



Advanced Energy Systems H₂ Turbine Program

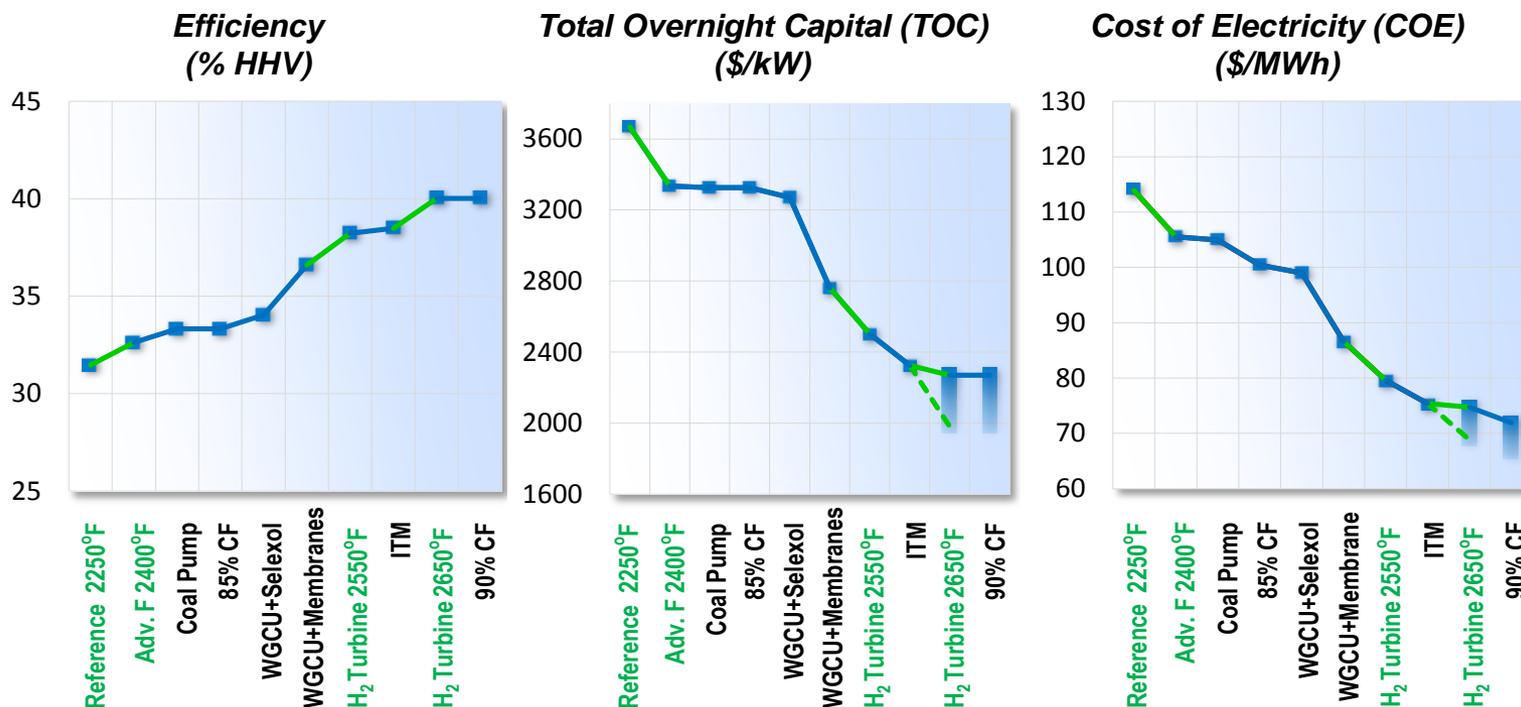
Richard A. Dennis
Turbine Technology Manager

Presentation Outline

FE Hydrogen Turbine Program

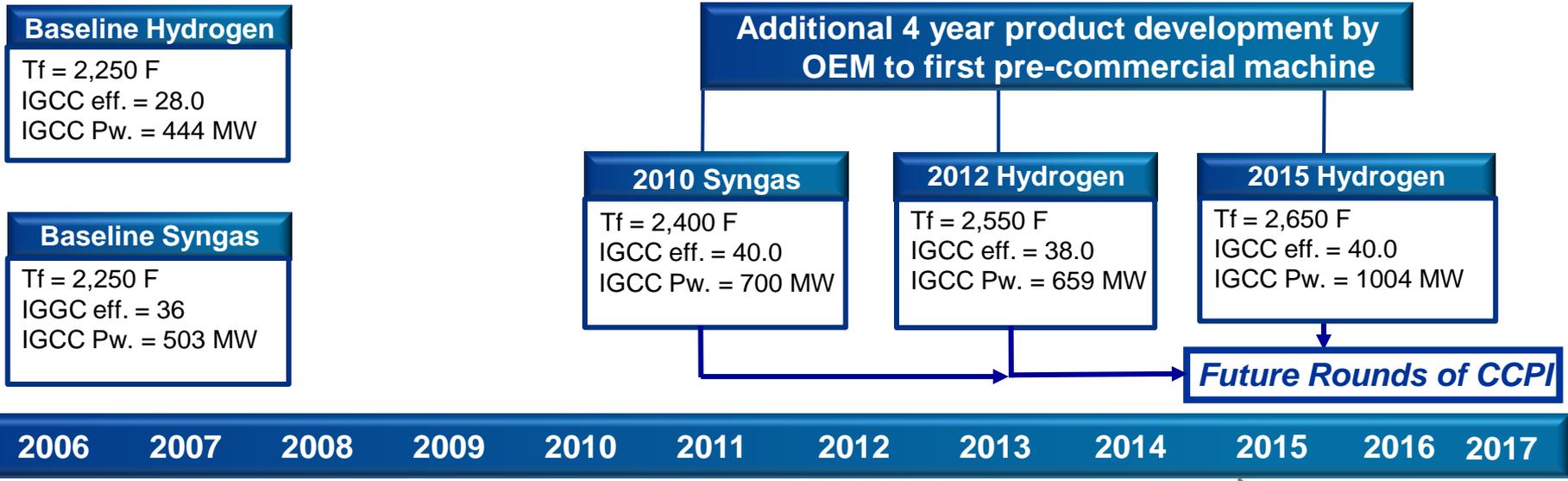
- **H₂ Turbine Projects**
- **UTSR Status**
- **H₂ Turbine Advanced Research**
- **Summary**

Expected Results from Advanced H₂ Turbine Provides the Largest Performance Benefit to IGCC w/CCS



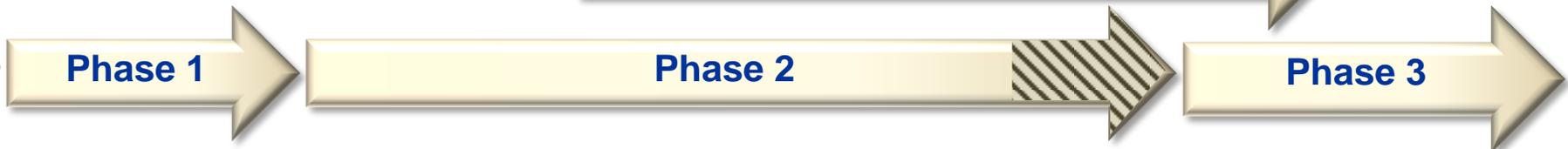
- 4.3 % points improvement in IGCC efficiency from reference case (1.2, 1.6, 1.5)
- Higher power and efficiency results in lower capital costs ~ \$645/kW
- Cost of electricity (COE) is reduced by \$16 per MWh (~15%)
- With a two-train plant (2 GT with one steam turbine) at a capacity of ~1 GW, results in \$285/kW additional decrease in TOC and 8% additional reduction in COE

Timeline for H₂ Turbine Development



H₂ Turbine Projects

ARRA



- Concept and Product Development Plan**
- Conceptual design studies
 - Go / No go lab testing
 - Systems studies

- Technology Development and Validation**
- System studies
 - Lab scale testing
 - Bench / pilot scale testing
 - Component design and testing

 **Expected no-cost time extension**

- Design, Manufacturing and Testing of Pre-Commercial prototype (Not Awarded)**
- Final component testing
 - Detailed design
 - Fabrication and assembly of machine
 - Pre-commercial testing

H₂ Turbine Program ARRA Projects

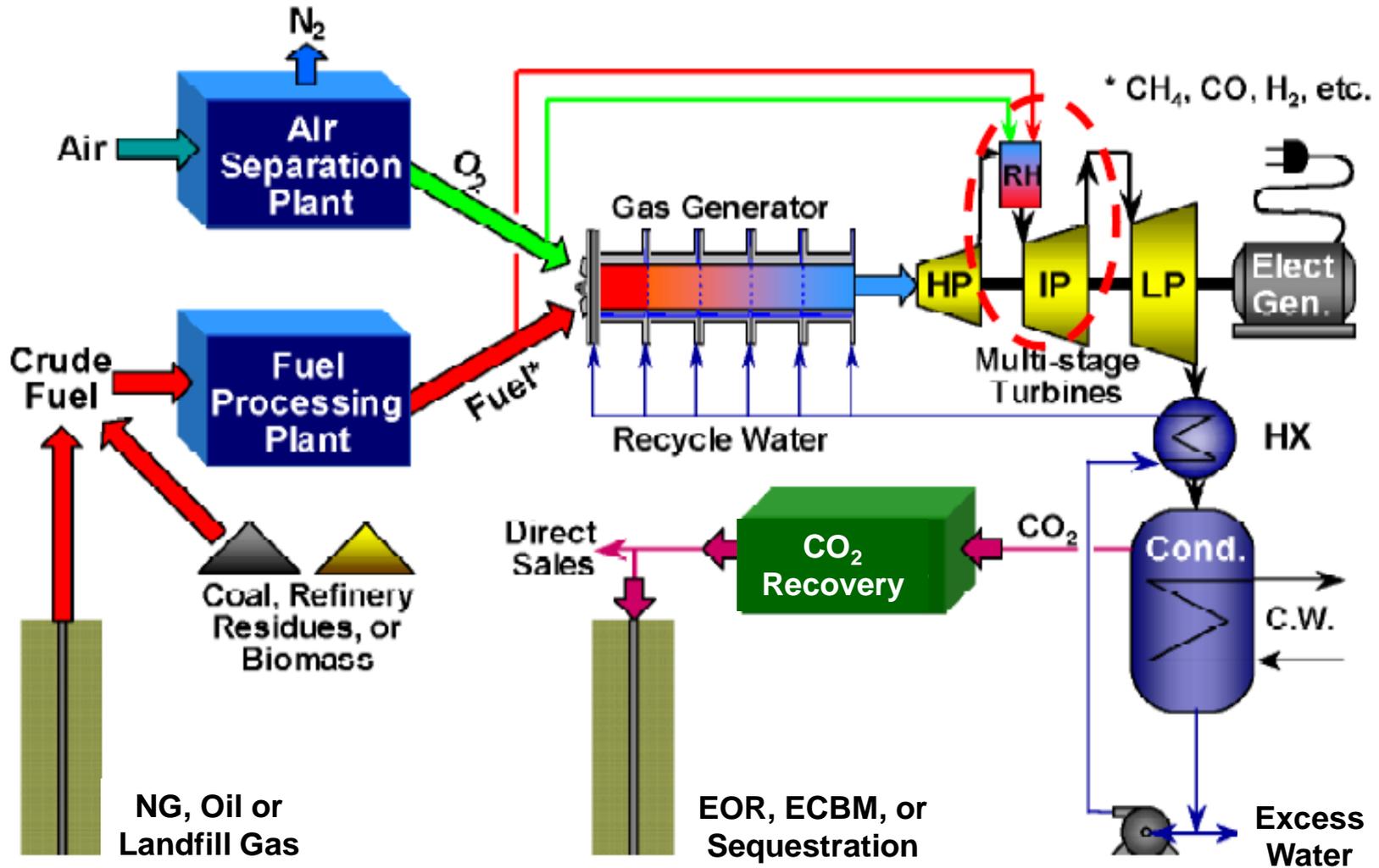
ARRA Funding Accelerates Base Program R&D

- **Scope of ARRA w/r FE turbine program**
 - Significant resources invested in turbo machinery
 - FE R&D ARRA funds must be expended by 9/30/15
- **H₂ Turbine for Industrial Applications with GE and Siemens**
 - Develop industrial-frame technology for H₂ fueled turbines
 - Leveraging synergies with Base projects
- **Oxy-fuel Turbine for Industrial Applications**
 - **CES** - Demonstrate an IP-OFT w/ oxy-fuel reheat combustor
- **SBIR Turbine Related ARRA Projects**
 - Mikro Systems Phase III Xlerator:
 - Physical Sciences Inc. Phase II



H₂ Turbine Program ARRA Projects

Clean Energy Systems



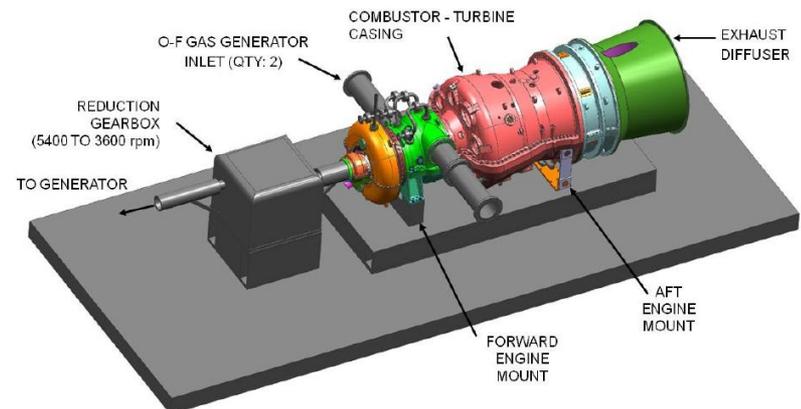
H₂ Turbine Program ARRA Projects

Clean Energy Systems

- **CES is expanding a prior project to develop an industrial-scale intermediate-pressure oxy-fuel turbine (IP-OFT)**
- **Objectives**
 - Procure used Siemens turbine
 - Design, fabricate, and install oxy-fuel modifications
 - Test site preparation
 - Test execution



Siemens SGT-900



University Turbines Systems Research

Salient Features of the Program

- **Overview**

- Projects established through annual competitive solicitation
- Topics established by FE goals and GT Industry needs

- **UTSR Projects Topic Areas**

- Combustion
- Aero-Heat Transfer
- Materials

- **UTSR Industry Committee**

- **Gas Turbine Industry Fellowship**

- **UTSR Academic Committee**



UTSR Solicitation Statistics

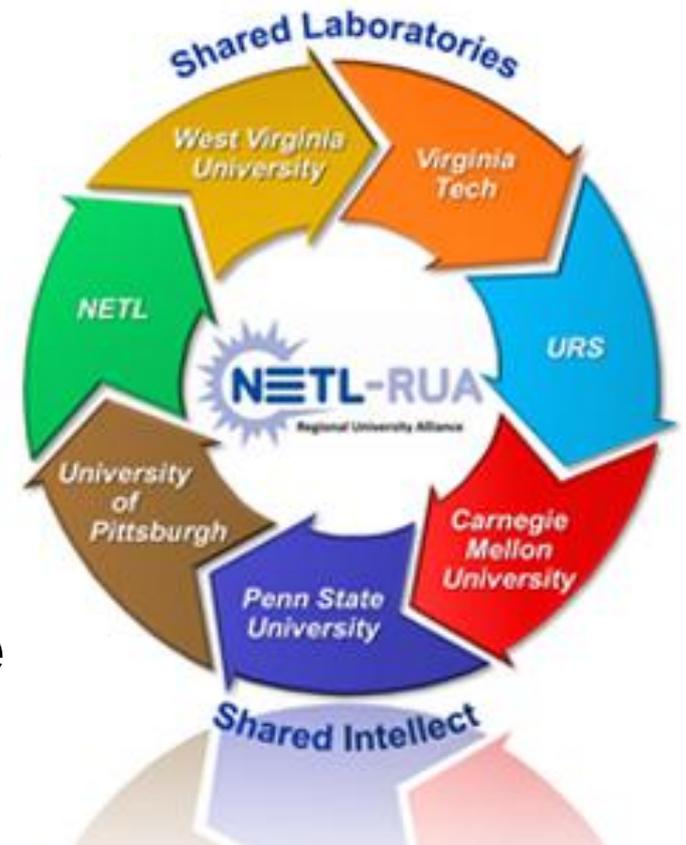
Proposals and Awards by Topic Area 2009 - 11

	FY09	FY10	FY11
Total Proposals	23	40	34
Total Awards	3	9	10
Combustion			
Proposals	6	16	13
Awards	1	2	5
Aerodynamics/Heat Transfer			
Proposals	7	12	11
Awards	1	2	1
Materials			
Proposals	10	12	10
Awards	1	3	4
TOTAL	\$1,501,123	\$3,312,215	\$4,702,891

NETL-RUA

Regional University Alliance

- **Combines NETL's fossil energy expertise with the capabilities of 5 regional universities**
- **Leverages facilities, specialty equipment, and professional staff**
- **Accelerates the development and deployment of innovative energy and environmental technology**



Hydrogen Turbine NETL-RUA Tasks

Focus on Advanced Materials / Cooling for Higher Temperature Operation

FY 2012 Tasks

- **Aero thermal and HX** - Identify internal/external cooling concepts for reduced cooling flow
- **Materials Development** – Develop material architectures for high temperature and environmental compatibility
- **Testing** - Bench-scale testing of advanced architectures under realistic conditions
- **Rotating Rig** – Construct a world-class test facility for cooling improvement strategies

Florida Turbine Technologies

SBIR Phase III Leads to Spar-Shell Airfoil Testing

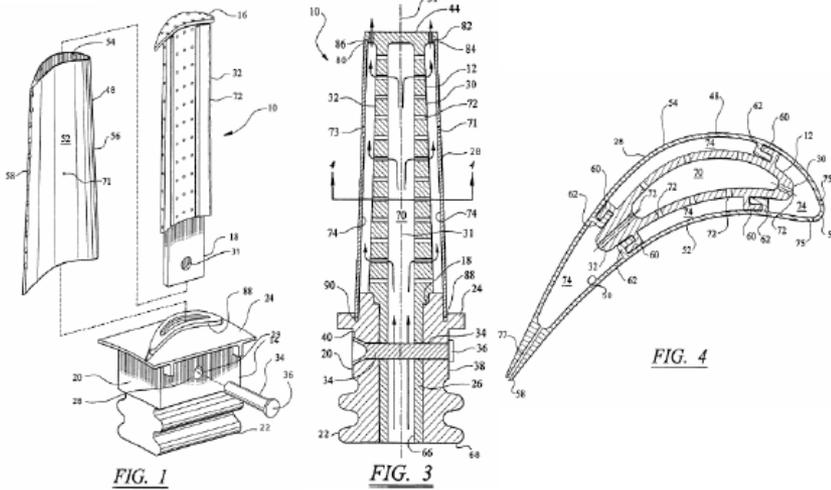


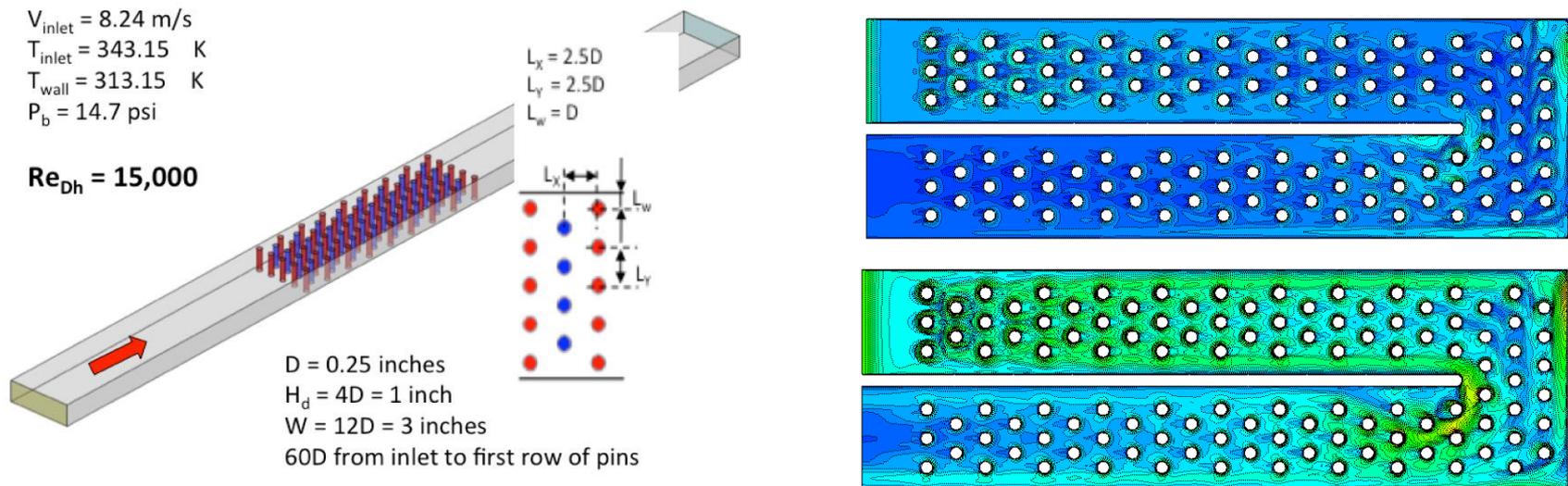
Figure 2: U.S. Patent #7080971
"Cooled Turbine Spar-Shell Blade Construction"



- Spar-shell airfoil is constructed with an internal structural support and an external covering
- Thermal / mechanical isolation enables advanced materials to be independently optimized
- Permits novel cooling approach
- This Phase III SBIR will culminate with 4 to 6 rotating airfoils being test in a full scale F-class turbine

AMES National Lab

- CFD simulations indicate similar Biot yield comparable magnitude and contours for normalized temperature and normalized heat flux
- Enables representative experimental comparison between turbine cooling experiments at near room



Phase III Xlerator: Rapid Commercialization of Advanced Turbine Blades for IGCC Power Plants

Mikro Systems

- **Program Objectives**

- Integrate Mikro's core technology into turbine fleet
- Demonstrate competitiveness of technology
- Certify foundry production readiness of cores
- Engine test qualification (Siemens)
- Obtain a commercial contract for core production

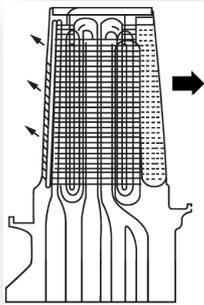


- **Project plan is divided into two main work areas:**

- 501F Row 1 Core Production (100 test blades)
- Core process optimization

Government, Industry, Small Business and National Labs Working A Common Initiative

SBIR Leads to License Agreement for Advanced Airfoil Manufacturing



*Innovative Designs
Siemens (DOE)*

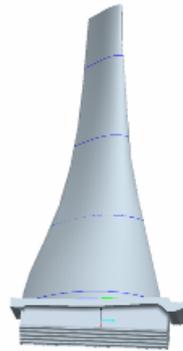
*Innovative Manufacturing
Mikro Systems (DOE & SBIR)*



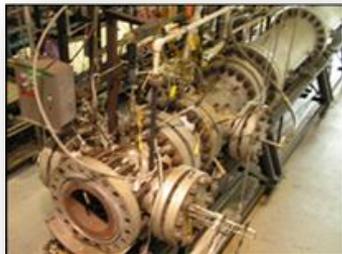
*NDE-GIS/IR Evaluation
Siemens (DOE)*



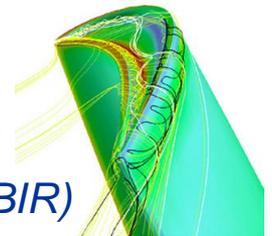
*HTC Model Test
Univ. of Pittsburgh (DOE)*



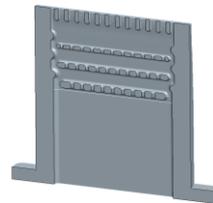
*Hi-Temp/Press Rig Test
DOE-NETL*



*CFD Analysis
Purdue Univ. (DOE & SBIR)*



*Casting Trials
(DOE & Mikro SBIR)*



NETL / EPRI Workshop

SCO₂ Chemical and Physical Property Data Needs

- **Industry, Government, and Academic professionals gathered to discuss needs related to super-critical CO₂**
- **Organizations Presenting**
 - NETL, Sandia National Laboratory, Dresser-Rand, NIST, SwRI, U-Texas, EPRI, CO₂ Global, OLI Systems, Gas Liquids Engineering
- **Topics as applied to chemical and physical property data needs included:**
 - Power cycles
 - EOR
 - Storage
 - CO₂ Transport
 - CO₂ Compression



EPRI

ELECTRIC POWER
RESEARCH INSTITUTE

NETL / EPRI SCO_2 Workshop Outcomes

NIST Tasked to Assess Thermodynamic Properties

- **NIST will measure properties of CO_2 and CO_2 -rich mixtures**
 - Measurement of the Water Dew Point in CO_2
 - Modeling $\text{CO}_2/\text{H}_2\text{O}$ Dew Points
 - Reference-Quality Viscosity Correlation for CO_2
 - Measurement of the Thermal Conductivity of CO_2
 - Reference-Quality Thermal Conductivity Correlation for CO_2

NETL / EPRI SCO_2 Workshop Outcomes

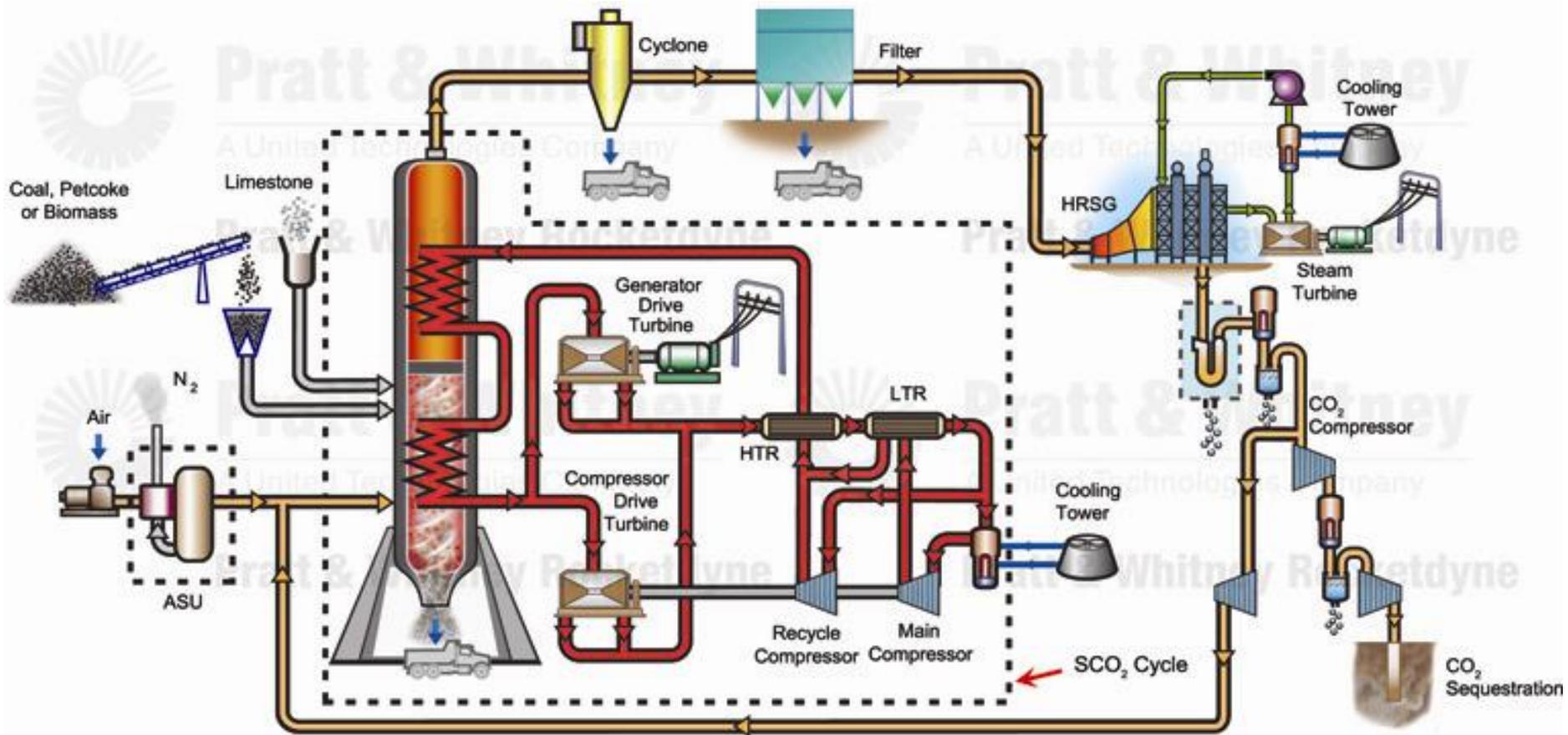
SwRI Tasked to Assess Applied Properties

- **SwRI - Property Measurements and EOS**
 - Applied to Turbomachinery Design to Support CCS and SCO_2 Power Cycles
 - Characterization of Representative Gas Mixtures
 - Compressibility Measurements of CO_2 Gas Mixtures
 - Speed of Sound Measurements
 - Specific Heat Measurements
 - Applicability of CO_2 Gas Mixtures EOS



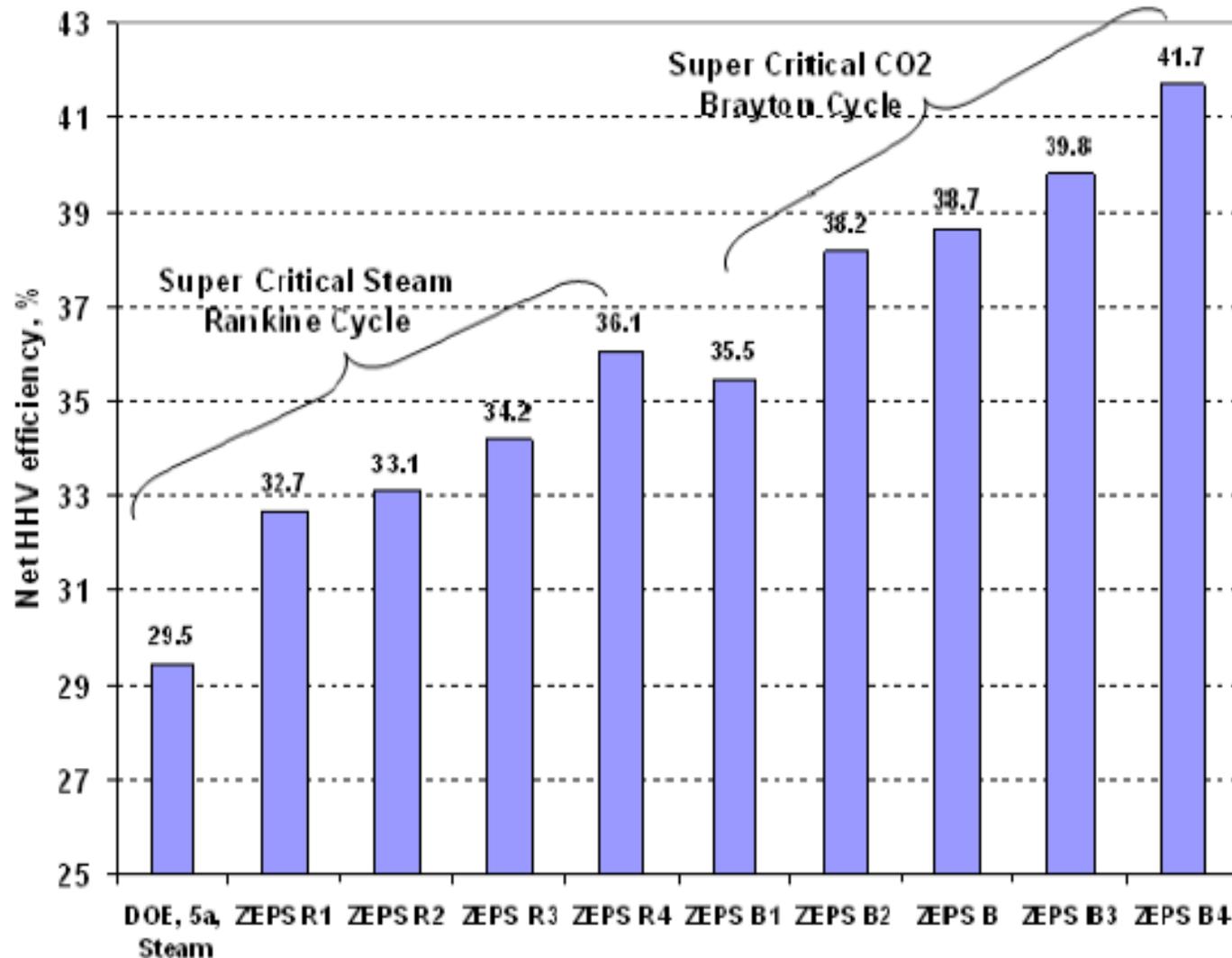
Pratt & Whitney Oxy Fuel PFBC

Oxy Coal Combustion for CCS / SCO_2 Power Cycle for Efficiency



Pratt & Whitney Oxy Fuel PFBC

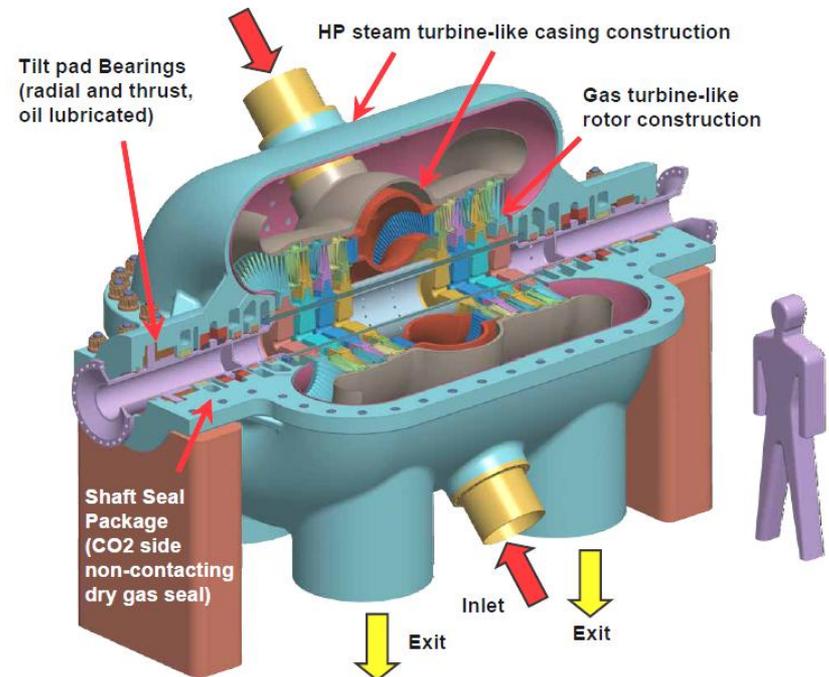
Significant Performance Benefits with a SCO_2 Power Cycle



Supercritical CO₂ Turbomachinery

P&WR Assessing Technology *Development*

- **SCO₂ Brayton cycle for advanced coal power plants**
- **Technology development plan to TRL 6**
- **Technology gaps:**
 - Turbomachinery
 - Heat Exchangers
 - Materials
 - Control Systems



Summary

- **FE H₂ Turbine Program is addressing R&D issues and performance of IGCC w/ CO₂ capture**
 - 4.3 % points improvement in IGCC efficiency
 - Higher power and efficiency results in lower capital costs ~ \$645/kW
 - COE is reduced by 15% (1x1) and 23% (2x1)
- **Ph II technology being demonstrated to realize these performance improvements**
- **UTSR projects providing benefits to turbine OEMs**
- **Working through NL, SBIR and turbine OEMs on initiatives to advance technology**
- **Budget constraints have impacts:**
 - Force Phase II extension
 - Delay consideration of UTSR FOA until FY 2013