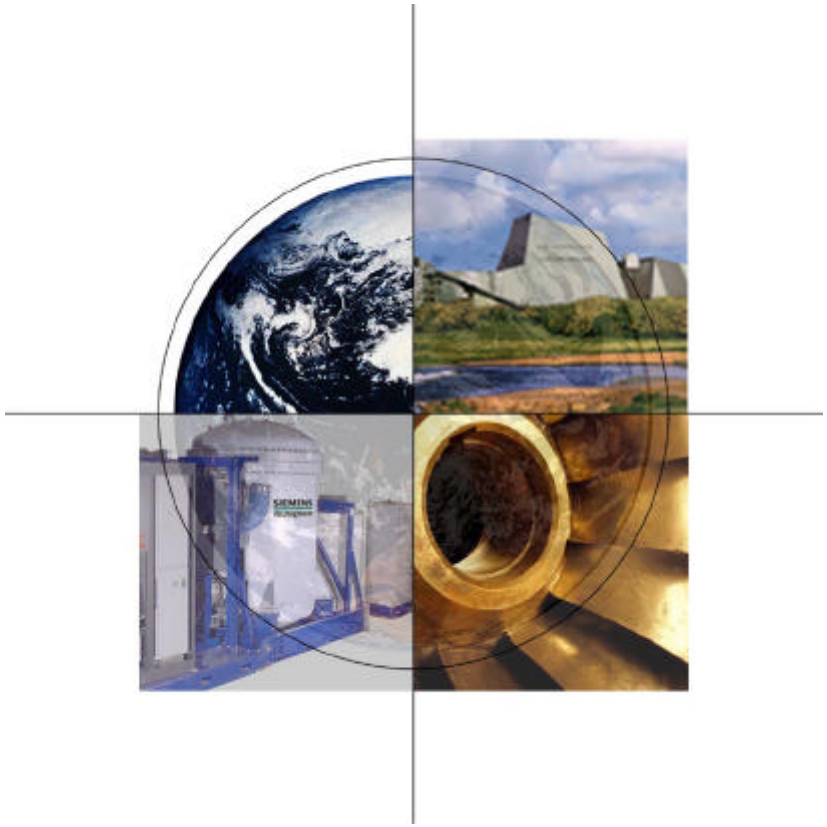
DOE's Fossil Energy Turbine Program



First International Conferenc on Industrial Gas Turbine Technology

July 10-11, 2003
Brussels, Belgium

Richard Dennis
Turbine Program Product Manager

National Energy Technology Laboratory

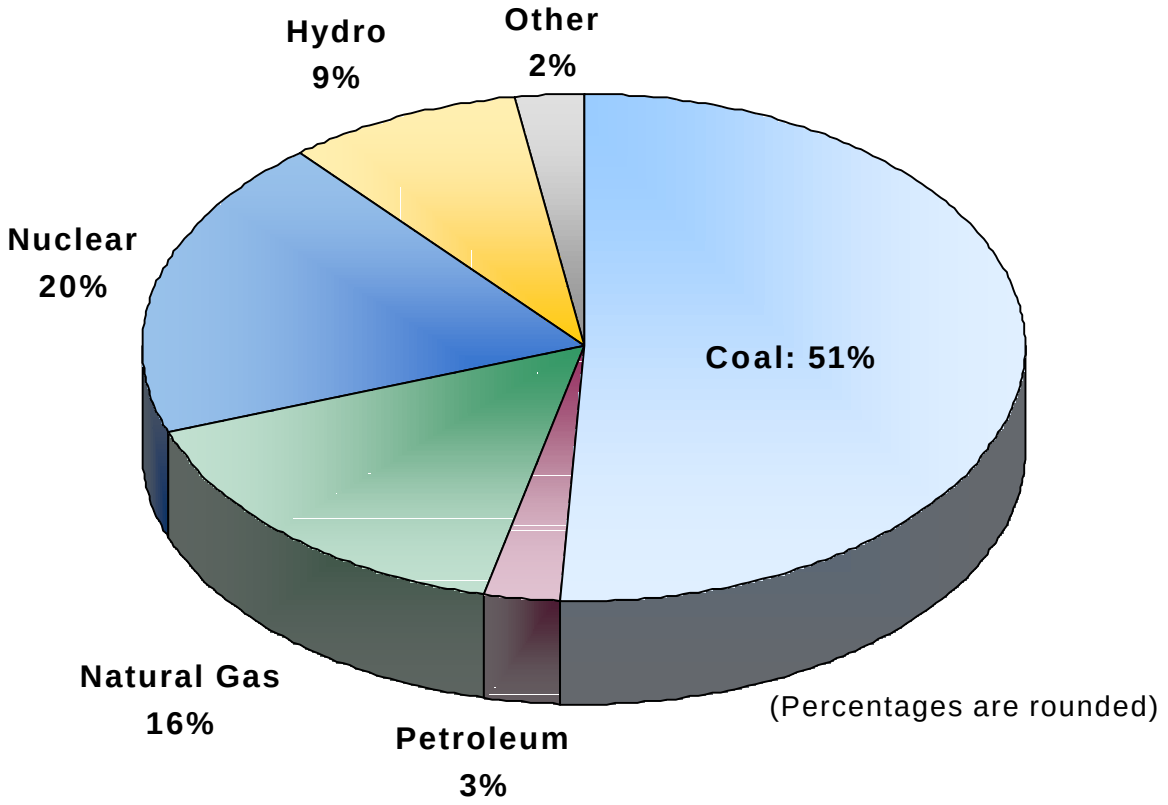
DOE's Fossil Energy Turbine Program

Presentation Outline

- **Why Turbines for Coal Fueled Power Systems**
- Mission and Program Areas
- Mission Critical Issues
- Projects & New Initiatives
- Summary

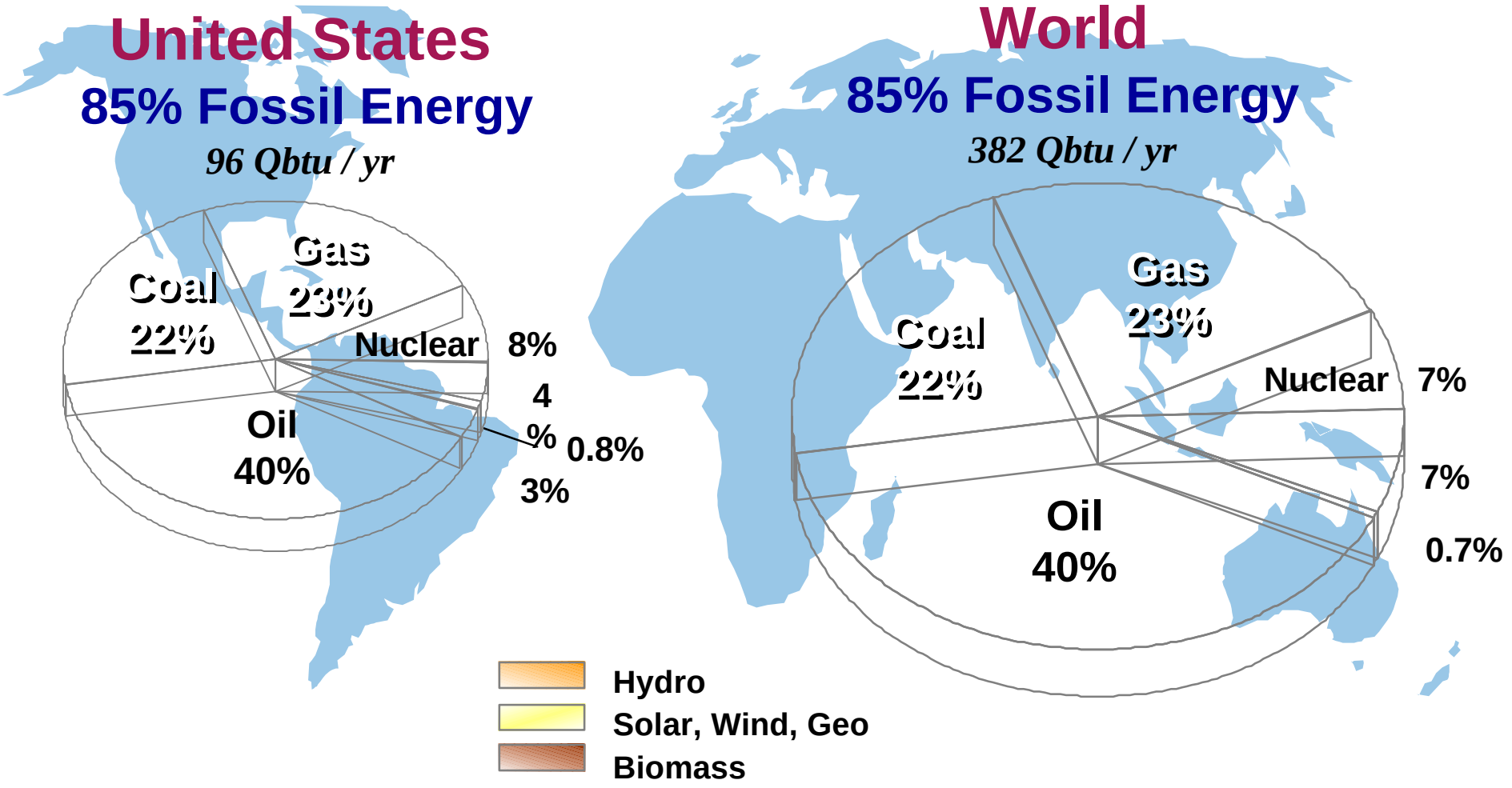
Coal Is America's Major Source of Electricity

Electricity Generation by Fuel, 1999
(Million Kilowatt Hours)

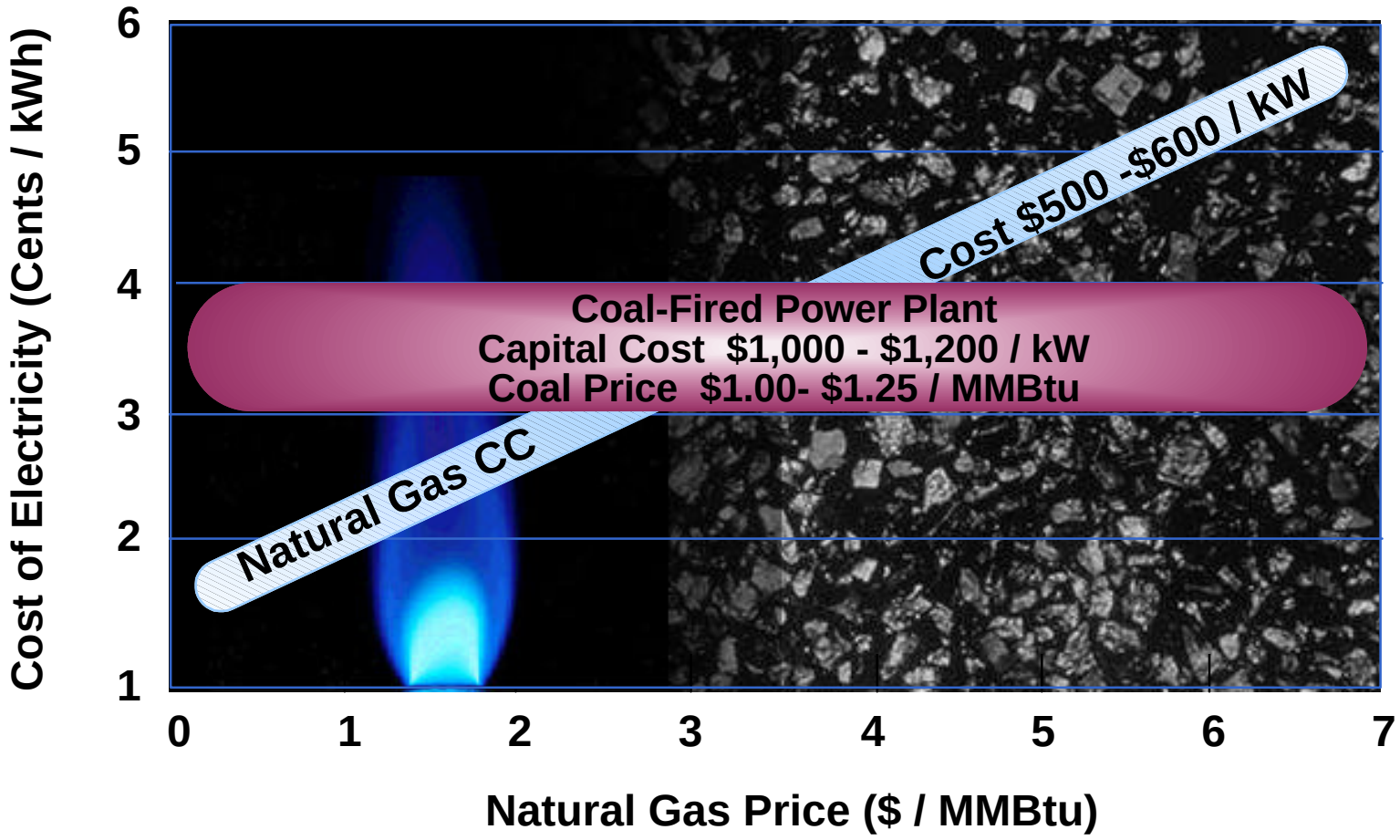


. . . providing more than half of U.S. electricity generation

U.S. and World Economies Based on Fossil Fuels

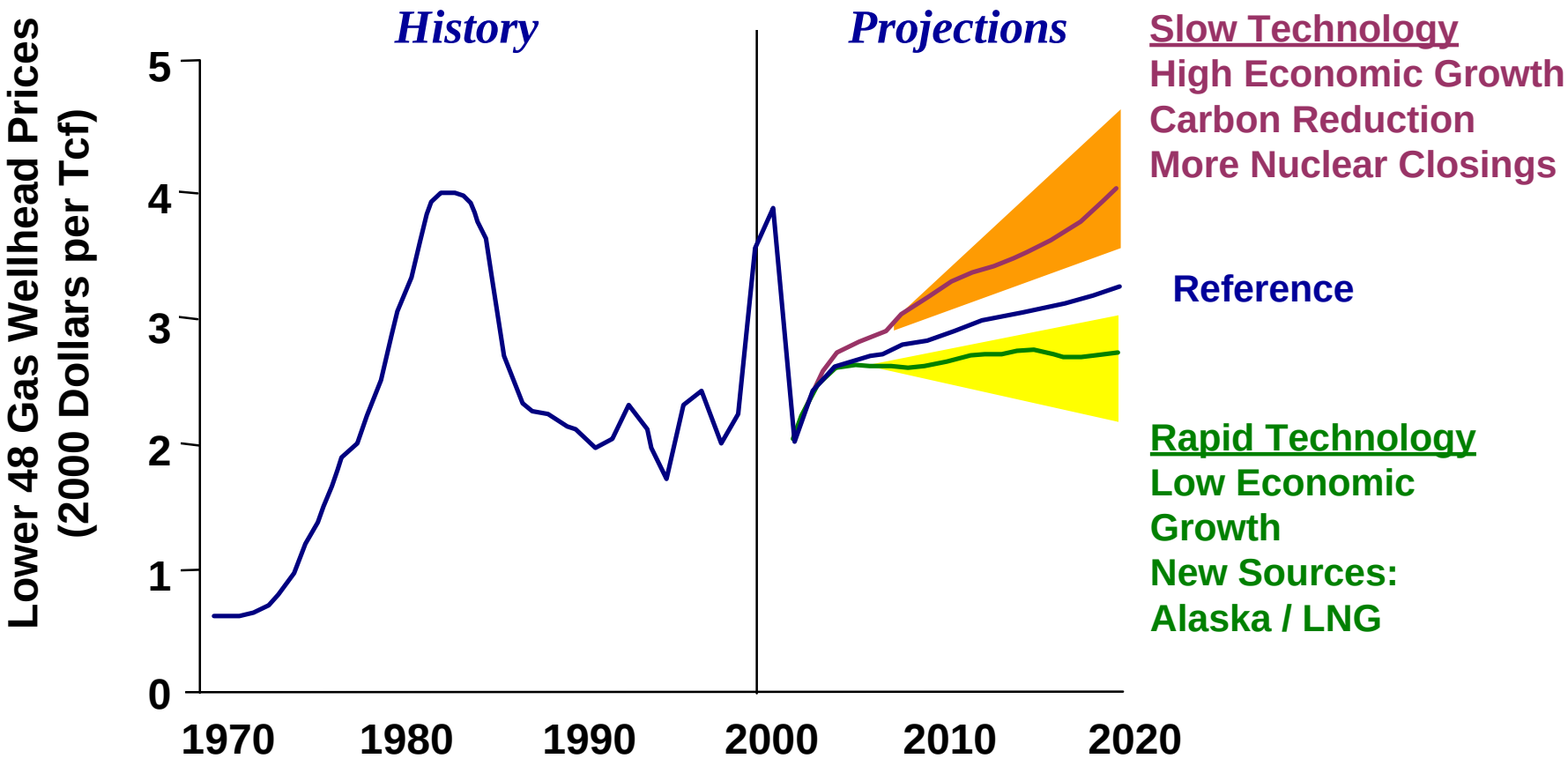


Working to Make Coal Competitive with Gas

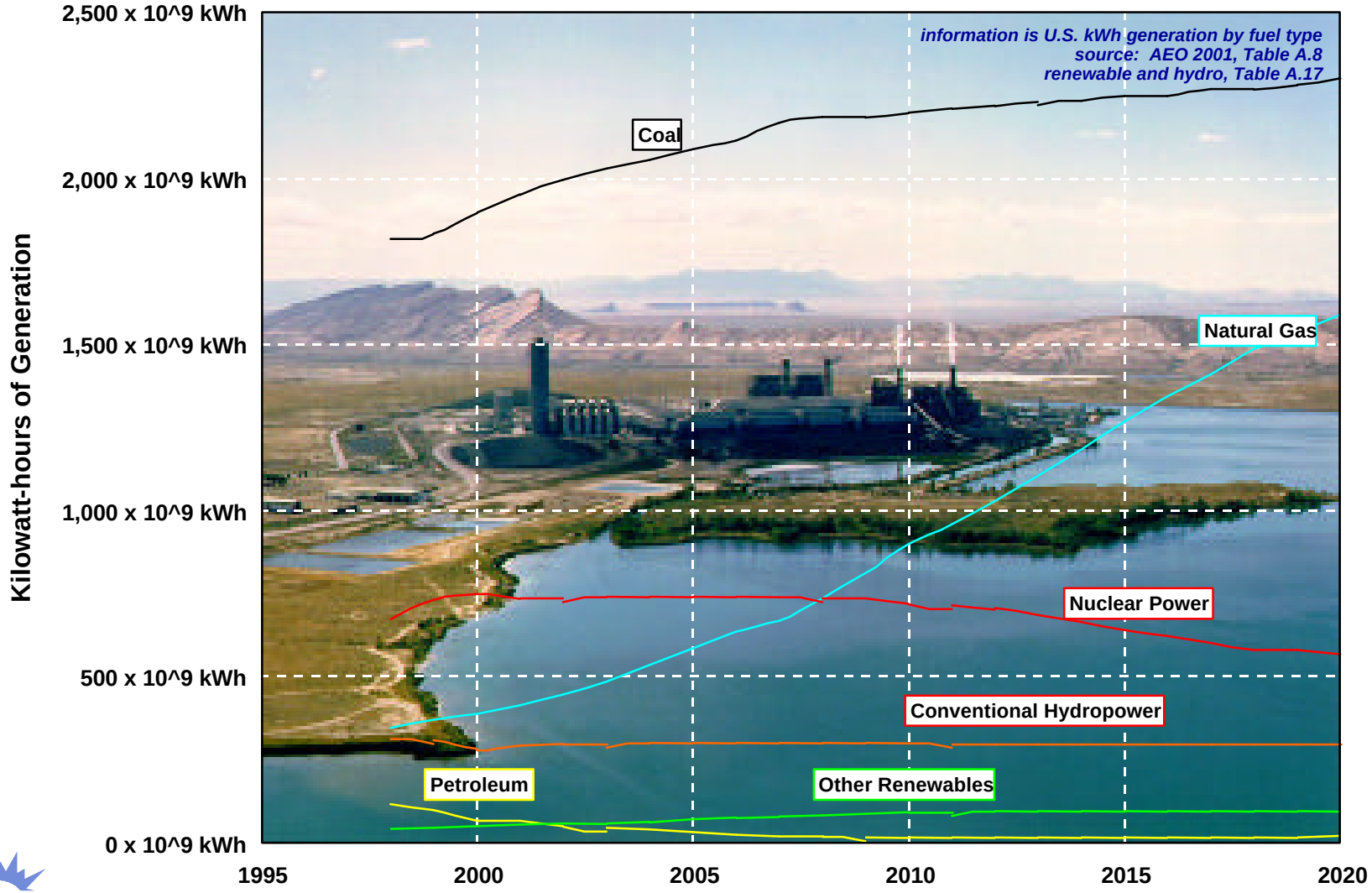


Natural Gas Prices

Projections Change With Assumptions



Projected Electric Generation by Fuel Type



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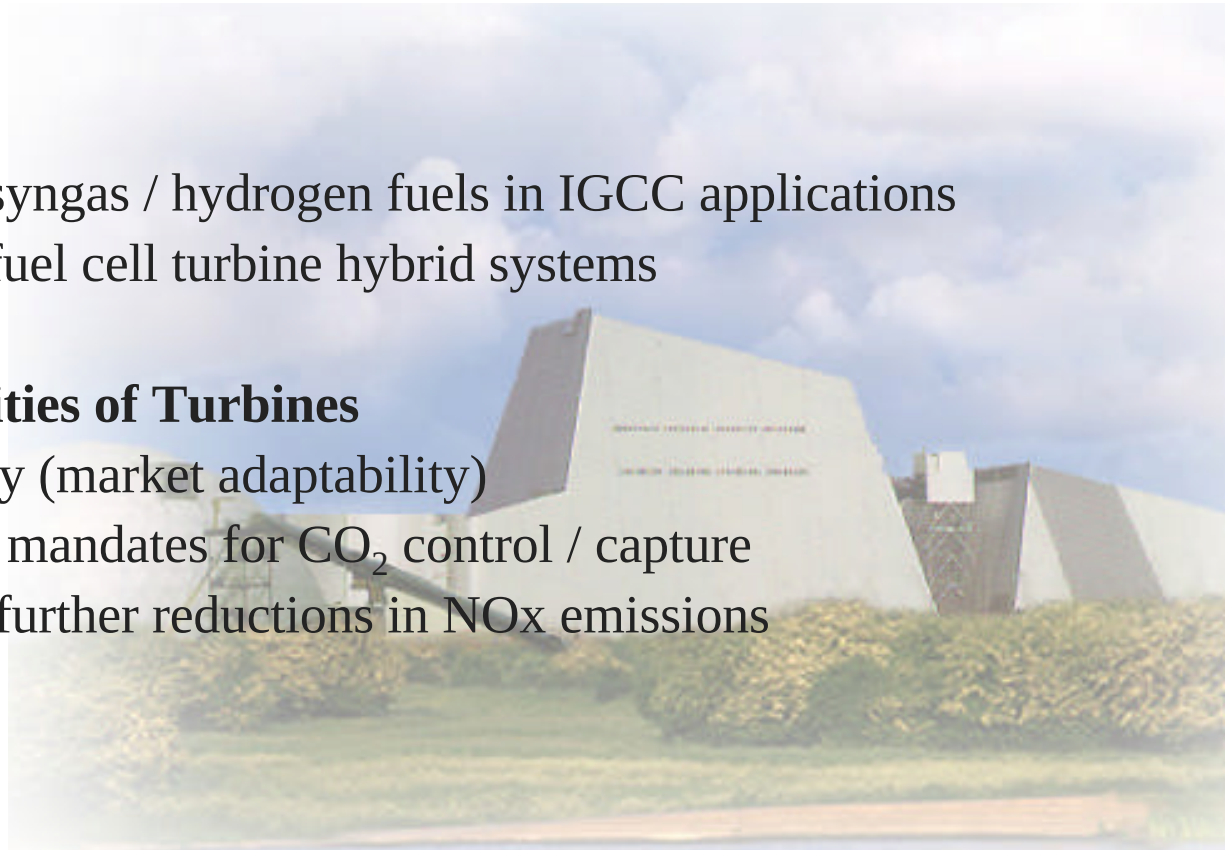
Mission

- **Purpose**

  Provide turbine power generation technology essential to the success of advanced fossil energy power systems in the 2008 and 2015 time frames

- **Program Areas**
  - –Turbines for syngas / hydrogen fuels in IGCC applications
  - –Turbines for fuel cell turbine hybrid systems
-
- **Unique Capabilities of Turbines**
  - –Fuel flexibility (market adaptability)
  - –Adaptable to mandates for CO_2 control / capture
  - –Amenable to further reductions in NOx emissions
  - –Scaleable



Program Goals

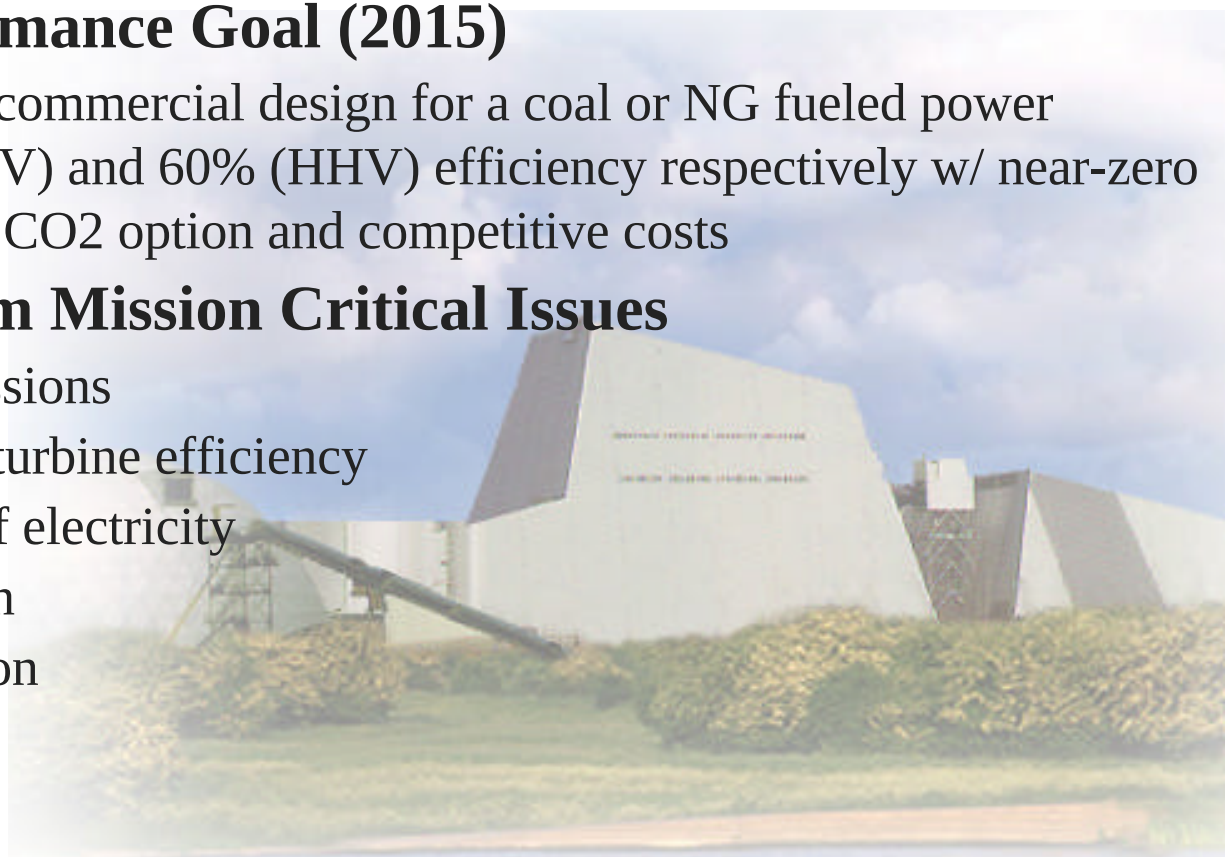
- **Program Strategic Performance Goal (PSPG) (2008)**

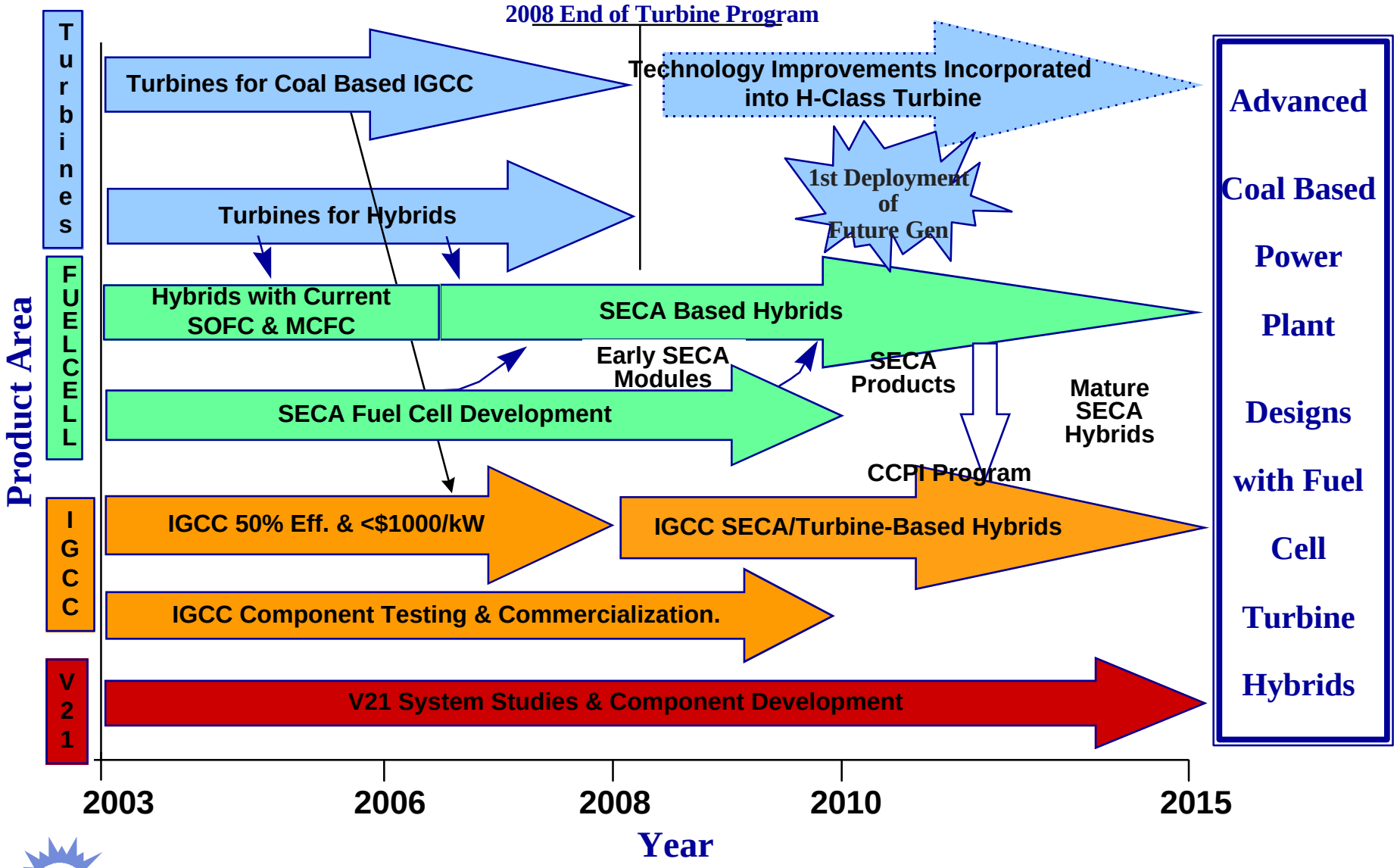
  By 2008 provide a commercial design for a coal-based power system at 50% efficiency and a capital cost < $1000/kW with near zero emissions

- **Vision 21 Performance Goal (2015)**

  By 2015 provide a commercial design for a coal or NG fueled power system at 75% (LHV) and 60% (HHV) efficiency respectively w/ near-zero emissions w/a zero CO2 option and competitive costs

- **Turbine Program Mission Critical Issues**
  - –Reduction in emissions
  - –Improvements in turbine efficiency
  - –Reduce the cost of electricity
  - –System integration
  - –Cycle configuration




2008 End of Turbine Program
Turbines
Turbines for Coal Based IGCC
Technology Improvements Incorporated into H-Class Turbine
Turbines for Hybrids
1st Deployment of Future Gen
FUELCELL
Hybrids with Current SOFC & MCFC
SECA Based Hybrids
Early SECA Modules
SECA Products
Mature SECA Hybrids
SECA Fuel Cell Development
CCPI Program
IGCC
IGCC 50% Eff. & <$1000/kW
IGCC SECA/Turbine-Based Hybrids
IGCC Component Testing & Commercialization.
V21
V21 System Studies & Component Development
Product Area
2003
2006
2008
2010
2015
Year
Advanced Coal Based Power Plant Designs with Fuel Cell Turbine Hybrids

DOE's Fossil Energy Turbine Program

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Mission Critical Issue for PSPG
Improve Efficiency

- **2 - 3 percentage points improvement in combined cycle (CC) efficiency**
  - H-Class CC machines (400 MW) on NG anticipated to be 60 % (LHV)
  - H-Class CC machines (400 MW) in an IGCC configuration anticipated to be 45-49 % (LHV)
  - 2 x 7FB (563 MW) CC on NG proven at 57. 5 % (LHV)
  - 2 x W501F (550 MW) CC on NG proven at 55.8 % (LHV)
  - Delta 15 % from NGCC to IGCC, 1.5 – 2 % lower for coal LHV to HHV
  - Tampa Electric and Wabash River IGCC proven at 38 and 40 % F-class machines (HHV)
  - Destec 400 MW IGCC w/ “G-class” turbine and cold cleanup 45 % (HHV); same w/ HGCU 47.6 % (based on NETL system studies)
- **Approach to goal**

  Need to increase firing temperature (~ 200 F) in F & G class machines, maintain combustor performance while reducing NOx, incorporate ATS technology into F & G class machines, fully integrate turbine w/ gasification process, air separation unit and steam cycle.

Mission Critical Issue for PSPG
Reduce Emissions

- **Reduction in NOx emissions for syngas to < 3 ppm**
  - Water or steam injection – lowest control levels 25 ppm (NG)
  - Dry Low NOX (DLN) for GE 7EA, FA and 6B gas turbines on natural gas 9 ppm at 15% O_2
    - Trapped vortex combustion may extend this limit
    - In these machines syngas has the potential for lower NOx
  - H-Class w/ DLN demonstrated 25 ppm, potential for 9 ppm
  - Catalytic combustion unproven in F-class machines potential for < 3 ppm
- **Approach to goal**

  Either extending the lean pre mix limit (TVC, H_2, others?) or catalytic combustion.

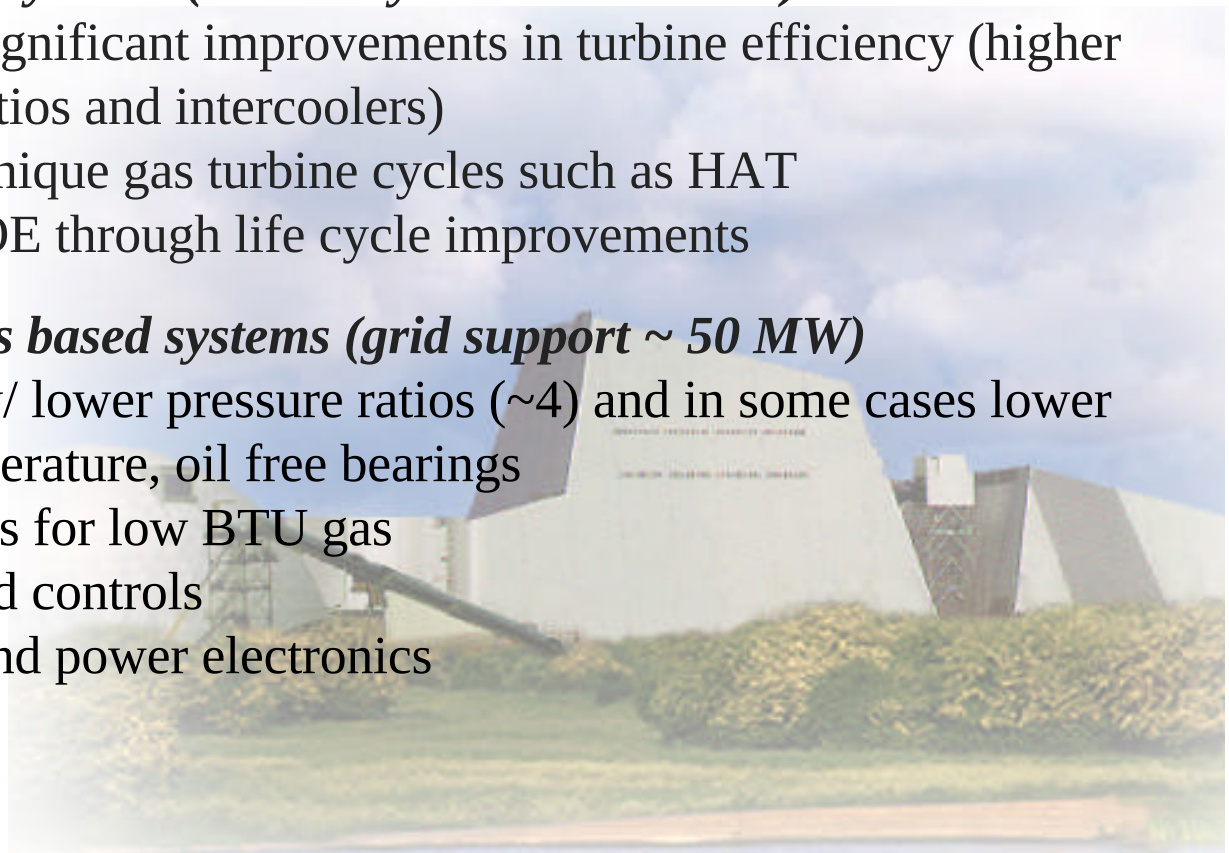
Mission Critical Issue for PSPG
Reduce Cost of Electricity

- **Reduction in cost of electricity through life cycle management and increase in specific power output**
  - Life cycle cost management is seen as the highest priority by gas turbine users, this issue is expected to continue or worsen in IGCC applications.
  - NG GT goals: 15% reduction in life cycle cost, limit degradation to 2%/yr., 400 starts/yr.
  - Syngas fired turbines may have a margin for increasing mass throughput and result in higher power rating per frame size
- **Approach**

  Focus on sensor development for turbines in IGCC applications to apply in life cycle management. For a given frame size extend / explore the torque and aerodynamic limitations in syngas applications to increase power output.

Vision 21 Mission Critical Issues

- **To achieve the V21 power system efficiencies for coal and natural gas fueled systems fuel cell turbine (FCT) hybrids are required.**
- –***For coal based systems (central systems > 300 MW)***
  - Requires significant improvements in turbine efficiency (higher pressure ratios and intercoolers)
  - Requires unique gas turbine cycles such as HAT
  - Reduce COE through life cycle improvements
- –***For natural gas based systems (grid support ~ 50 MW)***
  - Turbines w/ lower pressure ratios (~4) and in some cases lower firing temperature, oil free bearings
  - Combustors for low BTU gas
  - Sensors and controls
  - Inverters and power electronics



DOE's Fossil Energy Turbine Program

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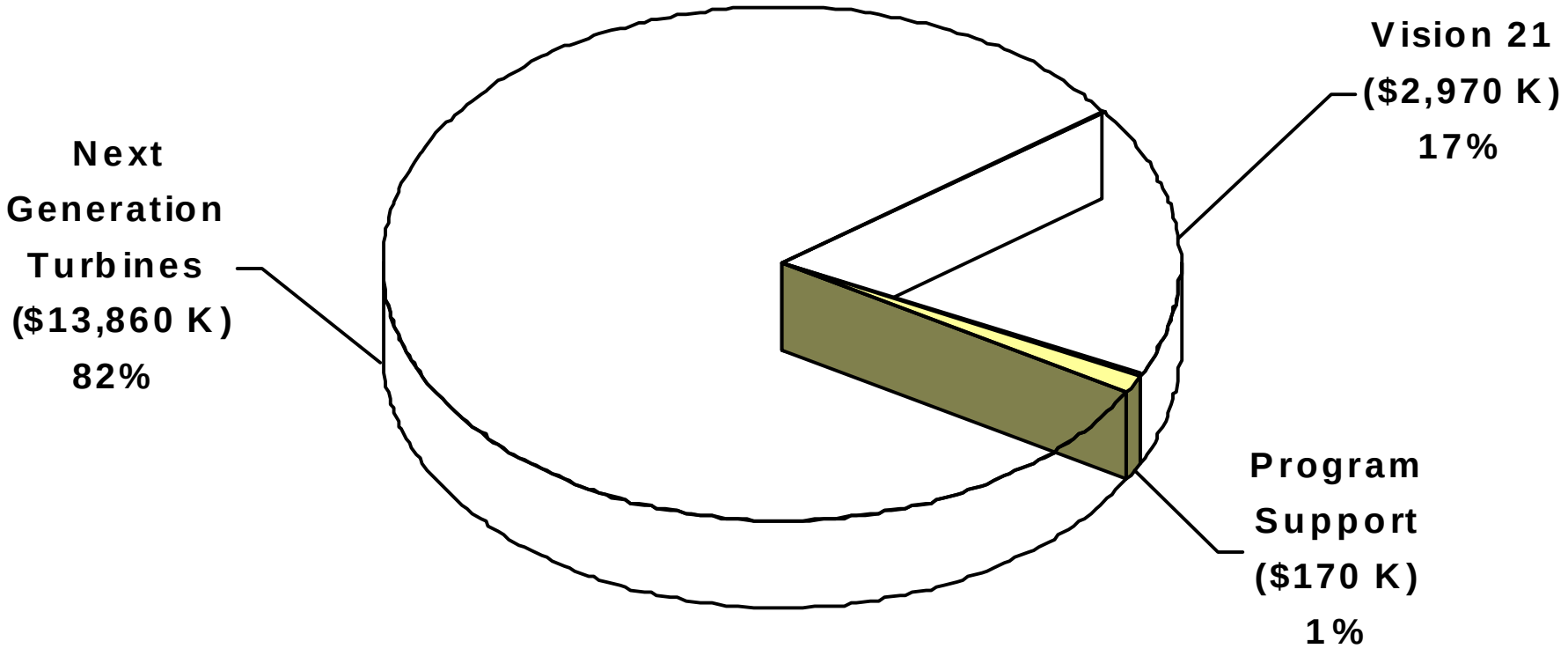
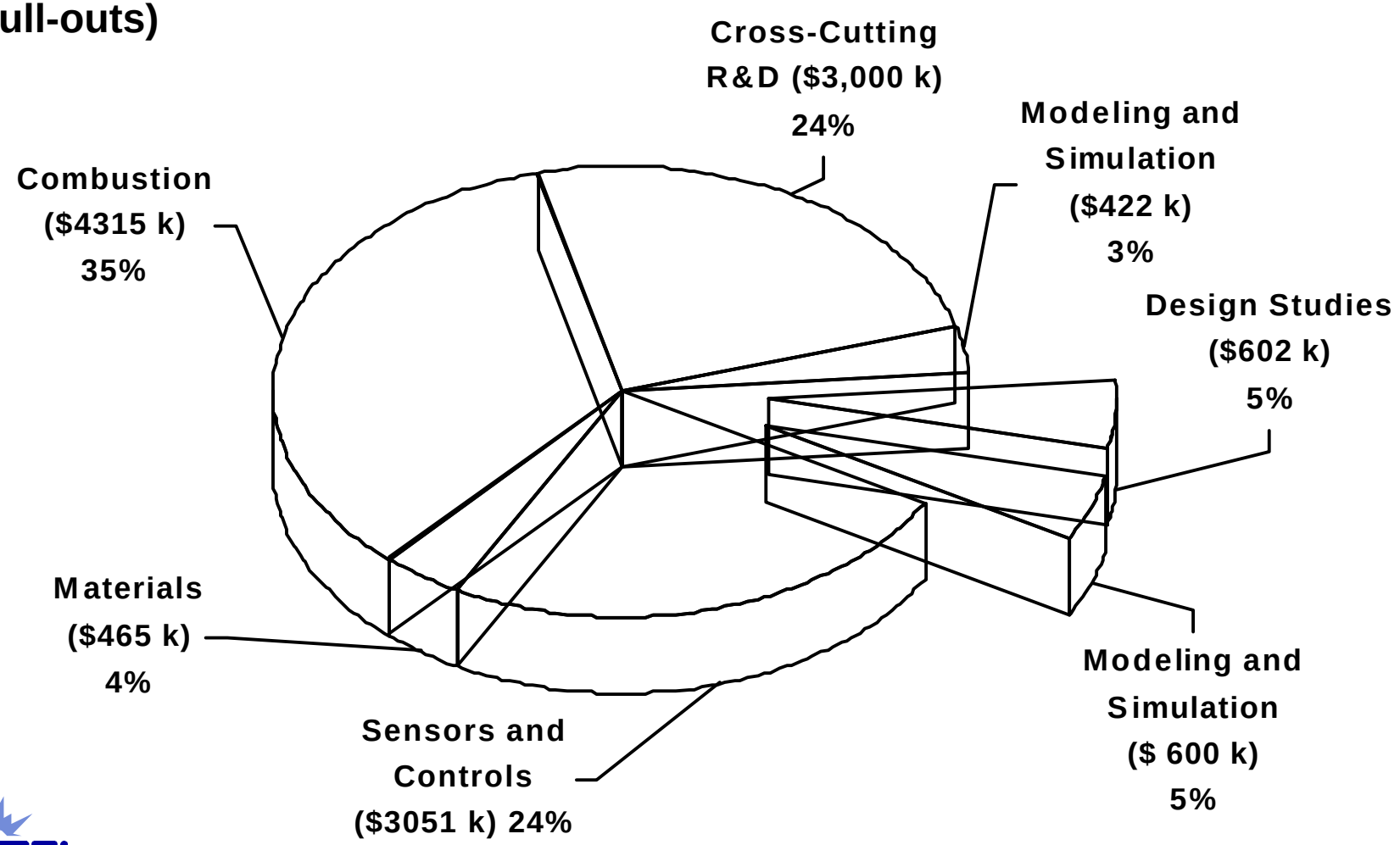
FY 2003 Turbine Budget - $17,000 K



FY 2003 Turbine Budget

Division of key activity Next Generation Turbines ($13,860 K) into technology R&D areas for the two sub-activities A) Coal Based Plants and B) Hybrids (Pull-outs)



Turbine Program Participants

Lawrence Livermore National Laboratory, Livermore - CA
Electric Power Research Institute (EPRI), Palo Alto - CA
Clean Energy Systems, Sacramento - CA
U CA Irvine – NFCRC - Irvine, CA
GE – Hybrid Power Systems, Torrance - CA

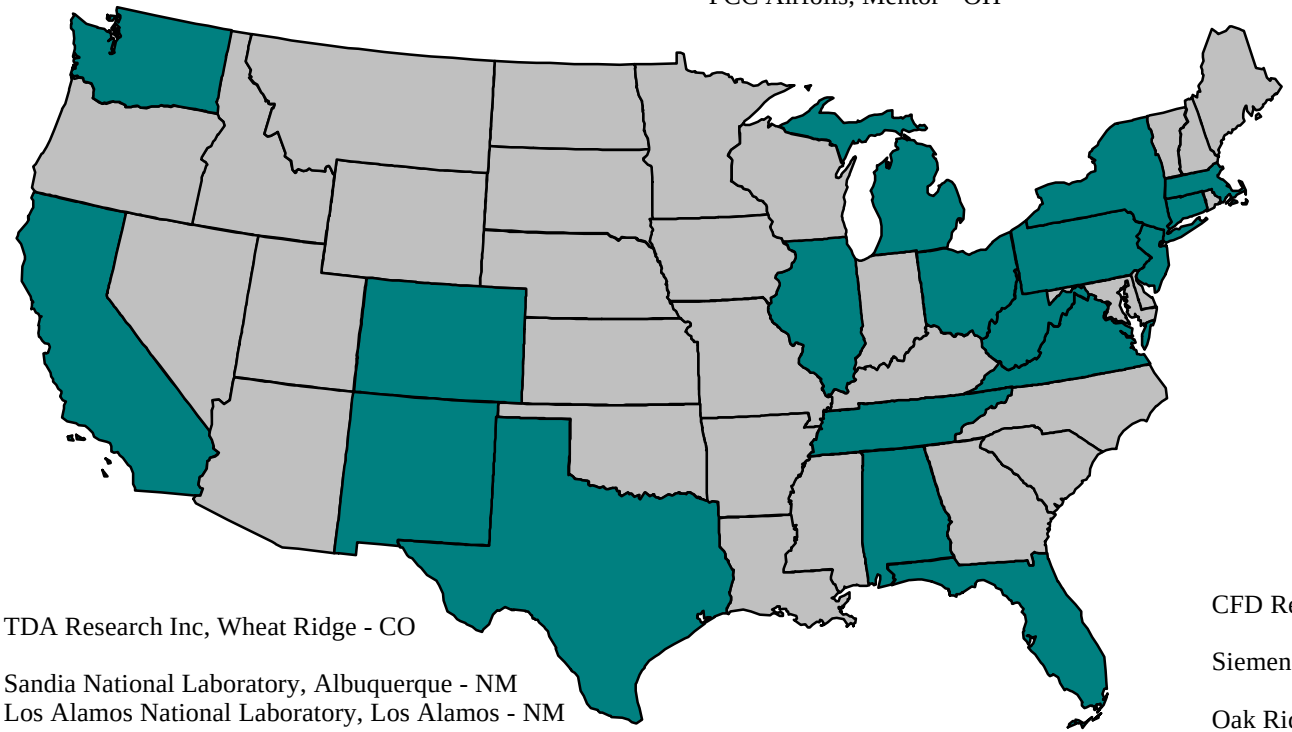
Ramgen Power Systems, Bellevue - WA

An additional 35 university R&D projects throughout the US

En'Urga, West Lafayette - IN

Howmet Corporation, Whitehall - MI

PCC Airfoils, Mentor - OH



Precision Combustion, North Haven - CT

Busek Company, Natick - MA
JENTEK Sensors, Waltham - MA

Howmet Corporation, Dover - NJ

General Electric, Niskayuna & Schenectady - NY
Mesoscribe Technologies, Stony Brook - NY

Siemens Westinghouse, Pittsburgh – PA

NETL – Morgantown, WV

TDA Research Inc, Wheat Ridge - CO

Sandia National Laboratory, Albuquerque - NM
Los Alamos National Laboratory, Los Alamos - NM

University of Texas-Pan American, Edinburg - TX
Texas A&M University, College Station - TX

CFD Research Corporation, Huntsville - AL

Siemens Westinghouse, Orlando -FL

Oak Ridge National Laboratory, Oak Ridge - TN

Luna Innovations Incorporated, Blacksburg - VA
Howmet Corporation, Hampton - VA

New Initiatives For FY 2003

1) Improve combustion turbine performance with coal derived synthesis gas (IGCC)

- **Performance enhancements: NOx emissions, thermal efficiency, material degradation, combustion stability, machine reliability and availability, tolerance to fuel variability and power plant integration.**
- **Three Phase Approach: Phase I–Implementation Plan, Phase II–Validation Test Program; and Phase III–Field Testing.**

New Initiatives For FY 2003 (Continued)

2) Develop NOx emissions reduction technology for fuel flexible turbines

-
- Enable fuel flexible gas turbines for IGCC or NG to achieve NOx emissions of 2 ppm or less.
- Develop technology that can be applied to existing or new gas turbines i.e. retrofitable
- Three Phase Approach: Phase I–Implementation Plan; Phase II–Validation Test Program; and Phase III–Field Testing

Turbine Program Supported Hybrid Projects

- **Fuel Cell Energy – Critical Components for Direct Fuel Cell/Turbine Ultra-Efficiency System (40798)**
- **Siemens Westinghouse – High-Temperature Tubular Solid Oxide Fuel Cell Generation Development (34139)**
- **University of California, Irvine – Systems Integration Methodology (40845)**
- **GE - SOFC Hybrid System for Distributed Power Generation (40779)**
- **Hybrid Performance Project (NETL In-House)**
- **Solid State Energy Conversion Alliance (SECA)**
- **TIAX – Scale-Up of Planar SOFC for MW-Scale Systems**

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Summary

- **Coal utilization is an attractive and essential U.S. resource for the production of clean and low cost electric power.**
- **NOx reduction, efficiency improvements and reduction in cost of electricity in IGCC applications is the primary target for the DOE FE Turbine Program.**
- **Fuel cell turbine hybrids offer the cleanest and most efficient fossil fuel based power systems in the sub-MW to multi-MW size ranges.**
- **Proposals under evaluation to address NOx reduction and efficiency improvements for IGCC application, awards expected in FY 03.**