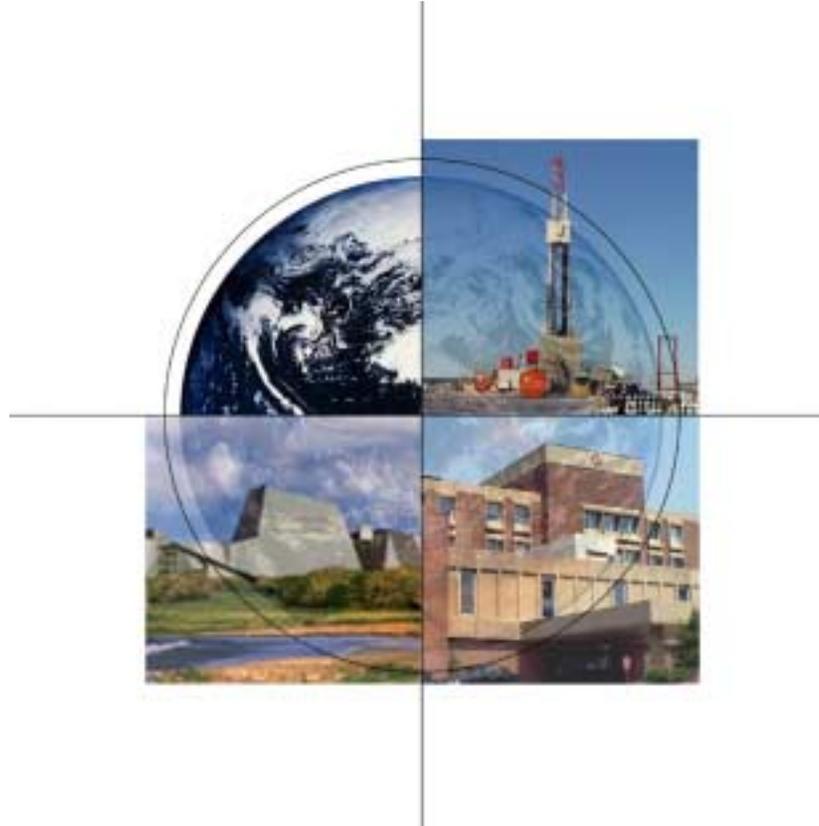


High Efficiency Engines and Turbines (HEET)



Abbie W. Layne
National Energy Technology Laboratory



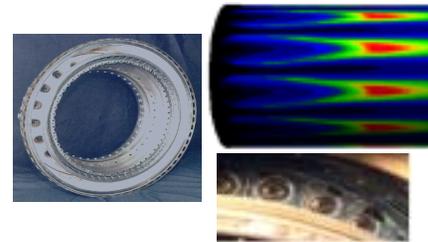
ATS/HEET Comparisons

**ATS-Product
Development Focused**



**HEET-Technology
Infusion Focused**

Combustion



**Materials &
Structures**



HEET Goals

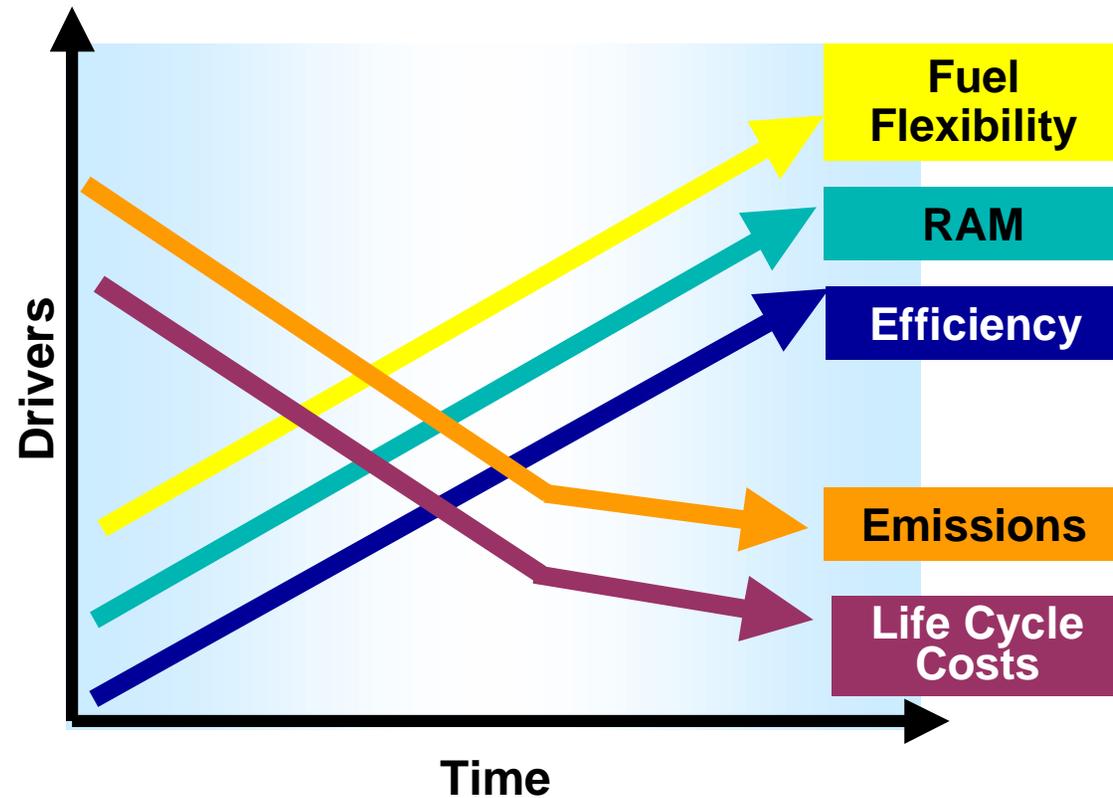
By the year 2010.....

- **Conservation through reduced fuel use**
 - 60% electric efficiency(HHV) coal plants
- **Near zero emissions**
 - No carbon, negligible nitrogen oxide and trace contaminates
- **Flexibility - fuels/operational**
 - Coal syngas, hydrogen/at least 400 starts per year
- **Improved electricity reliability**
- **Competitive life cycle cost**



Drivers for Research Direction

Drivers



Technology Roadmaps

• **Materials**

- Alloys, ceramics

• **Combustion**

- Catalysts, rich/lean

• **Aero/Thermal**

- Inter-cooling, blade design

• **Condition Monitoring**

- Sensors, controls, diagnostics

• **Design Tools**

- Large eddy simulations



National Energy Policy Responsiveness

- **Chapter 2 and 4: Development of CHP**
 - For the near-term almost all turbine planned products are combined heat and power (CHP) and all are high efficiency (47-63%)
- **Chapter 5: Protect Environment with Clean Coal Technologies**
 - The fuel cell turbine hybrid technology is a key power block component of most high-efficiency, coal-based Vision 21 power plants
- **Chapter 8: Support New Technologies to Address Global Climate Change**
 - Because of their high efficiency and low CO₂ and NO_x emissions, turbines are ideal for any global climate change initiatives

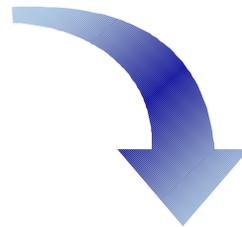


HEET Development Plan



2003-2005

- 65% efficient hybrids(<40MW)
- 50% efficient coal turbine plants

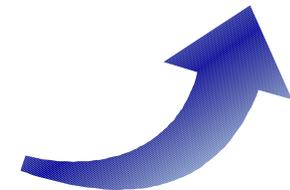


2010

- 70% efficient hybrids(40MW)
- 55% efficient coal turbine plants

2015

- 75% efficient gas plants
- 60+% coal plants
- Propulsion



Pathways to Achieve Clean Coal Goals

Technology Roadmaps

- Materials
- Combustion
- Aero/thermal
- Controls/Sensors
- Condition Monitoring
- Design Tools

Advanced Power Plants

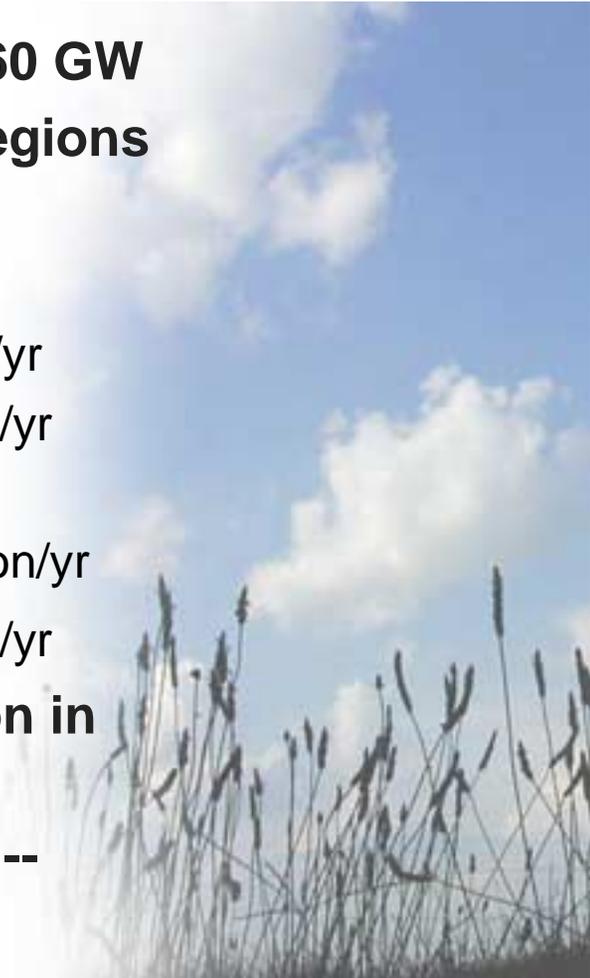
- Syngas/Hydrogen combined cycle
- Fuel cell/turbine hybrids
- Rocket engine steam cycle
- Ramjet engine
- Hydraulic compression

Technology roadmaps produce advanced coal fueled power plants



Public Benefits

- **Potential U.S. Market (year 2005-2015) - 160 GW**
- **Clean, reliable power in load congested regions**
- **By year 2020, cumulative savings*:**
 - **Advanced Natural Gas Plants**
 - Savings in the cost of electricity: \$3.5 Billion/yr
 - Carbon emissions reduction: 30 Million tons/yr
 - **Advanced Coal Plants**
 - Savings in the cost of electricity: \$350 Million/yr
 - Carbon emissions reduction: 15 Million tons/yr
- **Maintain U.S. industry competitive position in growing international power markets**
- **National solutions for power and defense -- Collaboration between agencies**



Planned Accomplishments -- FY 2002

Siemens - Westinghouse

501GS -- 60 Hz



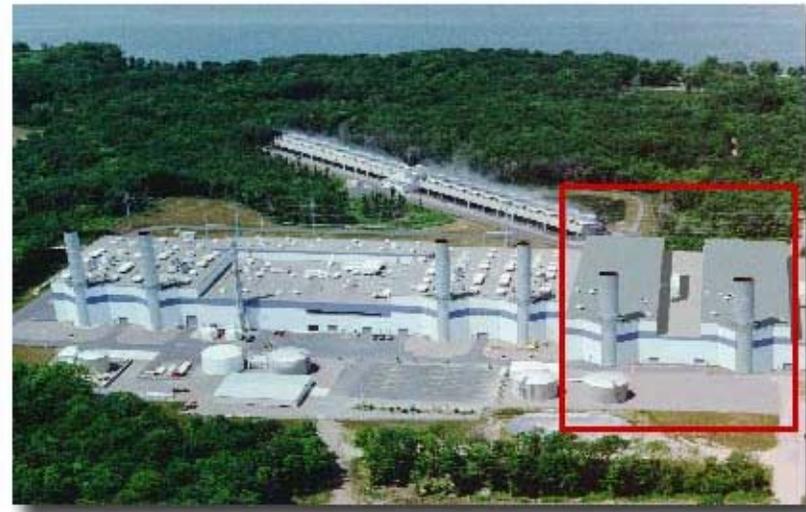
501G Launch Site
Lakeland, Florida

375 MW, 59% Efficiency

Component Test	2002
Operation	2003

General Electric Company

7H -- 60 Hz(ATS)



2 x 107H Launch Site
Scriba, New York, USA

400 MW, 60% Efficiency

FSNL Test	2000
Wales 50Hz Operation	09/02
Scriba Operation	2004



Planned Accomplishments -- FY 2002

Materials and Ultra-Low Emissions

- **ORNL Single Crystal Welding:** Employ computational thermodynamics to investigate mechanisms for stray crystal formation in single crystal weld repairs
- **ANL NDE Technology for Oxide-Based Composites:** Evaluate NDE data as a function of fatigue test damage on oxide composites
- **ANL Ceramic Reliability:** Complete finite element stress distribution analysis of miniature specimen geometry
- **CFD Research:** Beta release of software for design of low-emission combustion systems
- **GE Advanced Combustion:** Evaluate sub-scale trapped vortex combustor
- **Solar Laser Stabilization:** CFD simulations will be used to determine the best laser focal positions for optimum flame stabilization and combustion oscillations abatement



Planned Accomplishments -- FY 2002

Improved Electricity Reliability

- **S-W TBC Monitor:** Infrared emission from TBCs and associated progressions of deterioration will be characterized
- **EPRI Life Management:** Coating oxidation damage will be estimated, creep damage predicted and maintenance intervals will be established and compared to OEM's formulas
- **EPRI Advanced Monitoring:** Turbine anomaly detection and diagnostic software module will be developed to correlate performance shifts with degradation issues
- **GE Smart Turbine:** Fabricate and test flame temperature sensor



Program Funding Profiles

DOE-Office of Fossil Energy

<u>FY 2001 Appropriations</u>	<u>FY 2002 President's Budget</u>	<u>FY 2002 Congressional</u>
\$ 30.9 MM*	\$0	\$20.2MM
*\$12.4-ATS *\$18.5-NGT		



Non- DOE Collaborative Partners

DOD/NASA/DOE



Turbine Engine Alliance

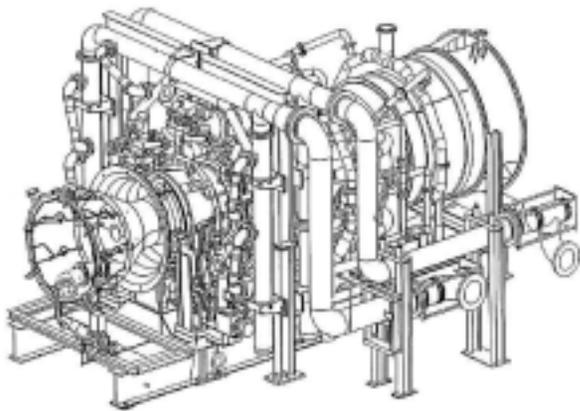
**California Energy Commission - Public Energy
Interest Research Program**

***Additional government collaborative
partners planned***

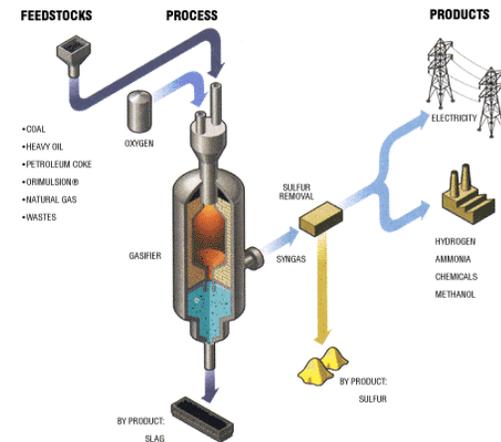


High Efficiency Engines and Turbines Road-Mapping Workshop

Results of the Reston, Virginia HEET Workshop



Reston, Virginia
February 7, 2002



Reston Roadmapping Summary

- **DOE and Gas Turbine Association sponsored a workshop in Reston, VA; February 7-8, 2002**
- **Focus was on industry recommendations for DOE sponsored R&D to support HEET Program**
- **Workshop yielded recommendations in three areas**
 - Policy
 - Program
 - Technology



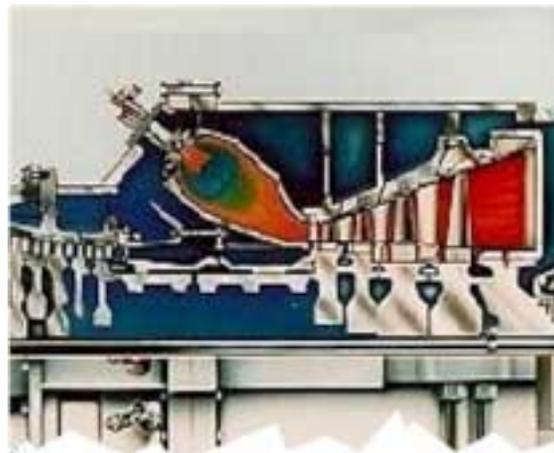
HEET Road-Mapping Workshop-Speakers

- **Opening remarks-Joseph Strakey, Carl Bauer**
- **Presentations**
 - Jeff Abboud (GTA): National Energy Plan, bills pending in Congress to limit coal fired emissions
 - Abbie Layne (DOE): HEET Program Report to Congress, planned accomplishments, program goals, early entry demonstrations
 - Harvey Goldstein (Parsons): Market hurdles, commonality across roadmaps prepared by different organizations (DOE, EPRI, CURC, OEM's)



Performance and Emissions

- The next two slides show where we are and where we are going in terms of performance and emissions
- HEET activities must advance the state of the art to get us closer to meeting the program objectives. The devil is in the details.



Performance & Cost of Coal-Based & Gas- Based Systems

	<i>Coal Fired Current PC</i>	<i>Coal Fired HEET-IGCC</i>	<i>Gas Fired Current G/H Frame</i>	<i>Gas Fired HEET</i>
Efficiency	39% hhv	60% hhv	60% lhv	75% lhv
COE	base	base-15%	base	base-15%
Fuel Flexibility	single type of coal	multi-fuel	nat gas or No. 2 oil	nat gas or syngas
Reliability	base	base +	base	base +



Coal-Fired & Natural Gas-Fired Emissions

Current Systems:

	PC-Fired	NGCC
Pollutant, lb/10⁶ Btu		
SO₂	0.12-0.35	Neg.
NOx	0.05-0.20	>0.03
CO₂	197-230	120-130
Particulate	0.001-0.010	Neg.

HEET Technology Based Systems: near zero emissions of SO₂, NOx, Hg, particulates. Sequestration-ready for carbon management



Policy Recommendations

- Industry must have regulatory (*emissions*) certainty in order to risk capital developing new technologies
- Clean Coal Enterprise Zones and tax incentives
- National Materials/Combustion Test Facility recommended (Wilsonville?)
- Government (DOE) must fund in areas where industry will not where risk exceeds existing commercial incentives



Program Recommendations

- **Determine realistic objectives for 2007**
- **Set mid-term goals with decision points and off-ramps**
- **Use distributed generation to demonstrate technology at a small scale**
- **Support cross-cutting technologies**
- **Encourage strategic partnerships
(*Gov't/NGO's/industry/academia*)**
- **Evaluate fuel cycle to define infrastructure requirements**



Technology Recommendations

- **Develop better materials and coatings**
- **Test materials and combustors on syngas**
- **develop fuel-flexible, low emission, low acoustic combustors**
- **Develop better system simulation models and techniques, and do a better job with systems definition and integration**
- **Numerous other items that all contribute to an integrated program were suggested**

