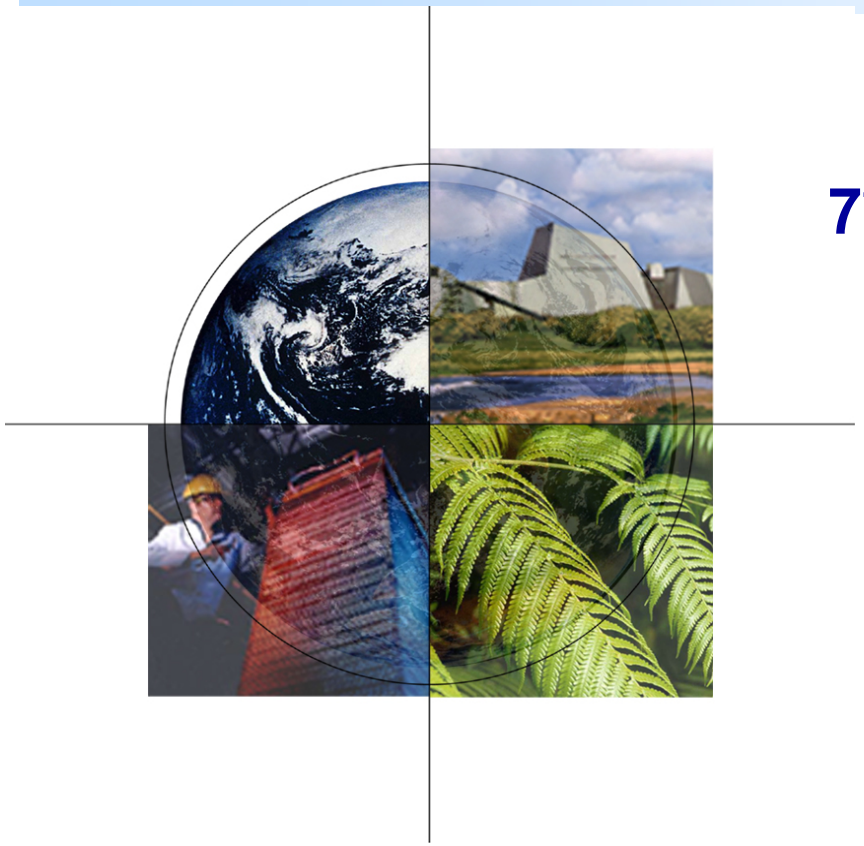
U.S. DOE Fossil Energy Fuel Cell Program



7th SECA PUBLIC WORKSHOP & PEER REVIEW

12September06

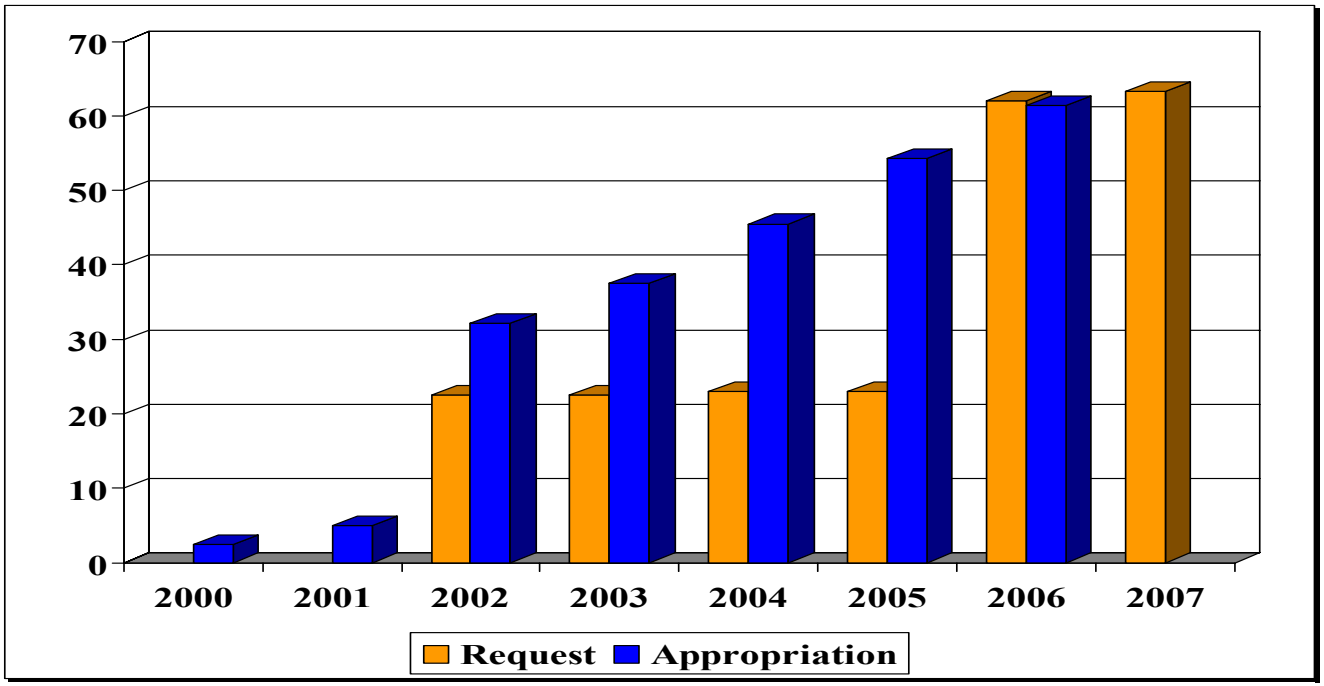
Philadelphia, PA

Wayne A. Surdoval, SECA Coordinator
National Energy Technology Laboratory
U. S. Department of Energy

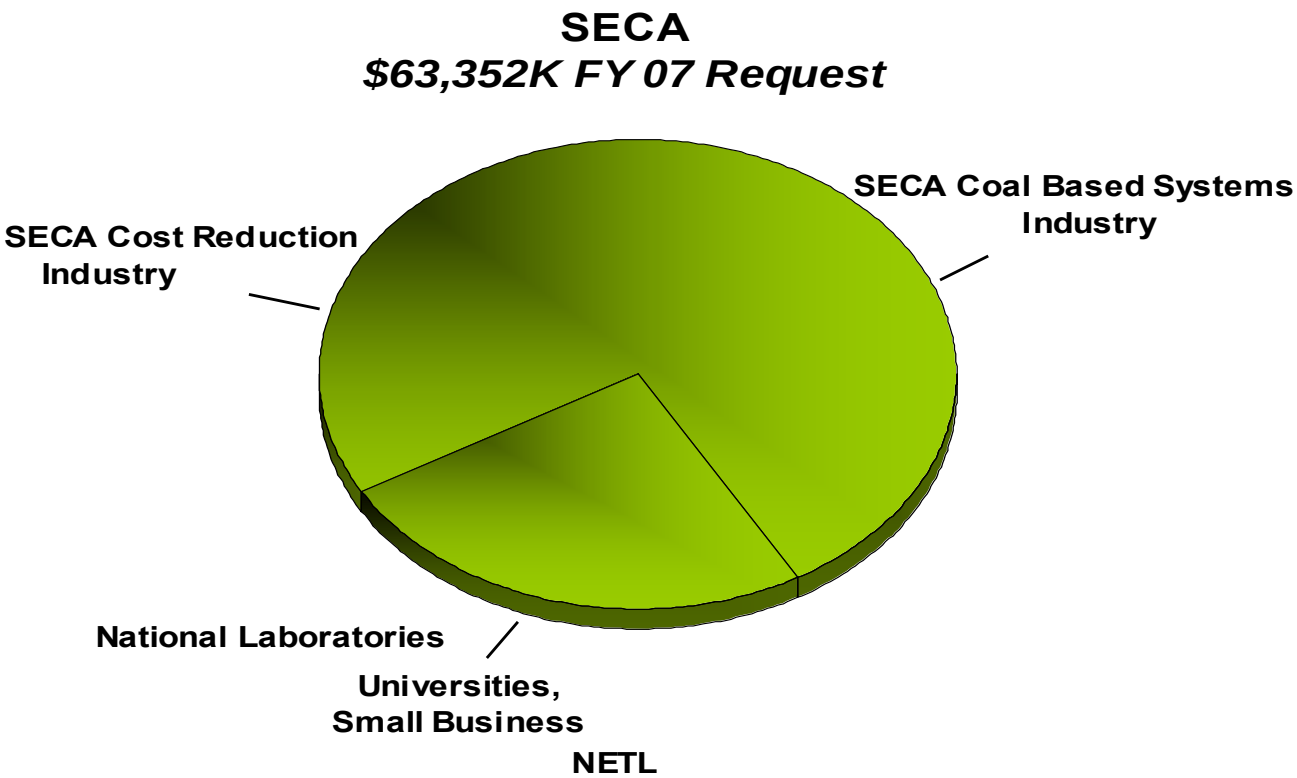
Office of Management and Budget citation
Solid State Energy Conversion Alliance
(President's FY 07 Budget)

"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."

SECA Historical Budget

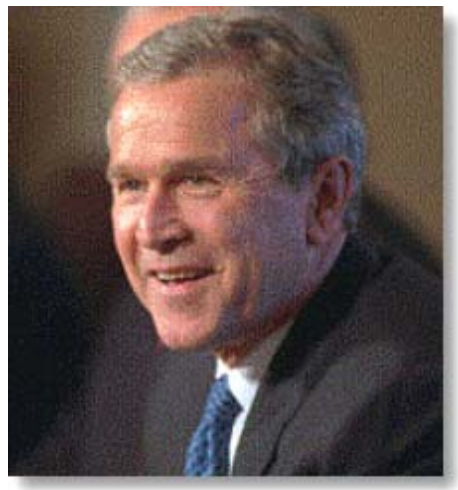


SECA FY 07 Budget Request



FutureGen
The Energy Plant of the Future

Statement by the President
February 27, 2003



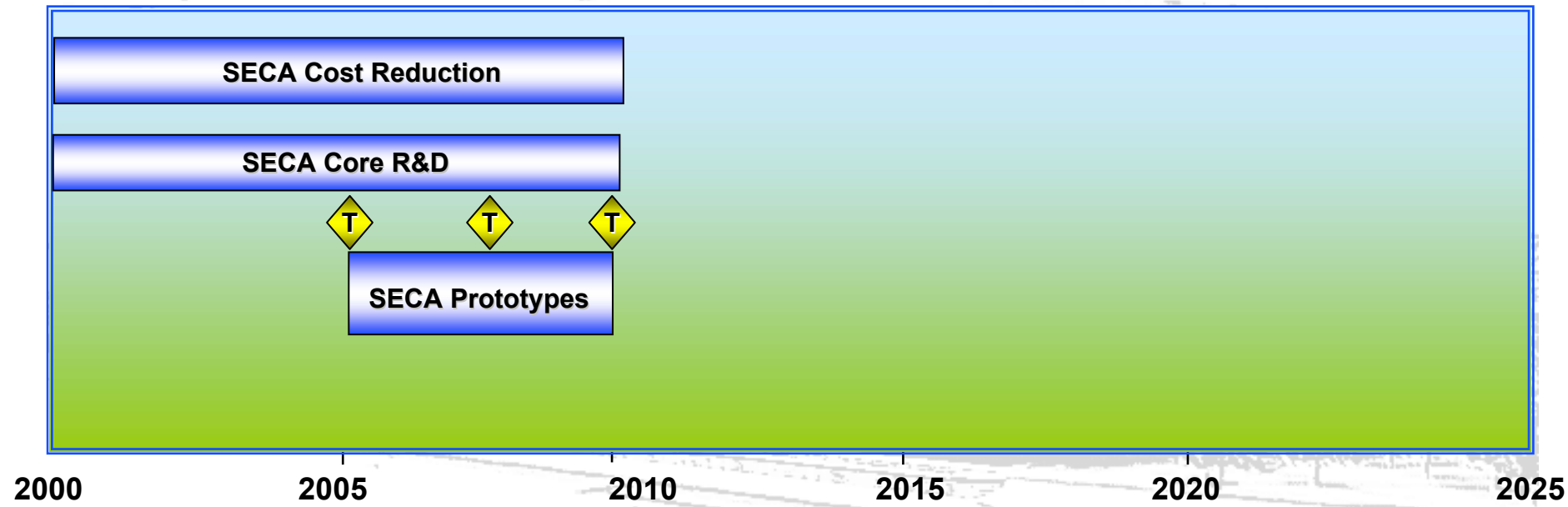
"Today I am pleased to announce that the United States will sponsor a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant . . . ."

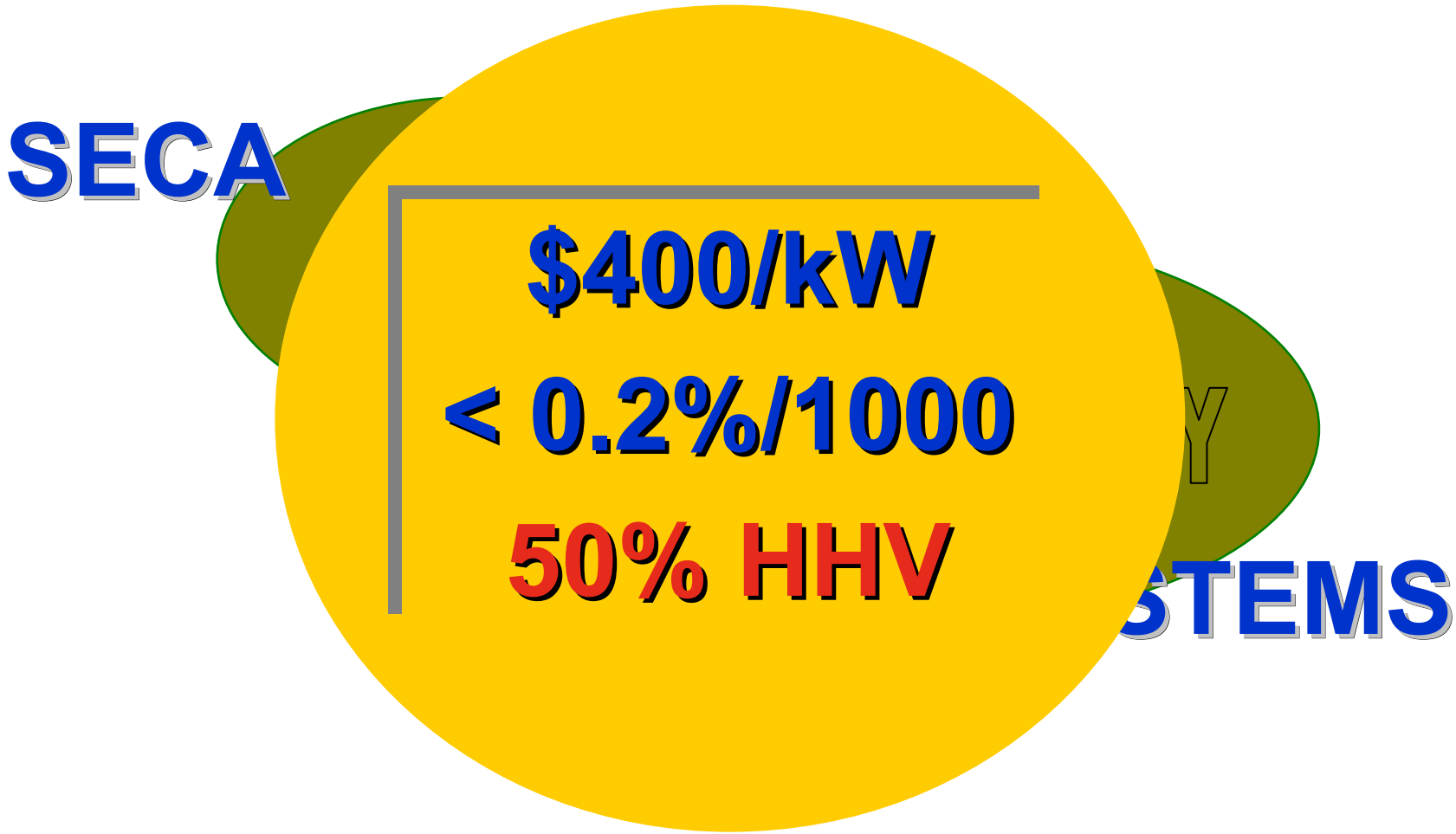
DOE Clean Coal Technology Roadmap

DOE Clean Coal Technology Roadmap - Performance Targets			
Parameter ↓	**Reference Plant**	**2010**	**2020**
Plant Efficiency (HHV)	**40%**	**45-50%**	**50-60%**
Availability	**>80%**	**>85%**	**>90%**
Plant Capital Cost ($/kW)	**1000-1300**	**900-1000**	**800-900**
Cost of Electricity (¢/kWh)	**3.5**	**3.0-3.2**	**<3.0**
Air Emissions	**98% SO_2 removal**	**99%**	**>99%**
	0.15 lb/10^6 Btu NO_x	**0.05 lb/10^6 Btu**	**<0.01 lb/10^6 Btu**
	0.01 lb/10^6 Btu Particulate Matter	**0.005 lb/10^6 Btu**	**0.002 lb/10^6 Btu**
	Mercury (Hg)	**90% removal**	**95% removal**

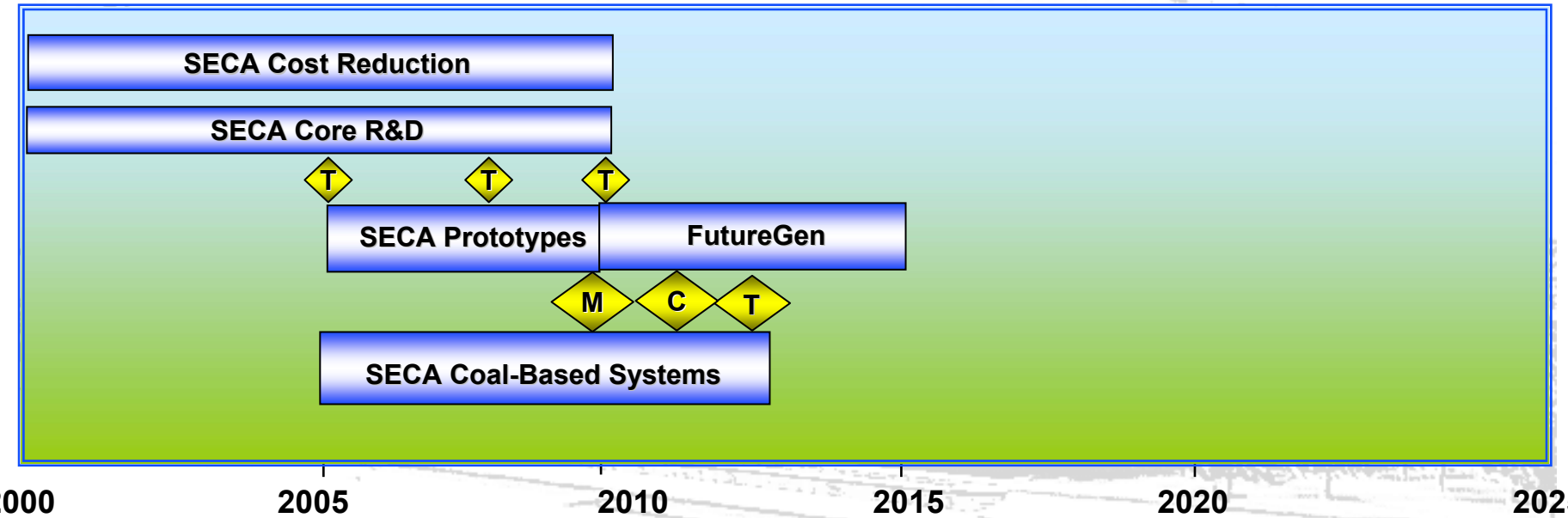

$40/kW
SECA

SECA Timeline




SECA
$400/kW
< 0.2%/1000
50% HHV
STEMS

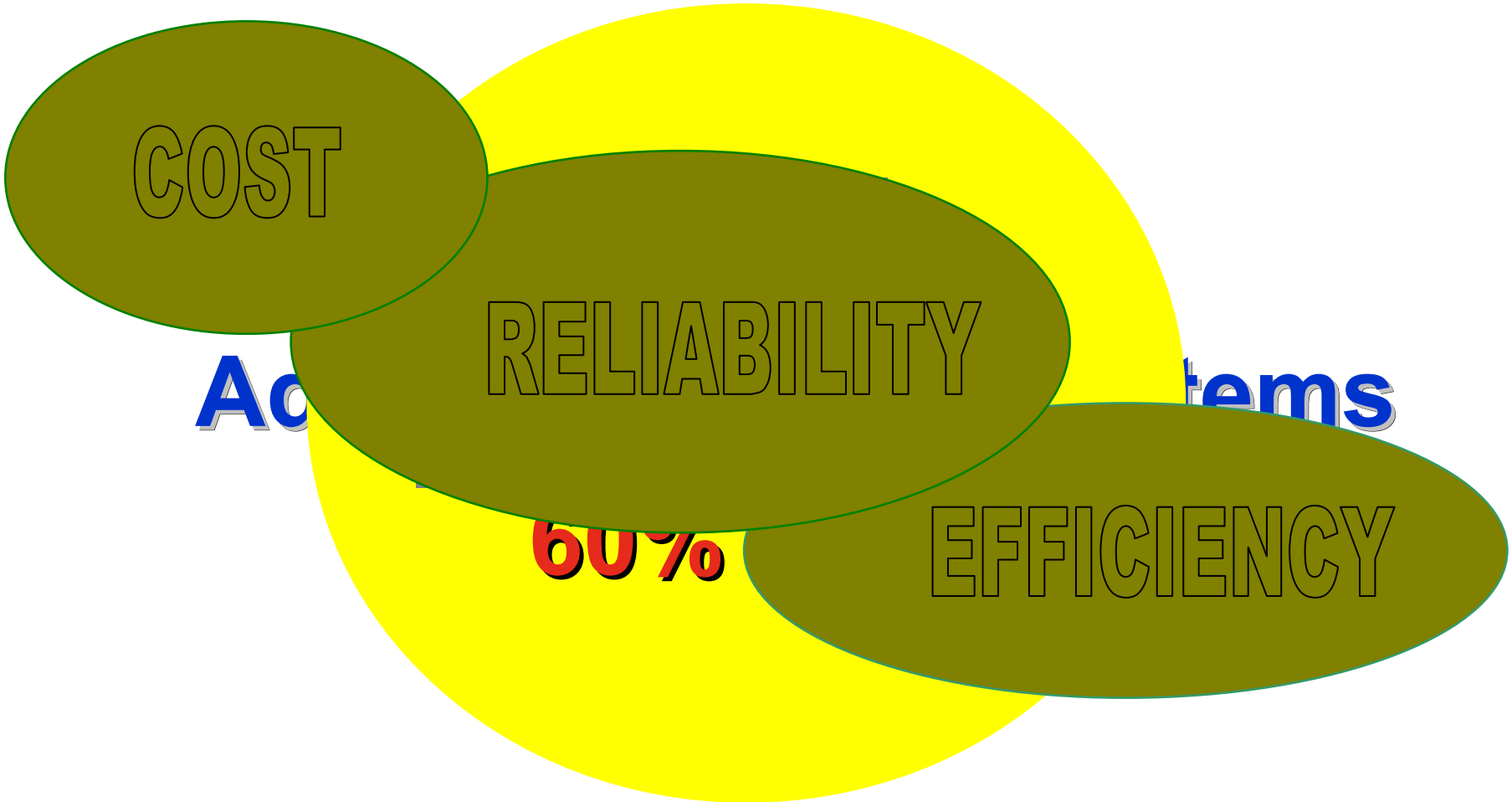
SECA Timeline



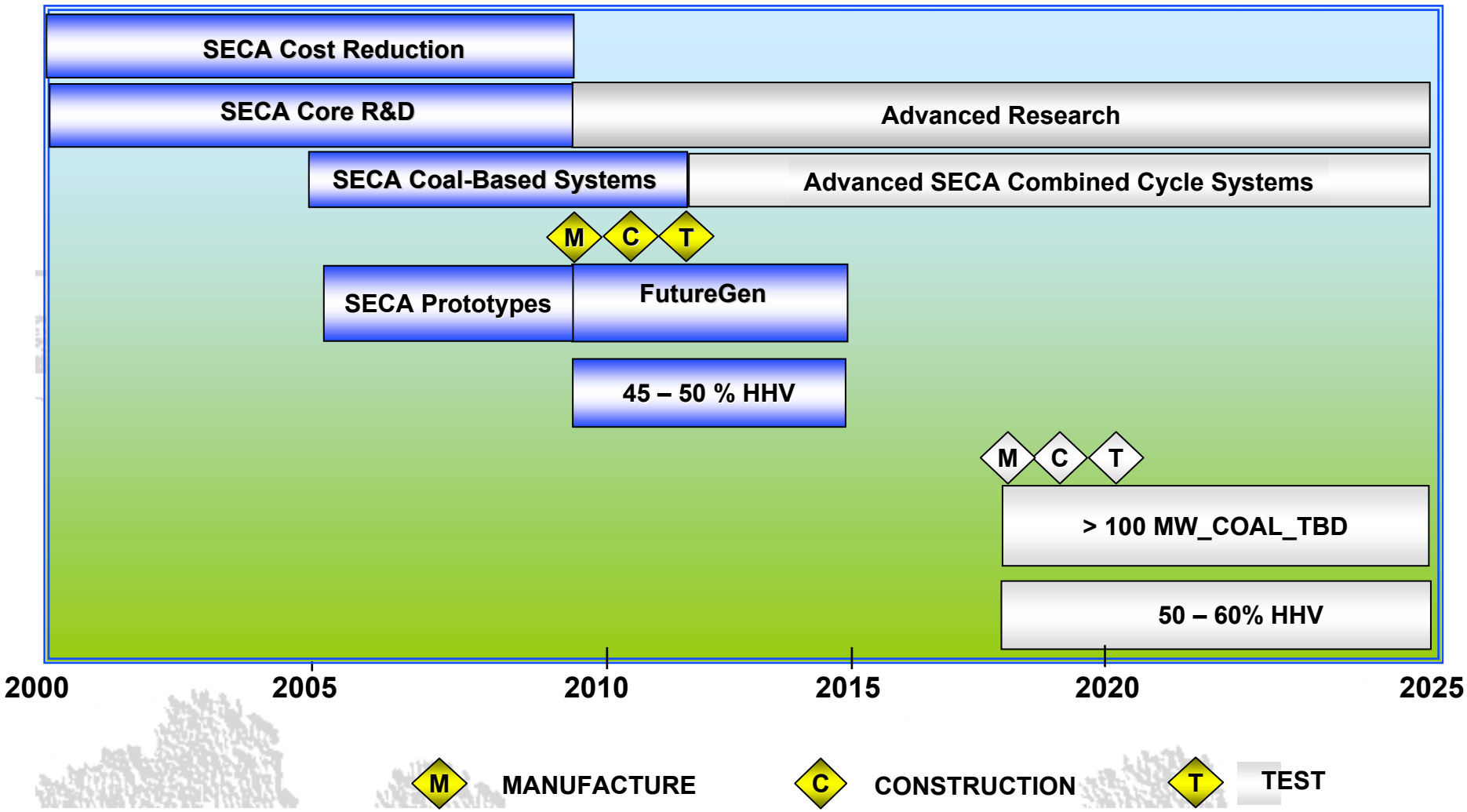
M MANUFACTURE

C CONSTRUCTION

T TEST


COST
RELIABILITY
EFFICIENCY
60%

SECA Timeline



Solid State Energy Conversion Alliance SECA: Making Fuels Cells a Reality

2005 & 2008

1st & 2nd Cost Reduction Prototypes

- R&D, Test & Evaluation
- Initiate Manufacture, 50MW

2010

$400/kW Modules

- Central Power
- Spin-off Applications
  - Residential, Commercial, Industrial CHP
  - DOD, Transportation APUs

2011 - 2015

- **FutureGen**
  - Deliver 10 - 50 MW

2020

- **Advanced SECA Combined Cycle Systems**
  - >100MW with SECA Power Block

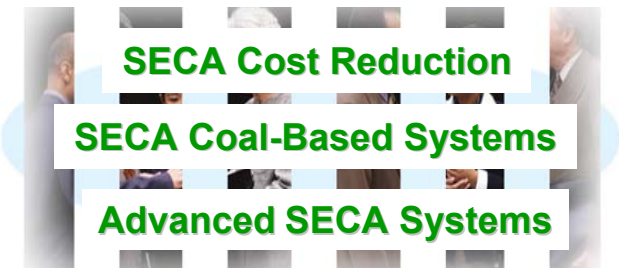
NETL

SECA Program Structure

Project Management

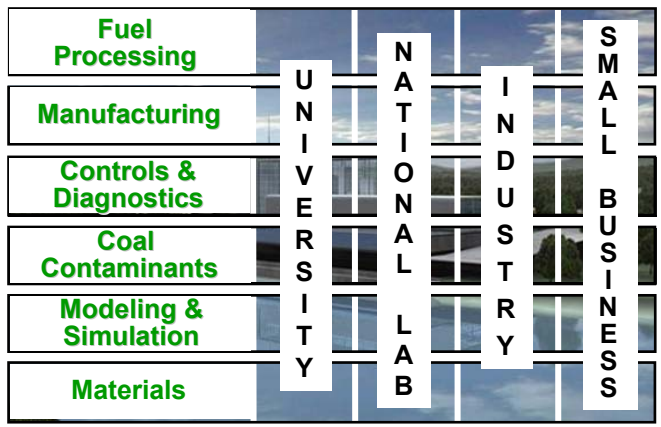
Needs

Research Topics



Industry Teams

Technology Transfer



Core Technology Program

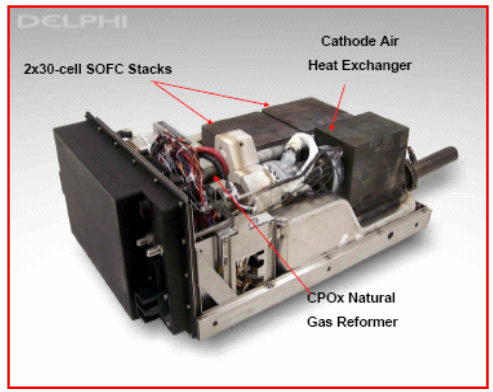
GE Completes SECA Phase I
Phase II Underway

General Electric	$746/kW
	38% LHV- AC

Delphi Completes SECA Phase I
Phase II Underway

Delphi	$761/kW
	37% LHV- DC

Schedule for SECA Industry Teams
Phase I Prototype Testing



Industry Team	Place of Event	Milestone Date	NETL Validation
General Electric	Torrance, CA	Complete	4Q 2006
Delphi	Rochester, NY	Complete	Complete
Fuel Cell Energy	Calgary	Complete	In-Test
Acumentrics	Westwood, MA	3Q 2006	4Q 2006
Siemens Power Group	Pittsburgh, PA	3Q 2006	1Q 2007
Cummins Power Gen.	Minneapolis, MN	4Q 2006	1Q 2007

Current Priorities:
SECA Core Technology Program

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

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

2	Interconnect	▪ Coatings ▪ Electrode to Interconnect Interface Contact Material ▪ Inexpensive Processing/Removal of Tramp Elements
2	Anode / fuel processing	▪ Catalyst Surface Modification ▪ Characterize Thermodynamics/Kinetics/ Contaminants ▪ Multi-component Catalysts
2	Heat Exchangers/ High Temperature Blowers	▪ Cost and Reliability ▪ Design Guidelines

NETL

Fuel Cell Coal-Based Systems Requirements

END DATE	FY2008	FY2010	FY2015
Fuel	Coal-Derived Hydrogen or Syngas		
Cost	-	$400/kW	
Efficiency	50% HHV /IGCC PLANT		
Validation Test (Hours)	1500	1500	> 25,000
Degradation (/1000 hrs)	≤ 4.0%	≤ 2.0%	≤ 0.2%

FE Fuel Cell Program Strategy: SECA → Fuel Cell Coal-Based Systems

Fuel cell technology demonstrated at FutureGen before use in large-scale Central Power Systems

- **Cost reduction through mass customization**
  - High-volume
  - Establish manufacturing and materials base
- **Scale-up to MW-class – SECA fuel cell technology**
  - Pressurization
  - Integration
  - Cycle Studies (Cost-Reliability-Efficiency)
  - Contaminants
- **Apply fuel cell-based designs to >100-MW class Fuel Cell Coal-Based Systems**
  - FutureGen
  - Advanced SECA Combined Cycle Systems

Current Priorities:
SECA Coal Based Systems
Research Priorities

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

Cathode performance	▪ Increase Permissible Thermal Gradient in Cell
	  ▪ Improve Performance for Cost Reduction
	  ▪ Increase Thermal Operating Window
	▪ Pressure Affects

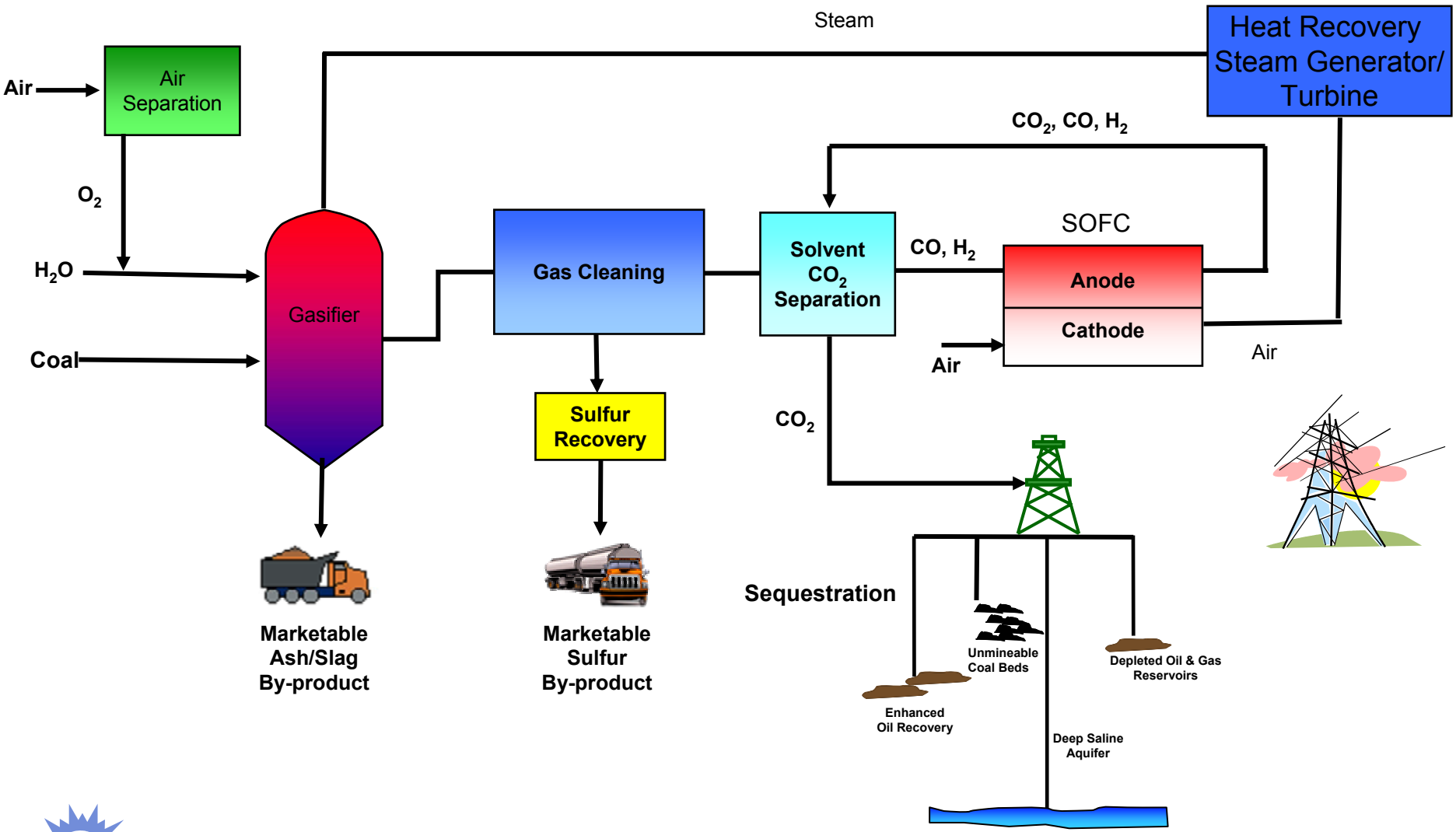
Anode / Coal Contaminants	▪ Catalyst Surface Modification ▪ Characterize Thermodynamics/Kinetics/ Contaminants ▪ Multi-component Catalysts ▪ Pressure Affects

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

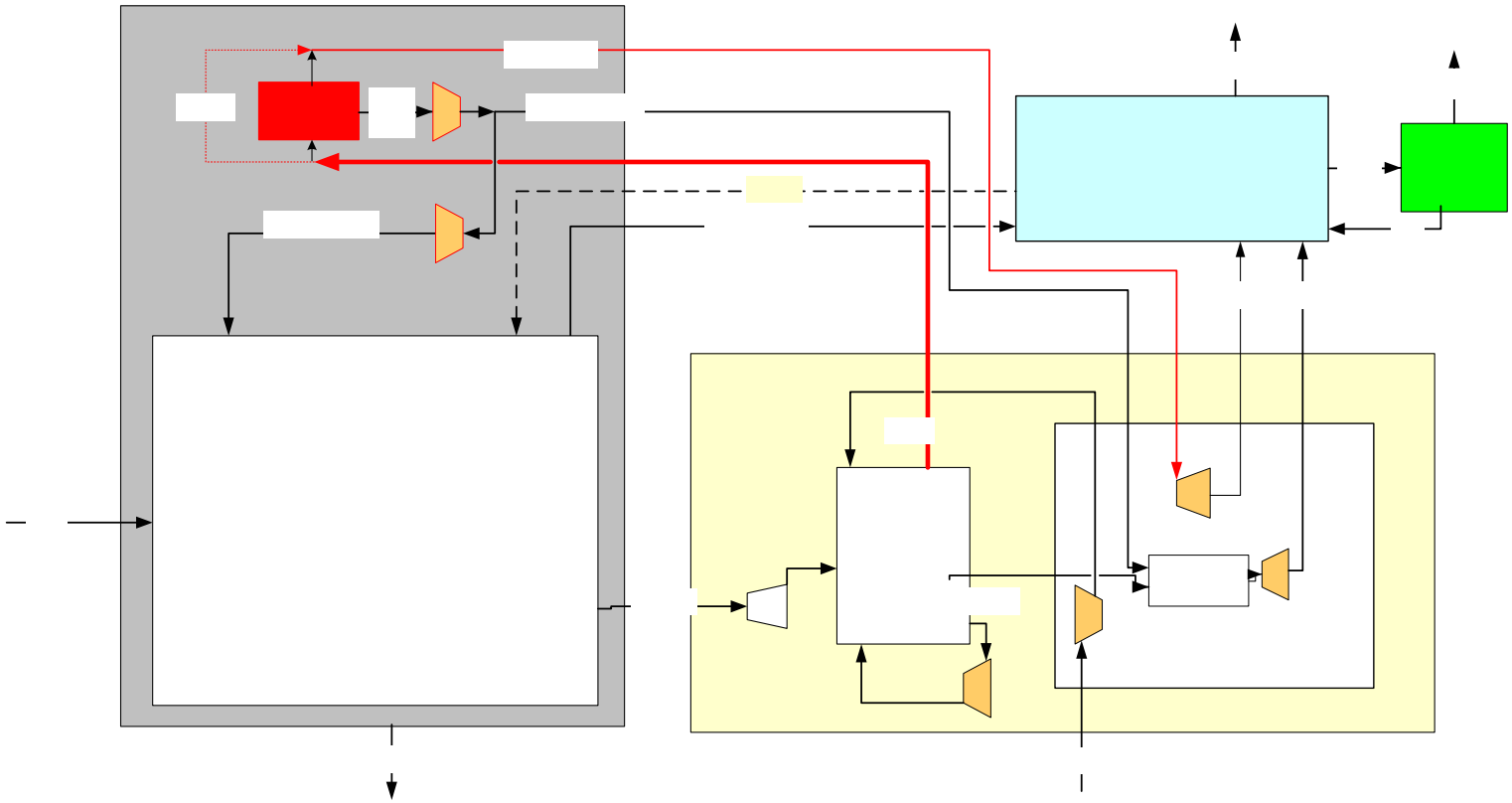
High Temperature Heat Exchangers/ High Temperature Blowers	▪ Enable High Efficiency
	  ▪ Reduce Stack Cooling Requirement
	  ▪ Recover High Quality Heat
	▪ Reliability of Components

NETL

SECA Coal Based Systems

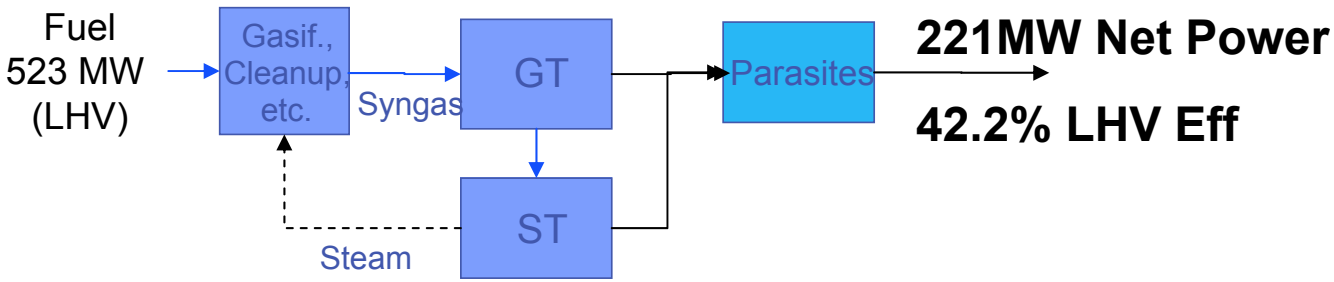


Advanced SECA Systems

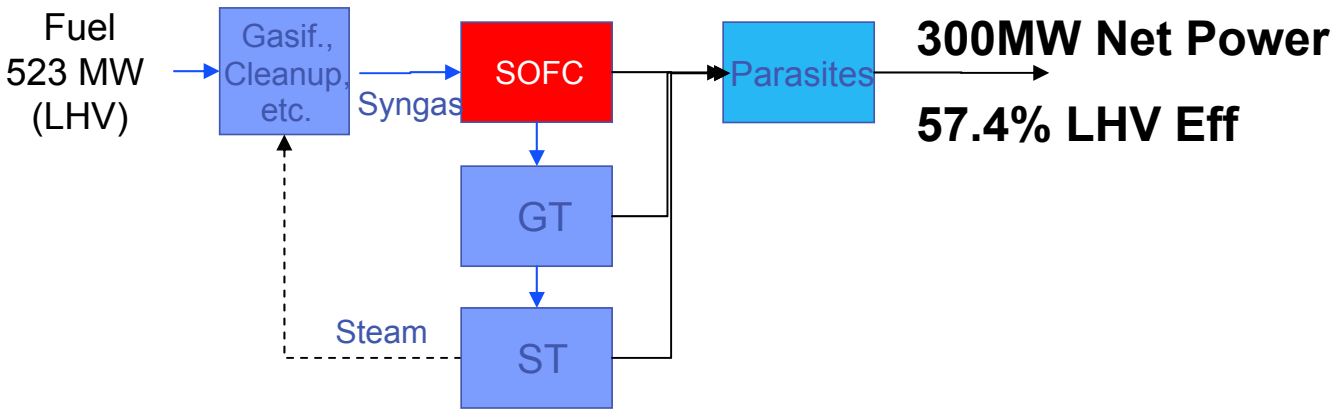


Coal Fueled SOFC

IGCC (BGL)



IGFC (BGL)



Power output improved by ~35% over IGCC…
Potential for 10% improvement in CoE

Based on GE Study

Fuel Cell Energy DFC/T

Close-up View of Alpha Unit at Montana Test Site

- **Continued operation at host site > 3200 hours as of 8/31/2006**
- **Achieved availability of >77%**
- **DFC/T has achieved a net efficiency of 56%**

Billings Clinic, Billings, MT

States with University Fuel Cell Centers Supporting SOFC Manufacturing

- **Michigan - Kettering University**
  - Center for Fuel Cell Systems & Powertrain Integration

- **Colorado – Colorado School of Mines**
  - Colorado Fuel Cell Center

- **Ohio – Stark State College of Technology**
  - Fuel Cell Prototyping Center

NETL

DOD and SECA

- **DOD**
  - Extend mission length
  - Quiet
  - Combined functions – power, heat and water
  - ***Volume and weight***
    - Operate with High Specific Energy Fuels – Liquids
- **SECA power density targets (based on cost) minimize stack size and volume to diminishing returns.**
- **Further size and weight improvement – BOP**
- ***SECA WILL PROVIDE STACK TECHNOLOGY***

Additional Information

CDs available from the website

- **FE Fuel Cell Program Annual Report 2006**
- **Annual SECA Workshop Proceedings 2006**
- **Fuel Cell Handbook (7th ed.)**

Reference Shelf

www.netl.doe.gov/technologies/coalpower/distgen

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