SECA Coal Based Systems (IGFC)

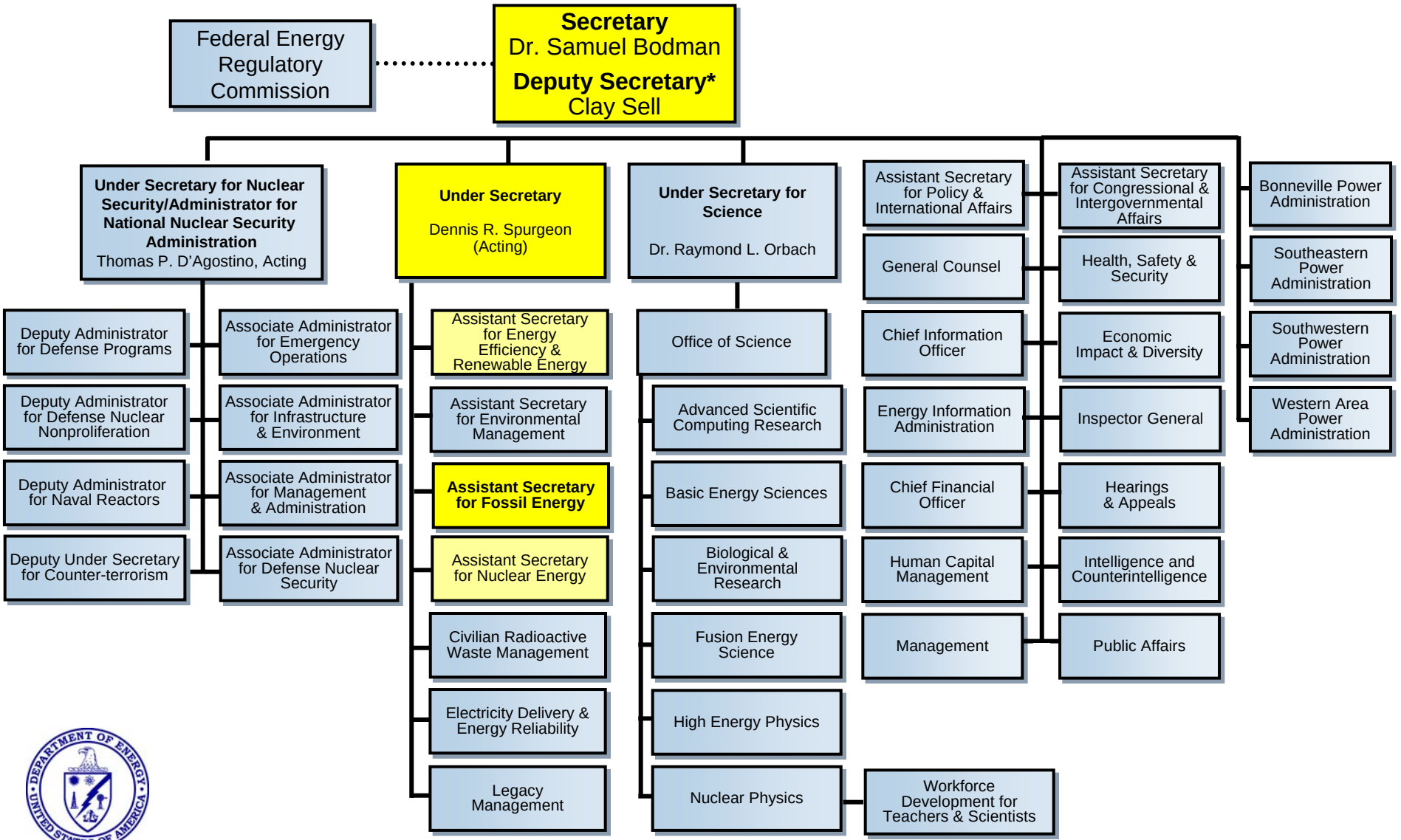


SECA Project Schedule

Conceptual System Design including Carbon Capture **NEPA – Manufacturing & Site** **SECA Module – < $225/kW**	**Sub-Module Prototype ~ 1MW** **Location – TBD** **$400/kW System**	**Manufacture – 10 MWs per System** **Full Scale Balance of Plant >50% HHV With Carbon Capture**	**Operation** **40,000 Hours**

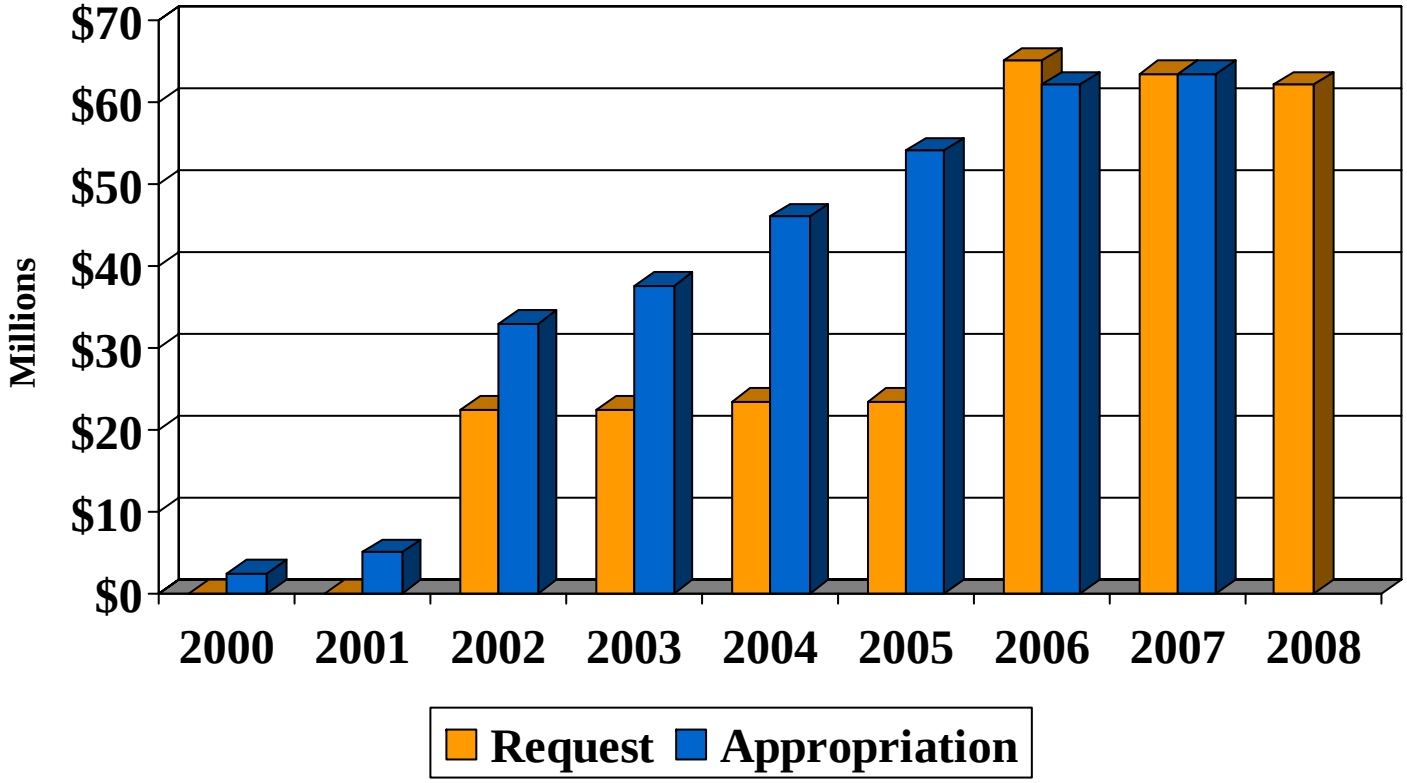


Department of Energy

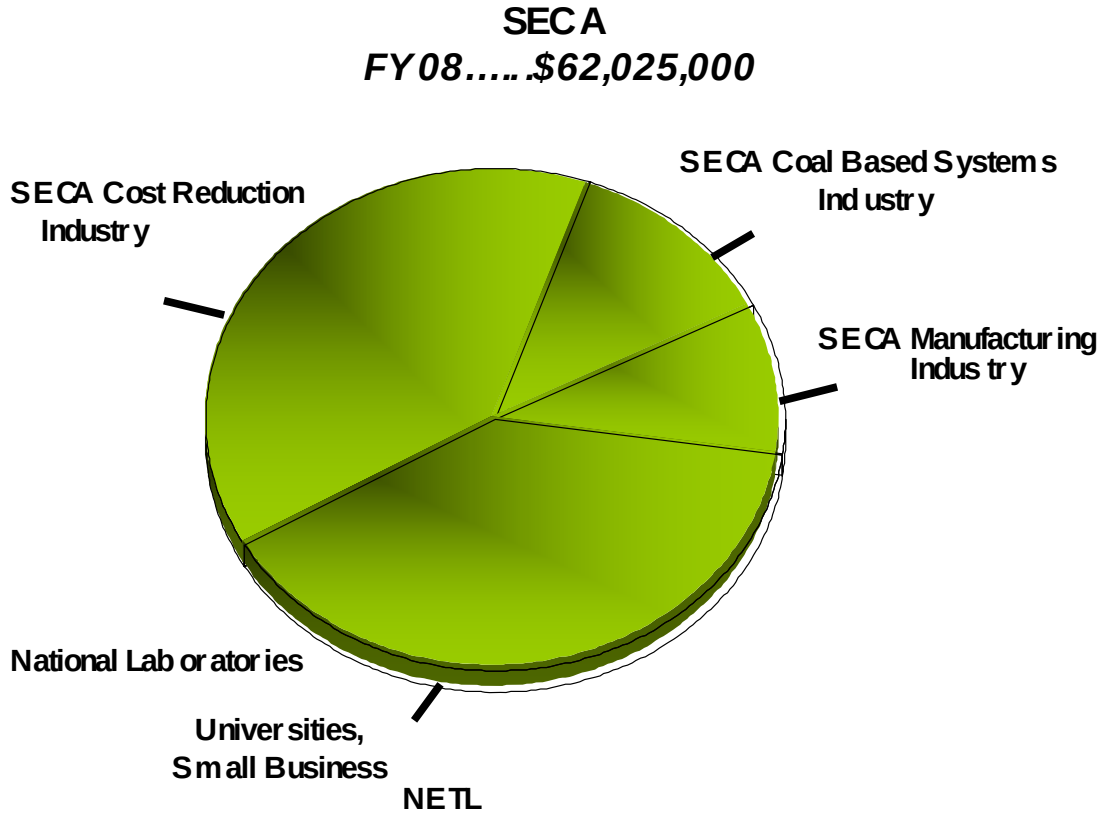


**Deputy Secretary also serves as Chief Operating Officer*

Solid State Energy Conversion Alliance (SECA) Historical Budget



Solid State Energy Conversion Alliance (SECA)
FY 08 Request ….$62.025 Million



SECA Program Structure

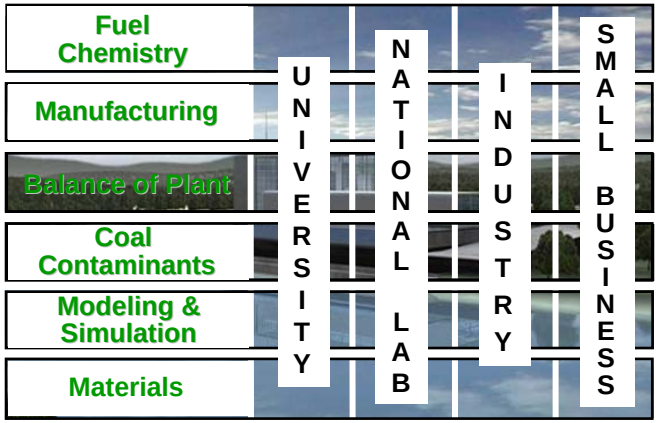
Project Management

Needs

Research Topics

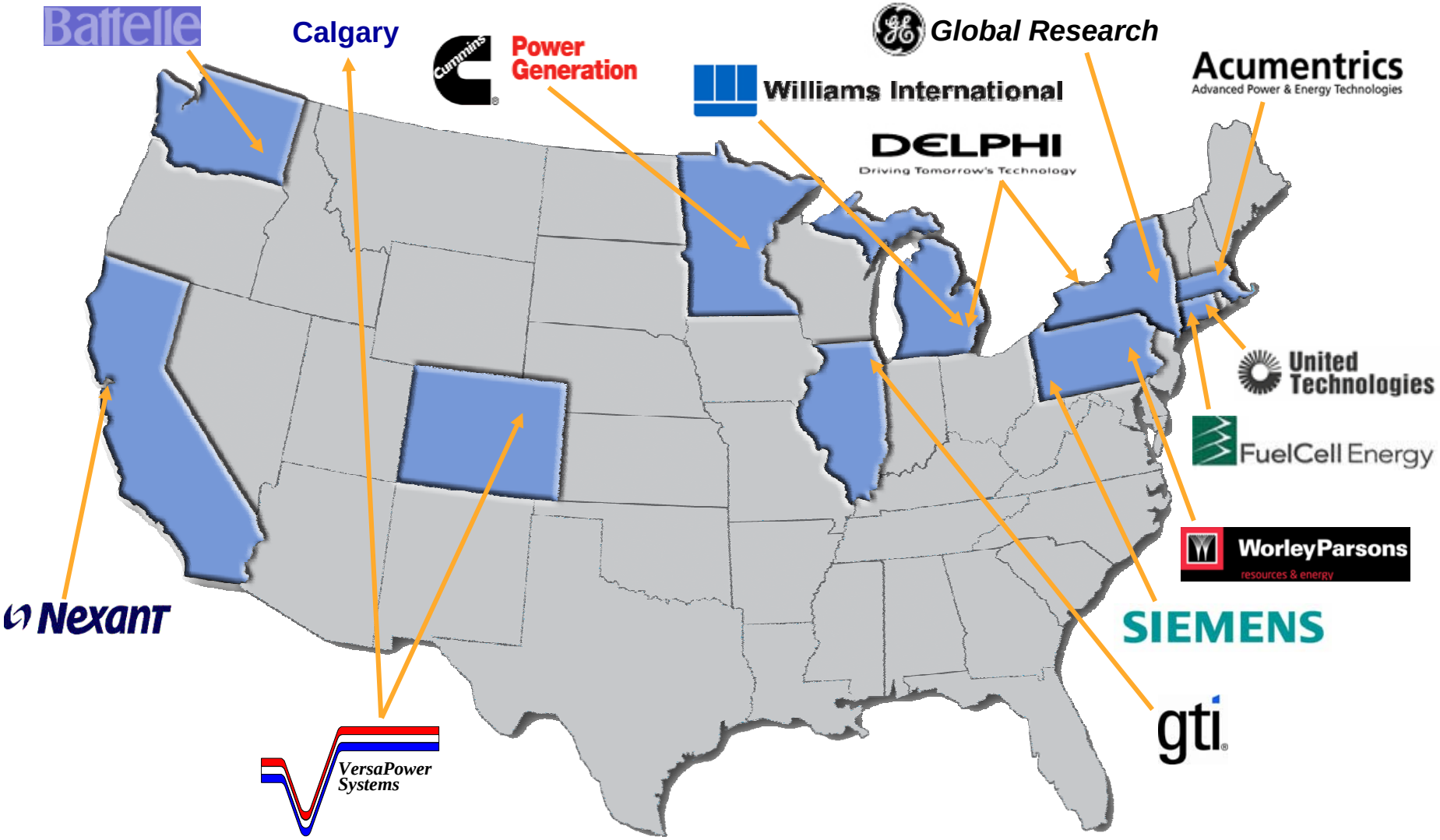
Industry Integration Teams

Technology Transfer



Core Technology Program

SECA Industry Teams & Major Subcontractors

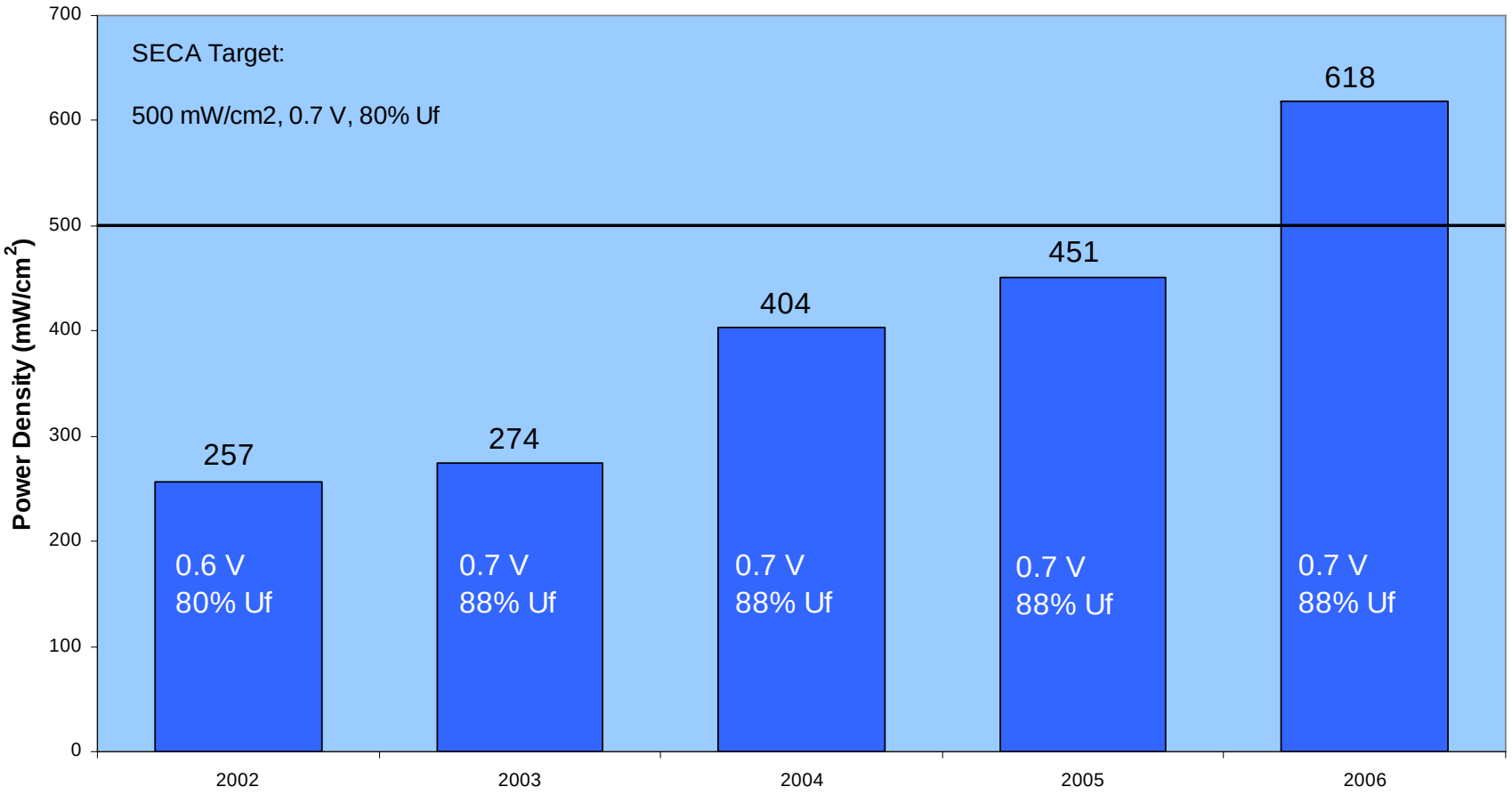


SECA Industry Teams
FY 2001 – FY 2007
Complete

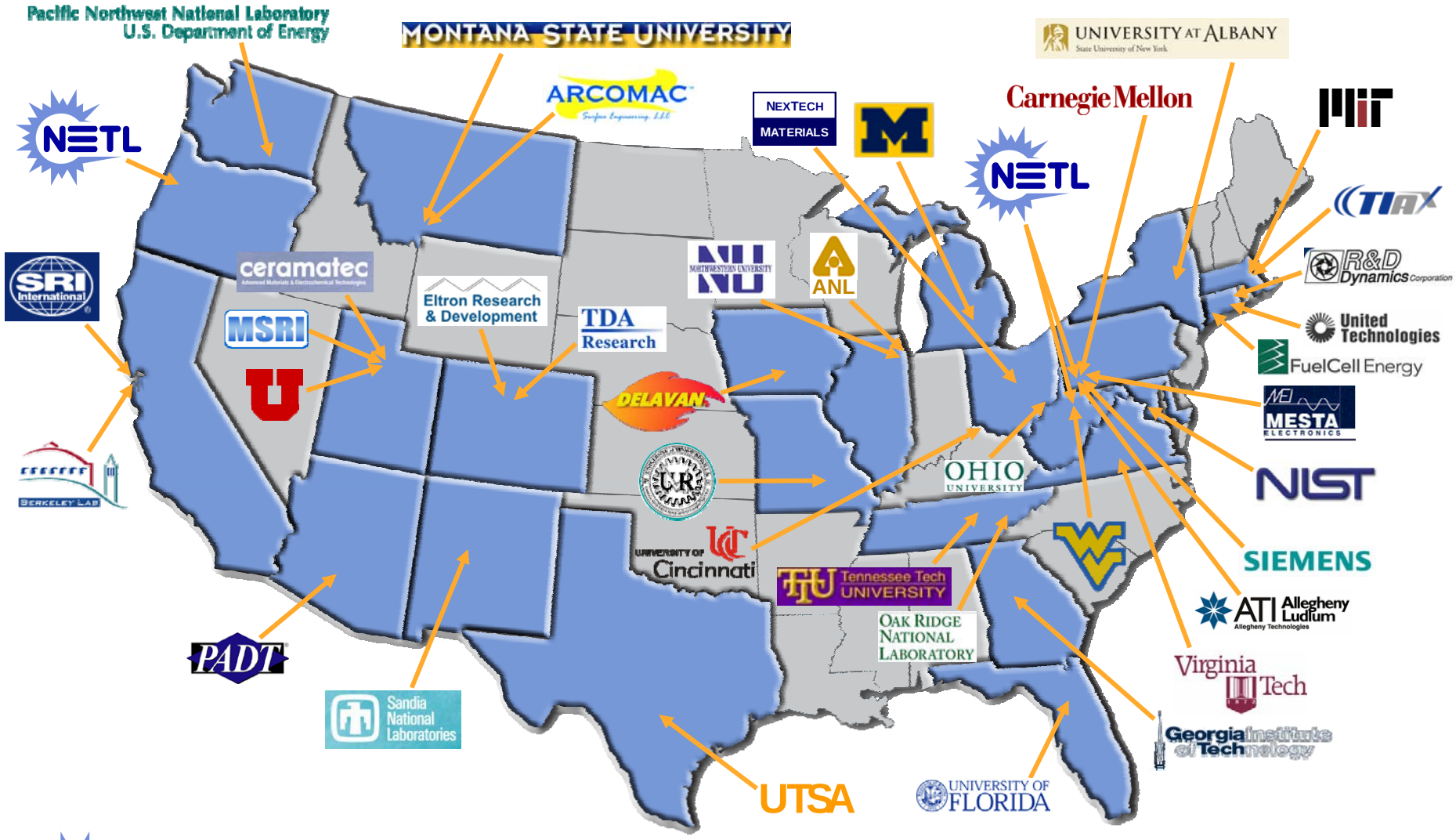
SECA Industry Team	*Location*	*Prototype*	*NETL Validation*
General Electric	Torrance, CA	Complete	Pass
Delphi	Rochester, NY	Complete	Pass
Fuel Cell Energy	Calgary, BC	Complete	Pass
Acumentrics	Westwood, MA	Complete	Pass
Siemens Power Group	Pittsburgh, PA	Complete	Pass
Cummins Power Gen.	Minneapolis, MN	Complete	Pass

	Size	Efficiency	Degradation	Availability	Cost
Target	3 – 10 kW	35 (LHV)	4%/1,000 hrs	90%	
Aggregate Team Performance	3 – 7 kW	35.4 – 41 %	2%/1,000 hrs	97%	$724 - $775/kW

Short Stack Performance Example



2007 SECA Core Technology & Other Partners



Research Priorities:
SECA Cost Reduction

Risk Level

Low

Moderate

High

	Gas Seals	▪ Glass and Compressive Seals ▪ Compliant Seals ▪ Self-healing Materials ▪ High Temperature Seal ▪ Brazes
	Failure Analysis	▪ Models with Electrochemistry ▪ Define Operating Window ▪ Structural Failure Analysis & Design Criteria

	Cathode performance	▪ Optimize Microstructure
		▪ Mixed Conduction
		▪ New Active Materials
		▪ Understand Mechanism
		  ▪ Ad-atom Modification of Surface
		  ▪ Modification through Infiltration

	Interconnect	▪ Coatings ▪ Electrode to Interconnect Interface Contact Material ▪ Inexpensive Processing/Removal of Tramp Elements
	Heat Exchangers/ High Temperature Blowers	▪ Cost and Reliability ▪ Design Guidelines

Research Priorities:
SECA Coal Based Systems

Risk Level

Low

Moderate

High

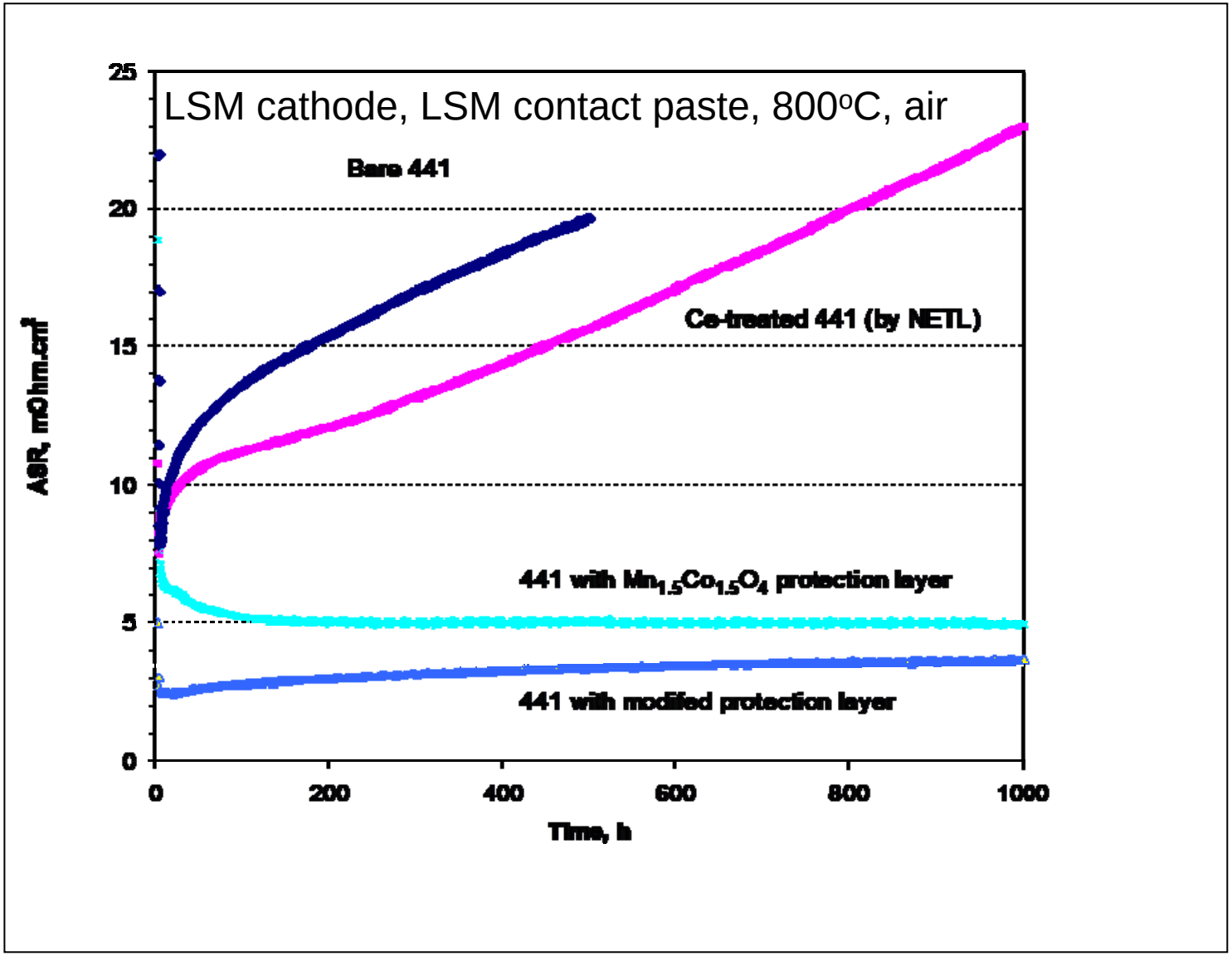
	Failure Analysis	▪ Combined Phenomenological Models with Electrochemistry
		▪ Structural failure Analysis & Design Criteria
		  ▪ Maximum Cell Size
		  ▪ Maximum Thermal Gradients
		  ▪ Transient Operating Conditions
		▪ Pressure Effects

	Anode / Coal Contaminants	▪ Catalyst Surface Modification ▪ Characterize Thermodynamics/Kinetics/ Contaminants ▪ Multi-component Catalysts ▪ Pressure Effects

	Power Electronics	▪ Improve Efficiency
		  ▪ Reduce Cooling Requirement
		  ▪ Optimize Topology

	High Temperature Heat Exchangers/ High Temperature Blowers/Compressors	▪ Enable High Efficiency
		  ▪ Reduce Stack Cooling Requirement
		  ▪ Recover High Quality Heat
		▪ Reliability of Components

Electrical Performance of Surface-Treated 441



SECA Fuel Cells in DOD Applications

- **DOD Requirements**
  - Extend mission length
  - Quiet
  - Combined functions – power, heat and water
  - ***Volume and weight***
    - Operate with High Specific Energy Fuels – Liquids
- **DOE's power density targets (based on cost) minimize stack size and volume to diminishing returns.**
- **Further size and weight improvements – Focus on the Balance of Plant.**

Anil Virkar
2007 National Academy of Engineering

Anil Virkar was elected a member of the National Academy of Engineering on February 9, 2007, for his contributions to the development of high-temperature ionic and electronic materials for fuel cells and batteries. Election to the National Academy of Engineering is among the highest of professional distinctions with a U.S. membership of 2,217

Dr. Virkar is the Distinguished Professor and Chair of the Department of Materials Science & Engineering at the University of Utah, the Vice President of Materials and Systems Research, Inc. (MSRI), and a board member of Versa Power Systems (VPS)

Nguyen Minh
2007 Francis T. Bacon Medal

Nguyen Minh is the recipient of the 2nd Francis T. Bacon Medal presented at the 5th Annual International Conference on Fuel Cell Science, Engineering and Technology held this past June in New York City. The medal is awarded for "outstanding contributions to the technological achievements and commercialization of fuel cell systems".

Dr. Minh is shown shaking hands with Mr. Edward Bacon, F. T. Bacon's son; he lives in London and he and his wife came to New York to present the medal. (photo courtesy ASME)

The medal is preesented by ASME and named after Francis T. Bacon inventor of the Bacon cell. Pratt & Whitney licensed his work for the Apollo spacecraft.

Subhash Singhal
2007 Fuel Cell Seminar & Exposition Award

The Fuel Cell Seminar & Exposition honored Mr. John Trocciola and **Dr. Subhash Singhal** with the 2007 Fuel Cell Seminar & Exposition Award. This award is given annually to those who have achieved outstanding leadership and innovation in the promotion of and overall advancement of fuel cell technology.

New Solicitation
SECA Coal-Based Systems

- **Draft released for public comment Monday, August 6, 2007.**
  - **DE-PS26-07NT43136-DRAFT**
  - **https://e-center.doe.gov/**
  - **Closes August 20, 2007.**

- **Formal release scheduled for August 27, 2007, with an application due date of October 2, 2007.**
  - **December 31, 2007 award date.**
  - **1-2 awards.**

- **Same structure and objectives as existing Coal-Based Systems projects.**
  - **Phase I: 12/07 - 9/08, $12.5MM DOE**
  - **Phase II: 10/08 - 9/10, $30MM DOE**
  - **Phase III: 10/10 - 10/15, $33MM DOE**

SECA Coal-Based Systems Minimum Requirements

	Phase I	Phase II	Phase III
Baseline System Efficiency (>100MWe IGFC, calculated)	40%	45-50%	45-50%
Cost (2002 $)	$600/kW	$400/kW	$400/kW
Deliverable	Scaled Stack	Module	POC
Deliverable Size	>10-15kW	250 – 1000 kW	~5 MW
Steady-State Test	5000 hr	5000 hr	>25,000 hr
SS Degradation	4%/khr	2%/khr	0.2%/khr
Fuel	Composite	Composite	Coal Syngas

For More Information About the DOE Office of Fossil Energy Fuel Cell Program

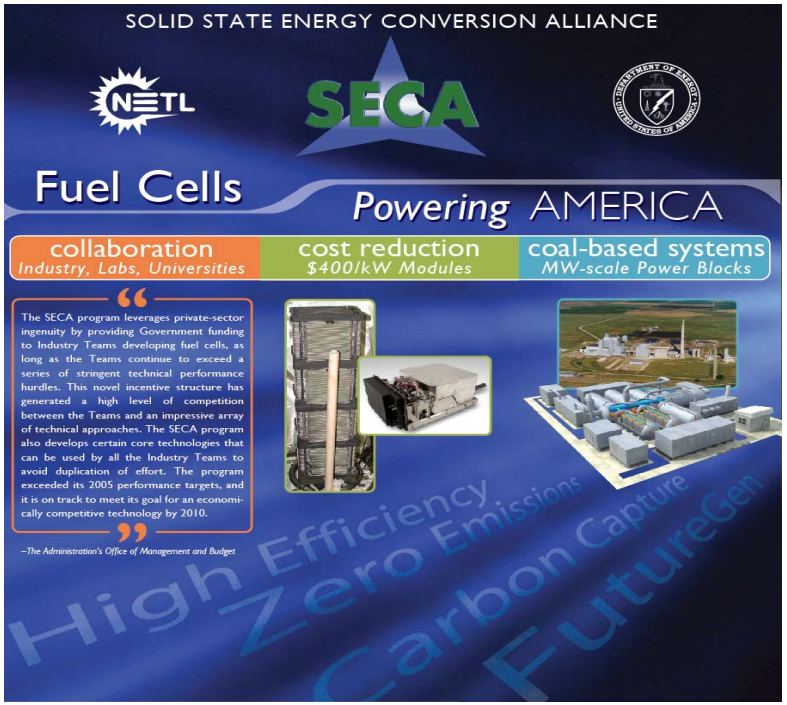
- **NETL website:**
  - –www.netl.doe.gov

Reference Shelf

CDs available from the website

- **FE Fuel Cell Program Annual Report _2007**
- **8th Annual SECA Workshop Proceedings (Coming Soon)**
- **Fuel Cell Handbook (7th ed.)**

- **Office of Fossil Energy website:**
  - –ww.fe.doe.gov
- **FutureGen Alliance website:**
  - – www.futuregenalliance.org



Wayne A. Surdoval
Technology Manager, Fuel Cells
National Energy Technology Laboratory
U. S. Department of Energy
(Tel) 412 386-6002
(Fax) 412 386-4516
wayne.surdoval@netl.doe.gov