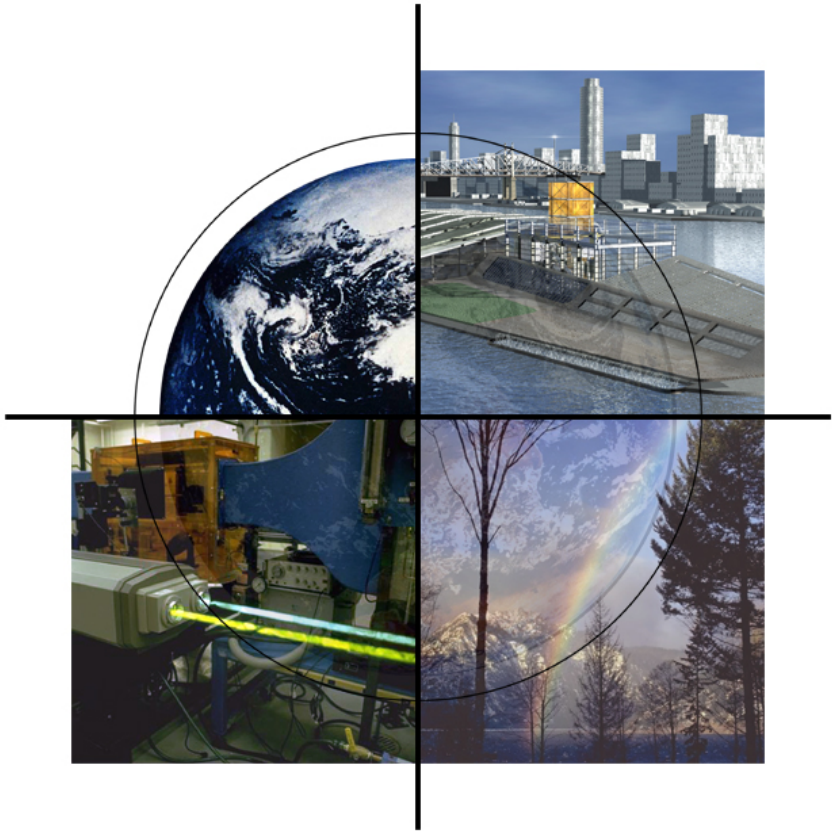
U.S. Scene for Electric Power & Future Energy Systems---



Economic Tipping Point or… Opportunity for Clean Coal Technologies

Carnegie Mellon University
October 27, 2005

Mike Eastman, Strategic Center for Coal
National Energy Technology Laboratory

NETL

- **Only DOE national lab dedicated to fossil energy**
  - Fossil fuels provide 85% of U.S. energy supply
- **One lab, four locations, one management structure**
- **1,100 Federal and support-contractor employees**
- **Research spans fundamental science to technology demonstrations**

Pennsylvania

West Virginia

Alaska

Oklahoma

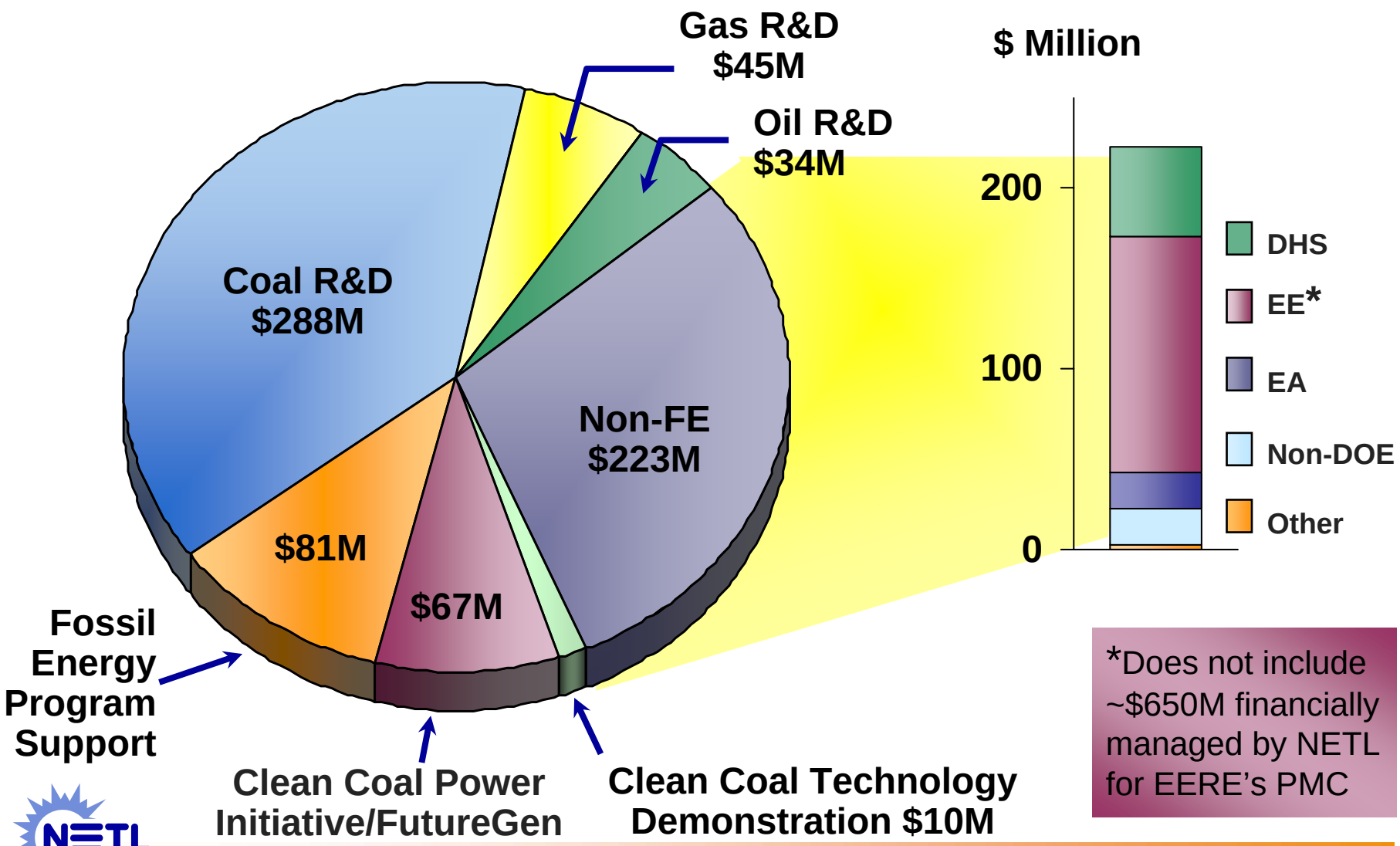
NETL Mission Areas

Strategic Center for Coal

Strategic Center for Natural Gas and Oil

Advanced Initiatives

NETL FY 2005 Budget: $748 Million



*Does not include ~$650M financially managed by NETL for EERE's PMC

NETL's Investment in Pennsylvania

Impacting Economy Through On-Site Operations

- **Contribute over $69M annually through Federal and contractor payroll, small purchases, and conferences**
- **Draw nearly 3,000 visitors to Pittsburgh area per year**

Impacting Economy Through R&D

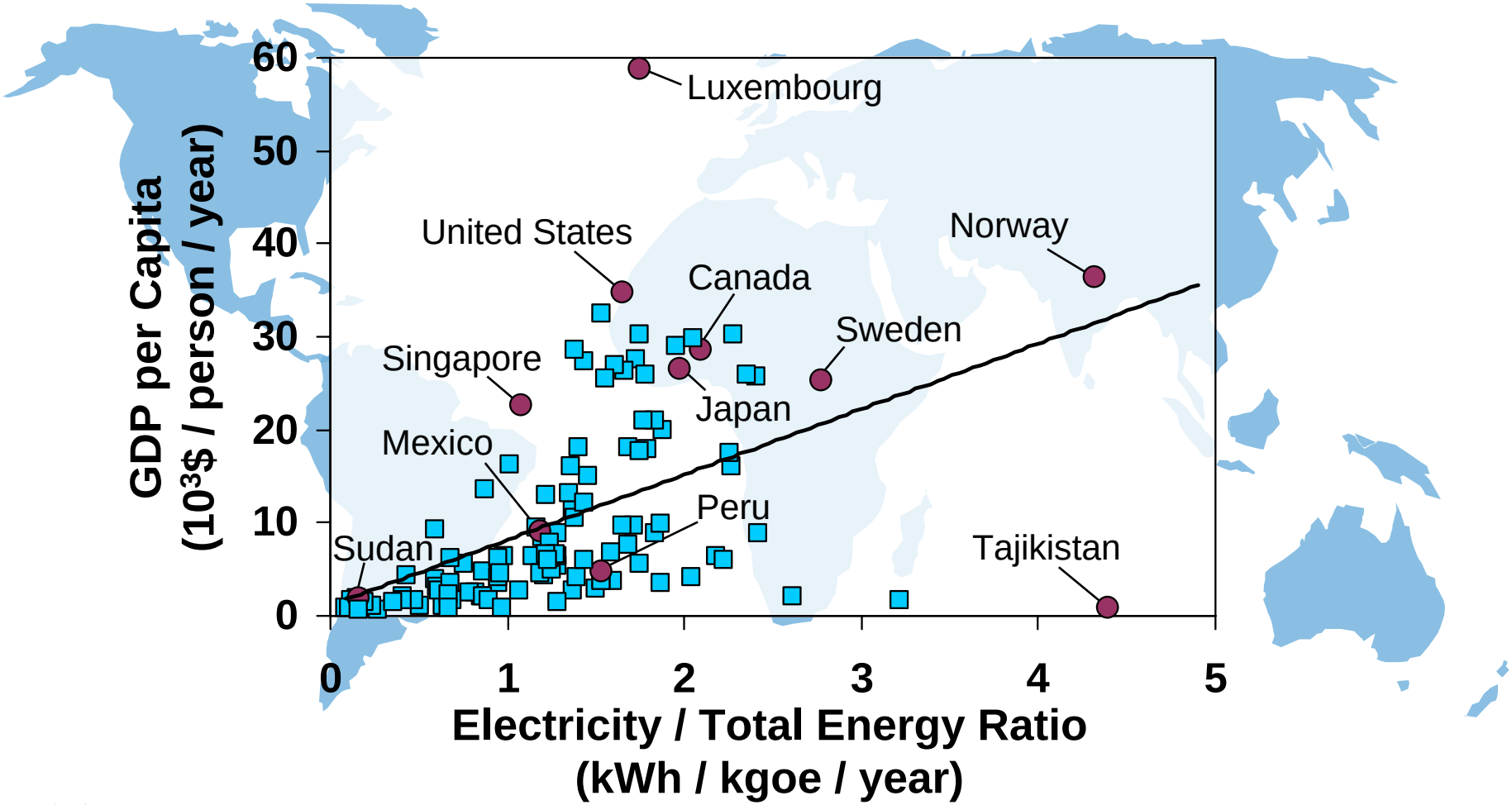
- **$1.3B total value of agreements and contracts**
- **Obligated $61M in FY04 generating 2,440 job-years in PA**
  - Small businesses - total value of $29M with $6M obligated annually
  - Colleges/universities - total value of $292M with $21M obligated annually

NETL

FY 2004

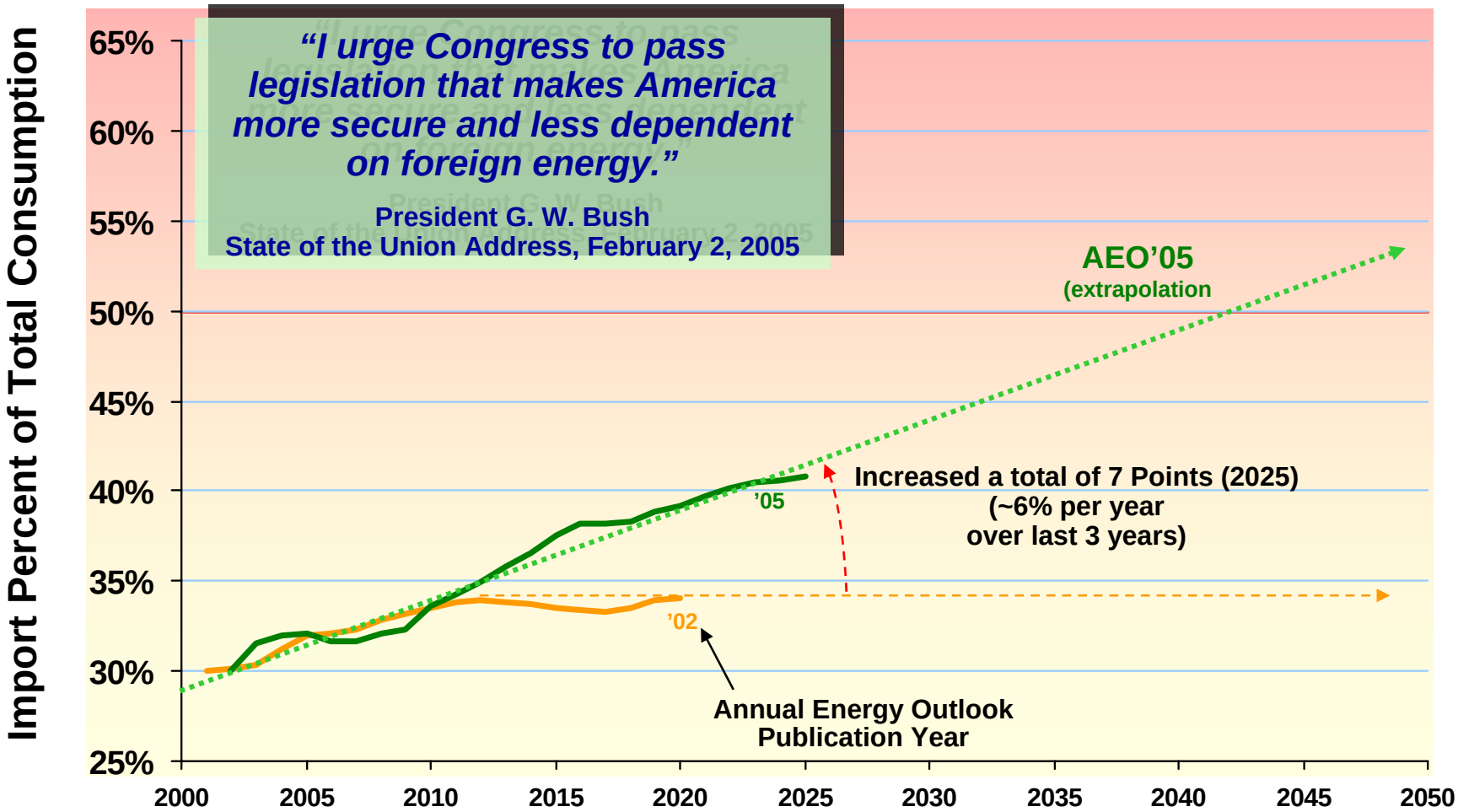
Electricity = Quality of Life

Poverty Impacts Global Security / Environmental Options



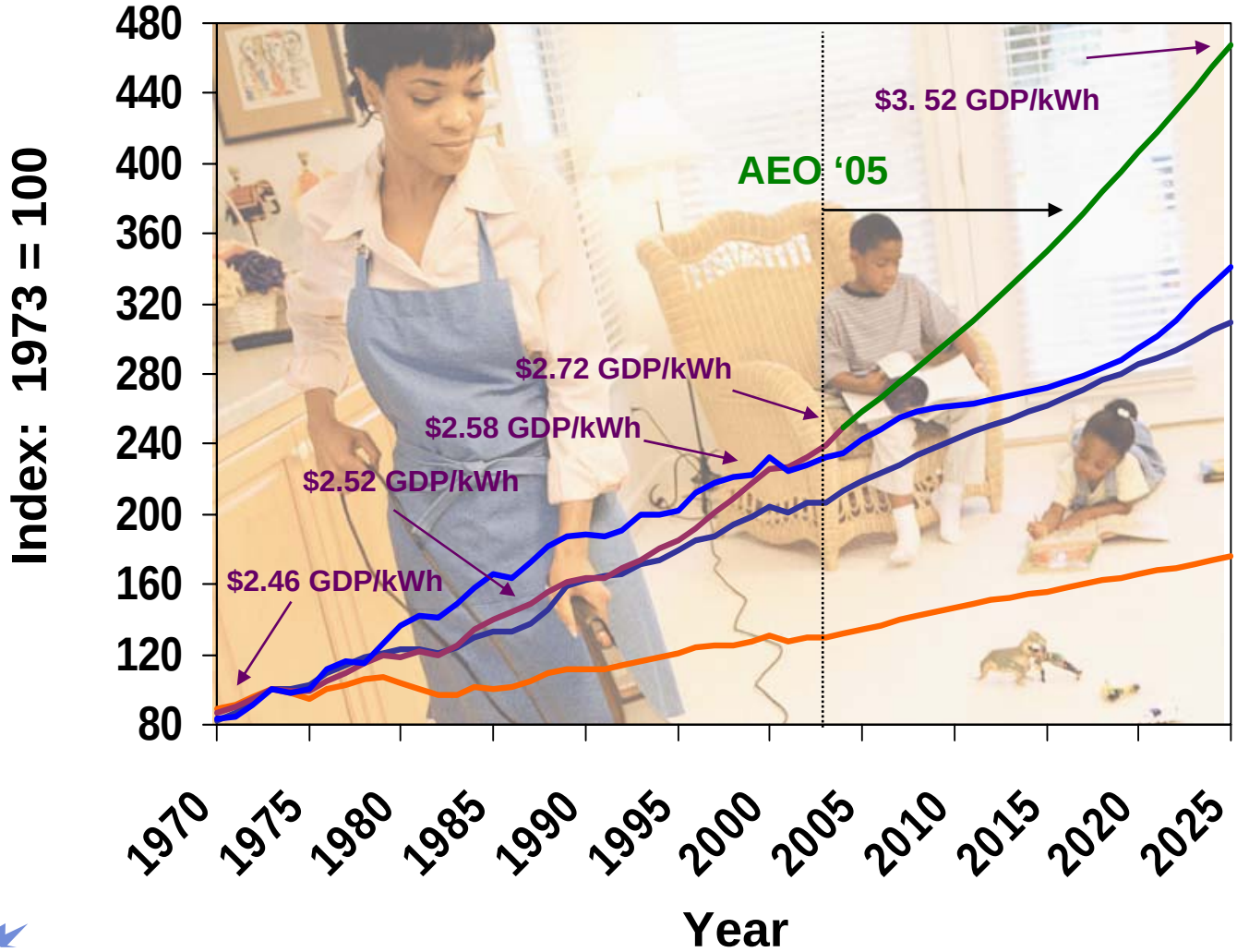
World Resources Institute Database, accessed September 1, 2005
http://earthtrends.wri.org/searchable_db/

Rapidly Increasing Dependence on Energy Imports



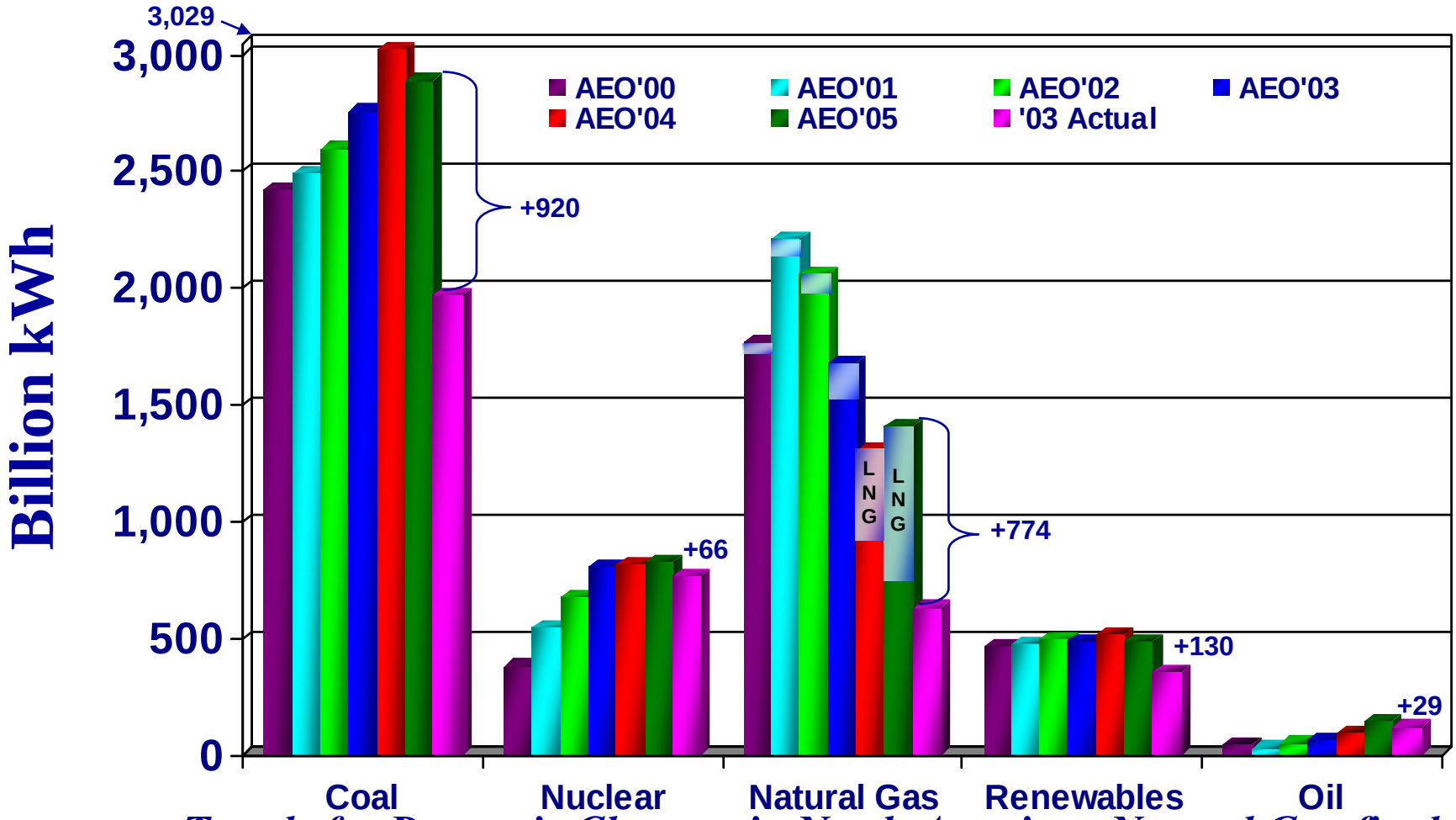
Foreign Energy Imports Growing Due to Oil and Natural Gas

Energy Use Compared to Economic Growth



GDP: History - U.S. DOC, Bureau of Economic Analysis; Forecast - Annual Energy Outlook 2004
Energy & Electricity: EIA, Annual Energy Review 2002; Annual Energy Outlook 2004

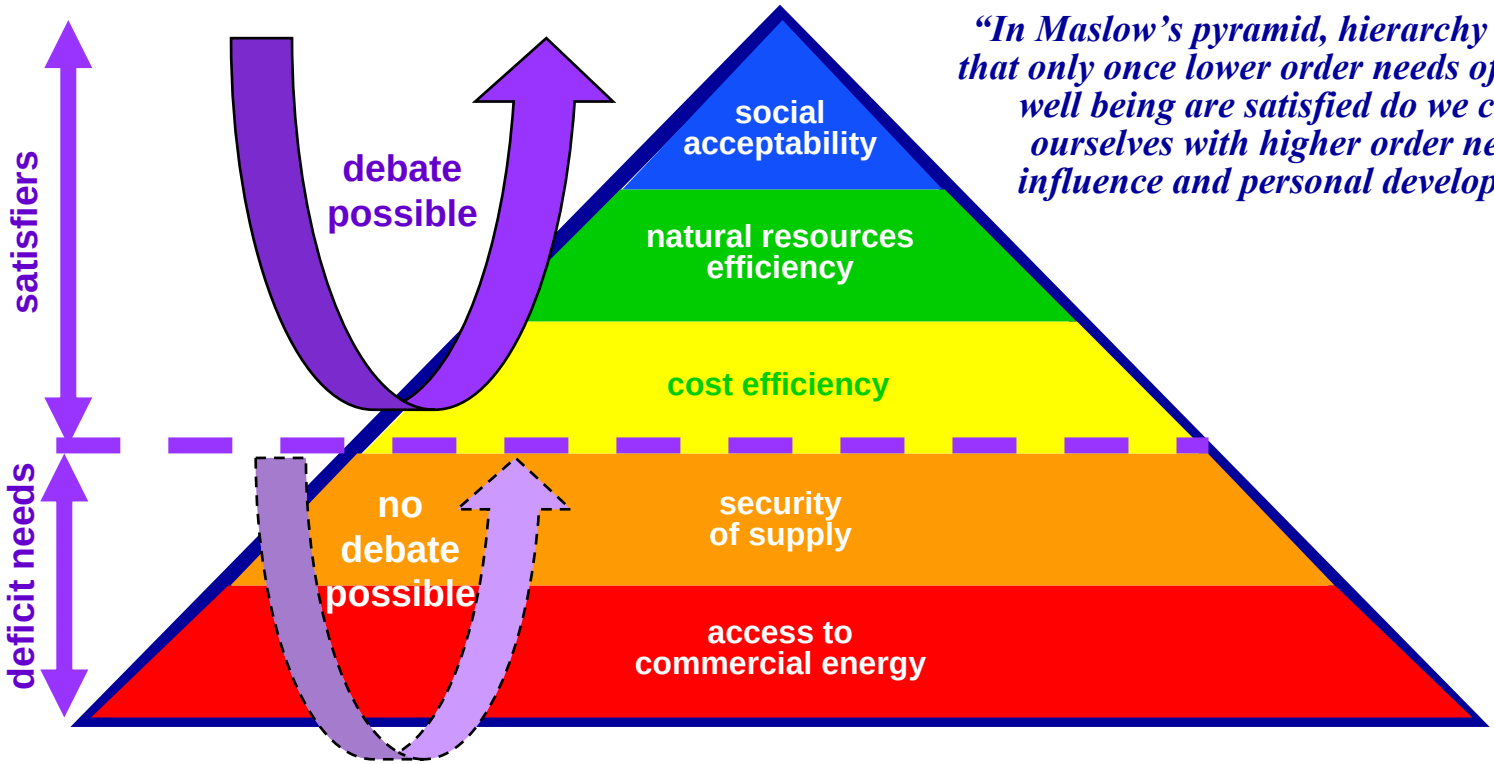
AEO Estimates of Generation Fuel Sources by 2025



Trends for Dramatic Changes in North American Natural Gas-fired Generation Forecasts; LNG Acceptance Begins to Displace Coal in AEO'05

EIA, Annual Energy Outlook 2000, 2001, 2002, 2003, 2004 and 2005
** - AEO 2000, 2001, 2002 trendline extrapolation from 2020 to 2025*

Energy Policy Needs Pyramid

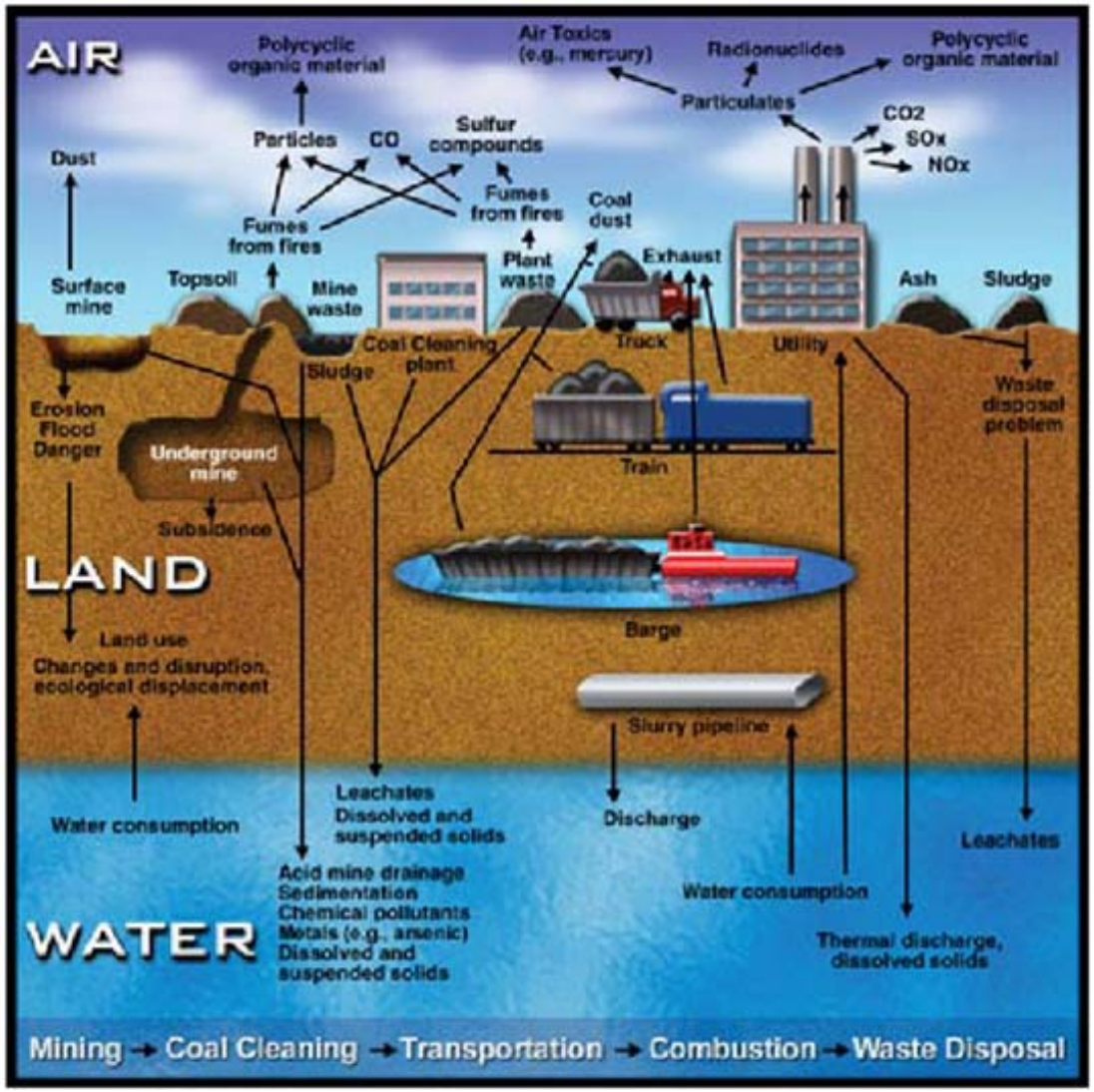


"In Maslow's pyramid, hierarchy illustrates that only once lower order needs of emotional well being are satisfied do we concern ourselves with higher order needs of influence and personal development."

"Can we observe similar patterns in historically observed energy priorities?"

Christoph W. Frei, The Kyoto Protocol – a victim of supply security? or if Maslow were in energy politics; Energy Policy 32 (2004) 1253-1256

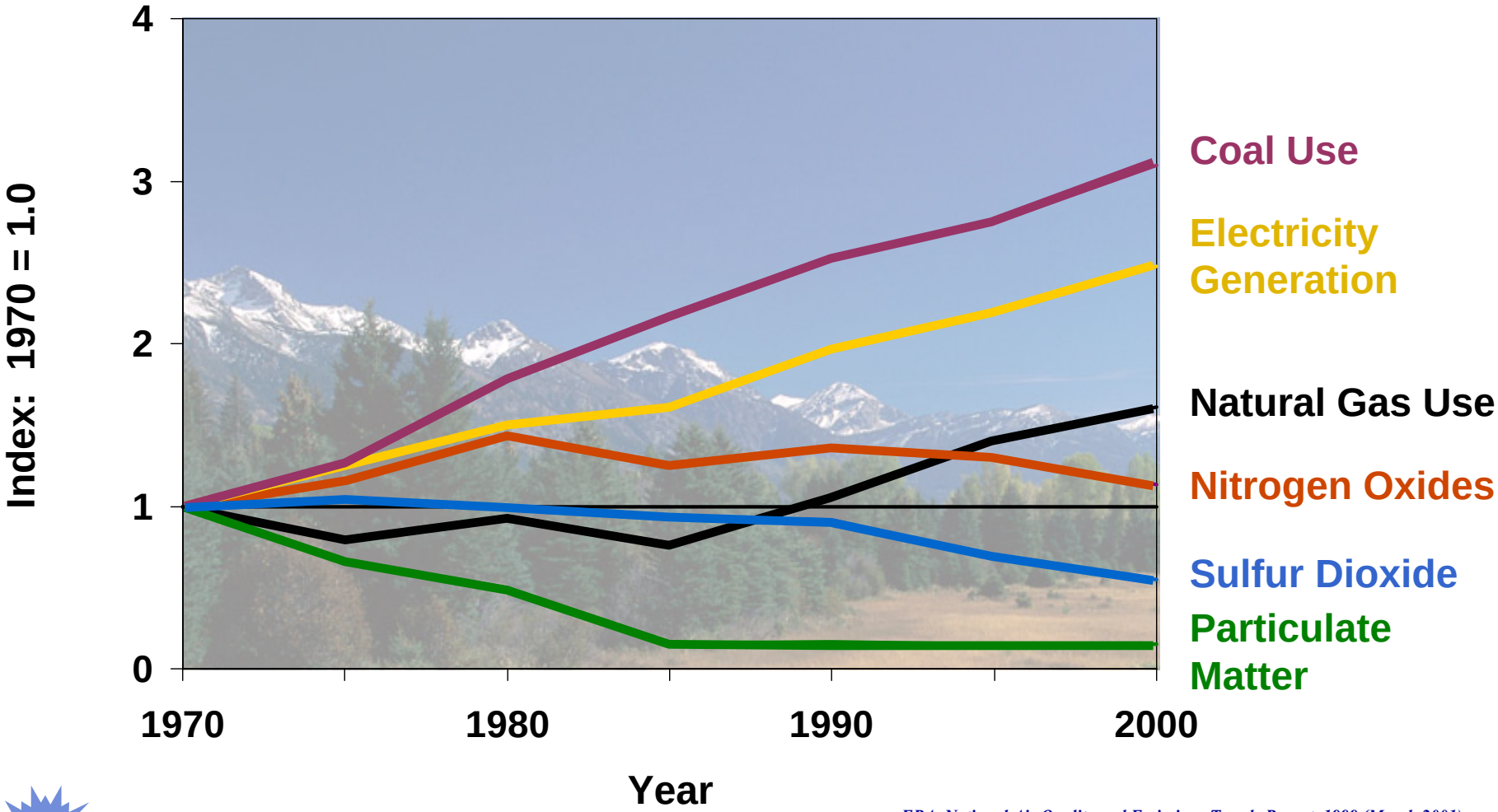
Broad Environmental Concerns About Coal



Cradle to Grave: The Environmental Impacts from Coal, Clean Air Task Force, Boston, MA,June 2001

Contaminant Emissions Down Sharply

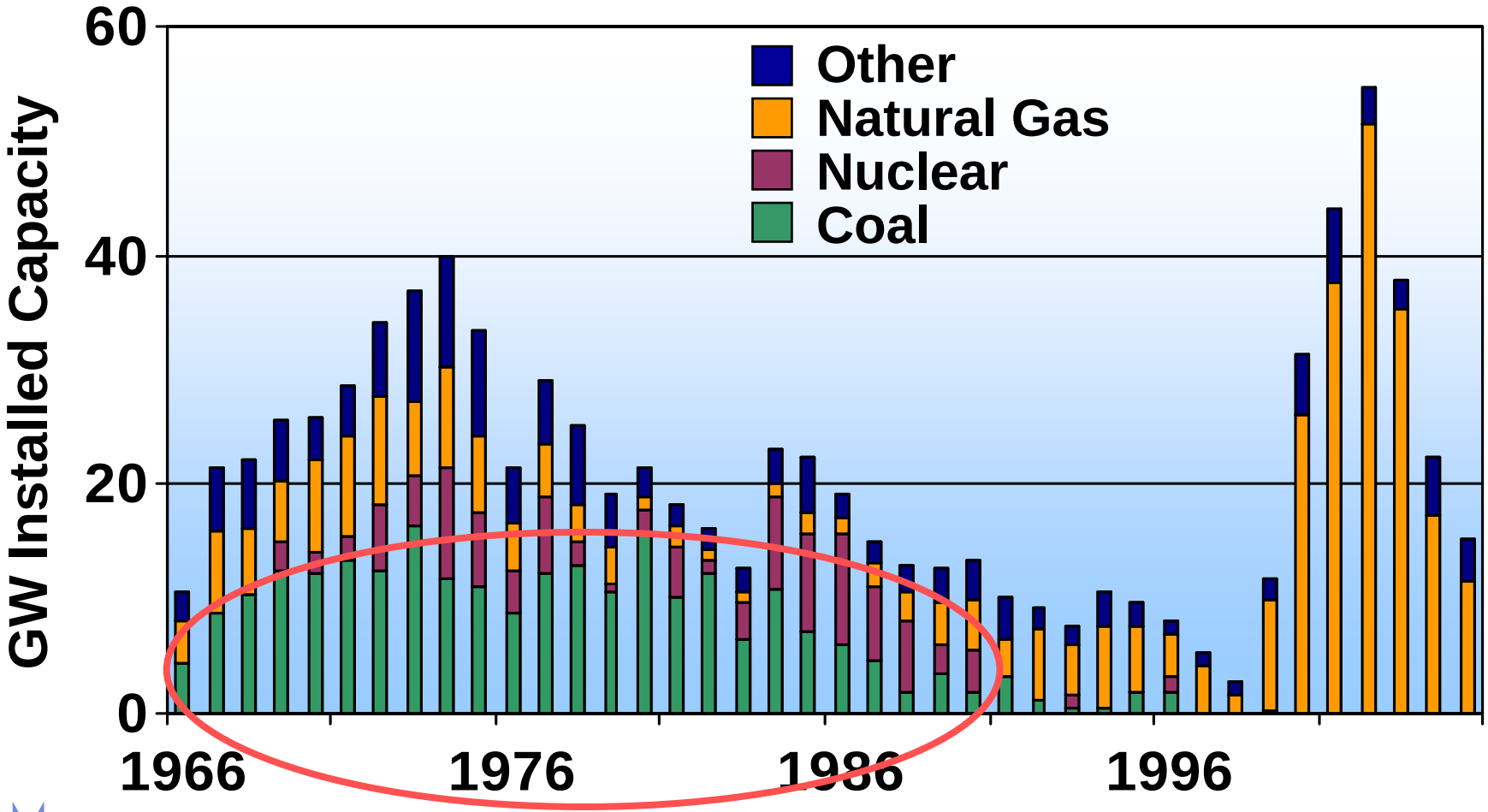
U.S. Power Plants



EPA, National Air Quality and Emissions Trends Report, 1999 (March 2001)
DOE, EIA Annual Energy Review

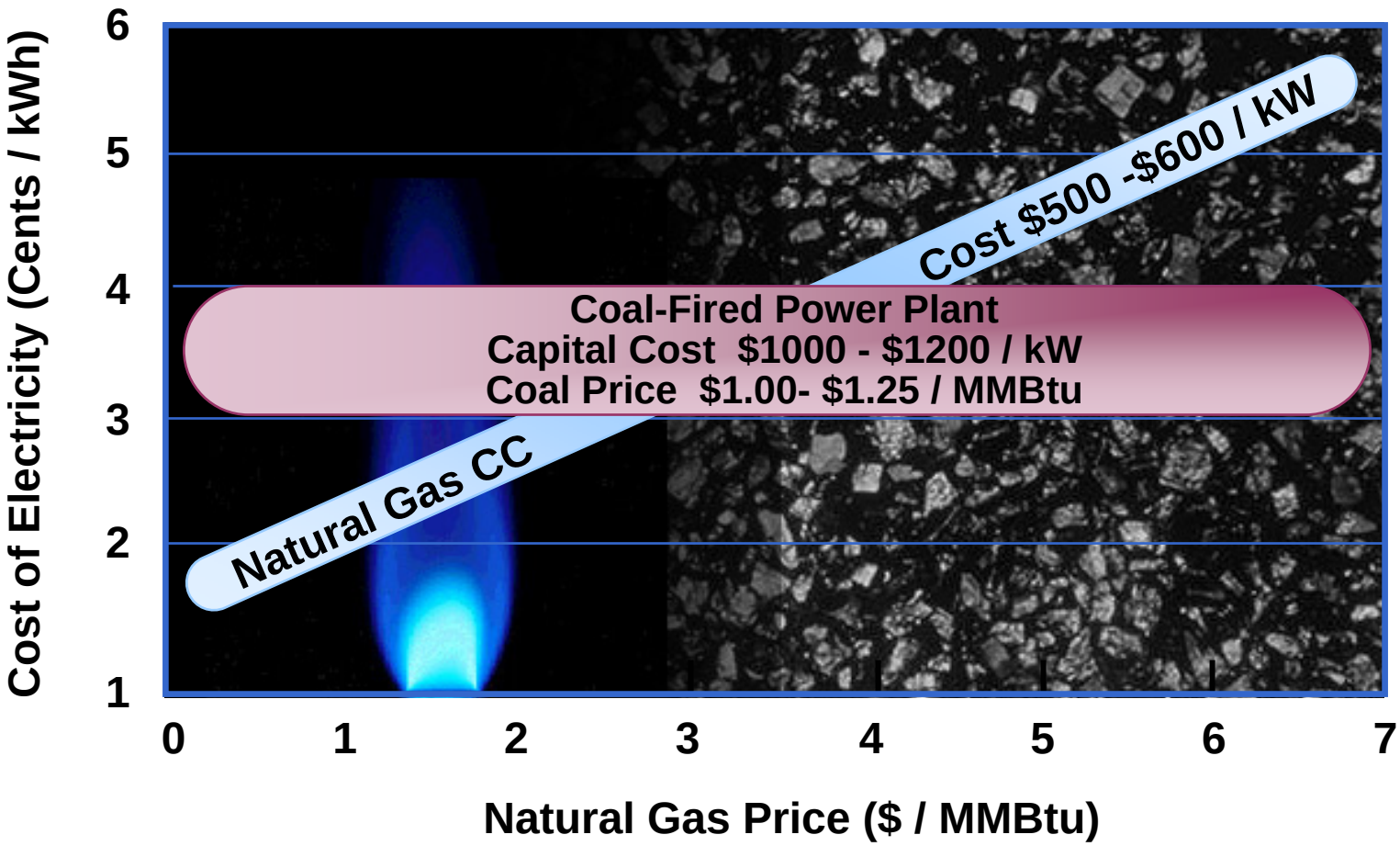
330 GW of Coal-Fired Capacity

Historic U.S. Generation Capacity Additions

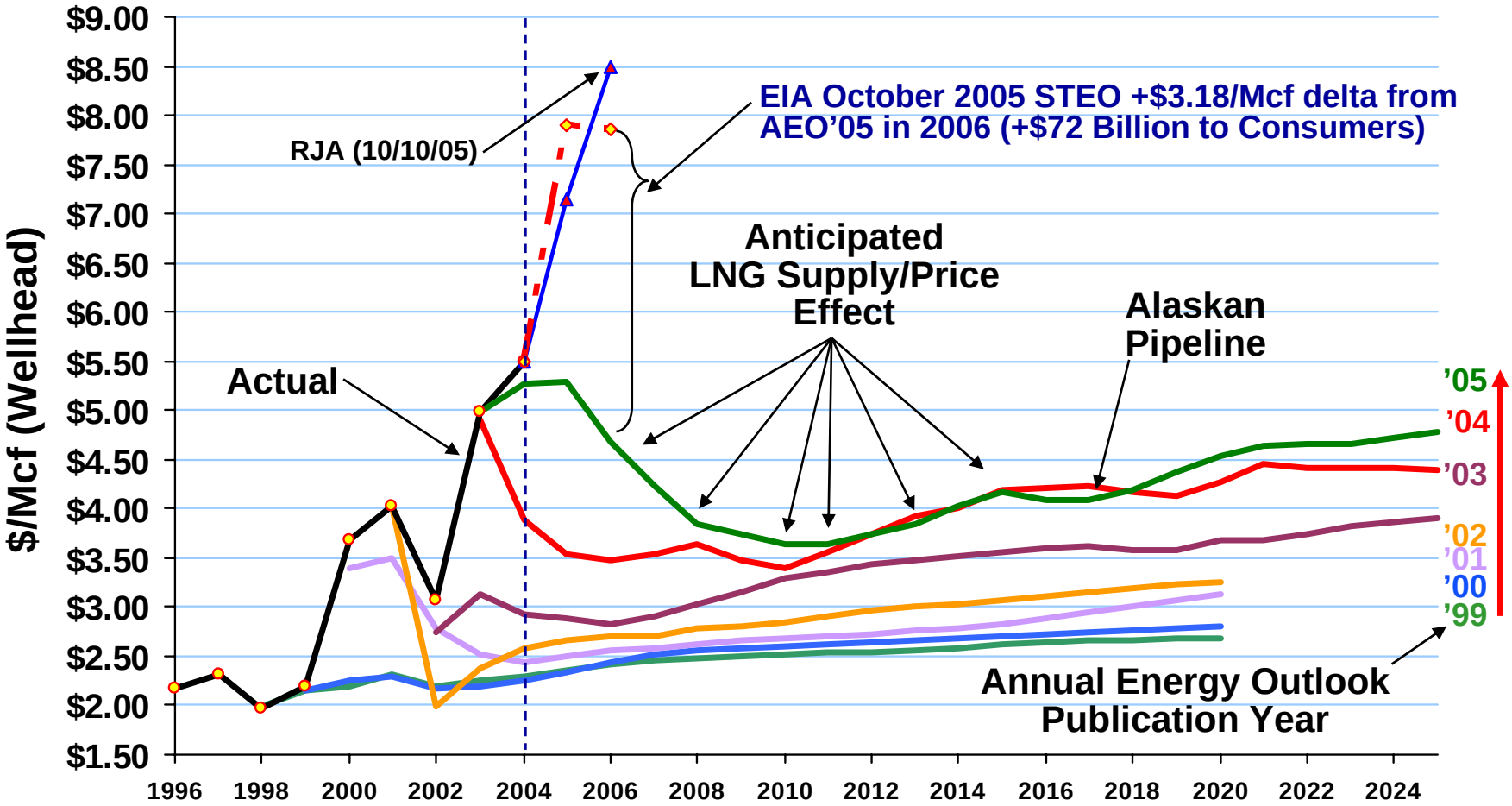


NPC Study 2003 based on EIA, Platt's , AEP

Coal Technologies Must Be Cost Competitive !



Increasing Trend in Natural Gas Price Forecasts



Forecasts of Near-term Price Troughs Hinder Coal Plant Development

EIA, Annual Energy Outlook 1999, 2000, 2001, 2002, 2003, 2004 and 2005
Short Term Energy Outlook, October 2005
Raymond James "Energy Stat of the Week" 10/10/05 (Henry Hub reduced by $0.75)

One Year Price Forecast Comparison
2001 - 2004


Energy
Industry Brief

J. Marshall Adkins

Wayne Andrews

Pavel Molchanov

EQUITY RESEARCH

February 7, 2005

RAYMOND JAMES

Raymond James' Energy "Stat of the Week"
How Predictable Are Oil and Gas Prices?

Time and time again, we encounter institutional investors who are convinced that investing based upon non-consensus oil and gas price forecasts is a loser's game. Most believe that there are simply too many variables and too much volatility to ever get an oil and gas price forecast right. We would agree that getting these forecasts exactly right is very difficult, if not impossible, in today's energy world. That being said, **we think that investors can make money by investing based upon directional moves in energy prices relative to consensus.**

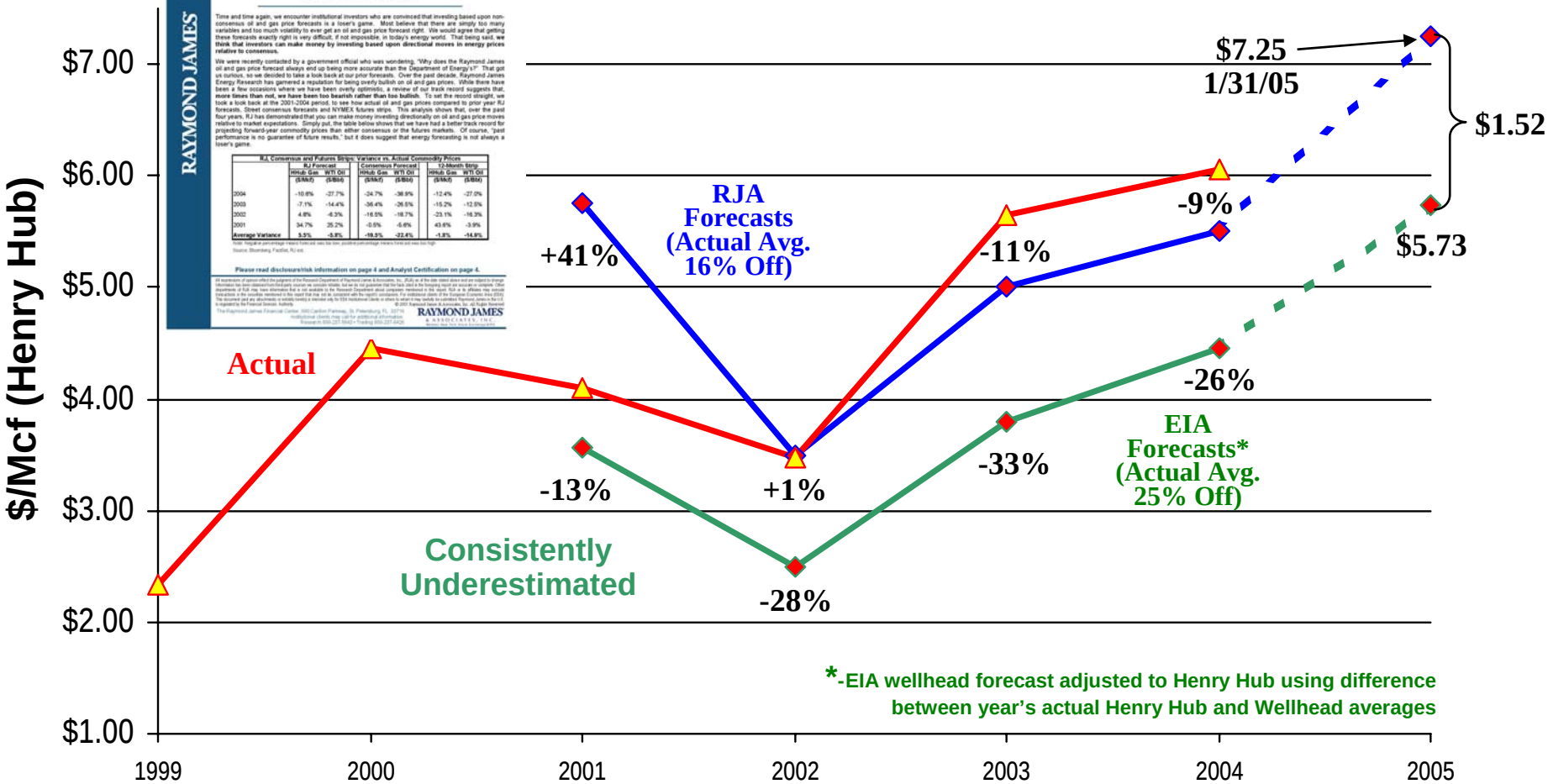
We were recently contacted by a government official who was wondering, "Why does the Raymond James oil and gas price forecast always end up being more accurate than the Department of Energy's?" That got us curious, so we decided to take a look back at our prior forecasts. Over the past decade, Raymond James Energy Research has garnered a reputation for being overly bullish on oil and gas prices. While there have been a few occasions where we have been overly optimistic, a review of our track record suggests that, **more times than not, we have been too bearish rather than too bullish.** To set the record straight, we took a look back at the 2001-2004 period, to see how actual oil and gas prices compared to prior year RJ forecasts, Street consensus forecasts and NYMEX futures strips. This analysis shows that, over the past four years, RJ has demonstrated that you can make money investing directionally on oil and gas price moves relative to market expectations. Simply put, the table below shows that we have had a better track record for projecting forward-year commodity prices than either consensus or the futures markets. Of course, "past performance is no guarantee of future results," but it does suggest that energy forecasting is not always a loser's game.

RJ, Consensus and Futures Strips: Variance vs. Actual Commodity Prices

	RJ Forecast		Consensus Forecast		12-Month Strip	
	HHub Gas ($/Mcf)	WTI Oil ($/Bbl)	HHub Gas ($/Mcf)	WTI Oil ($/Bbl)	HHub Gas ($/Mcf)	WTI Oil ($/Bbl)
2004	-10.8%	-27.7%	-24.7%	-38.9%	-12.4%	-27.0%
2003	-7.1%	-14.4%	-36.4%	-26.5%	-15.2%	-12.5%
2002	4.8%	-6.3%	-16.5%	-18.7%	-23.1%	-16.3%
2001	34.7%	25.2%	-0.5%	-6.6%	43.6%	-3.9%
Average Variance	5.5%	-5.8%	-19.5%	-22.4%	-1.8%	-14.9%

Please read disclosure/risk information on page 4 and Analyst Certification on page 4.

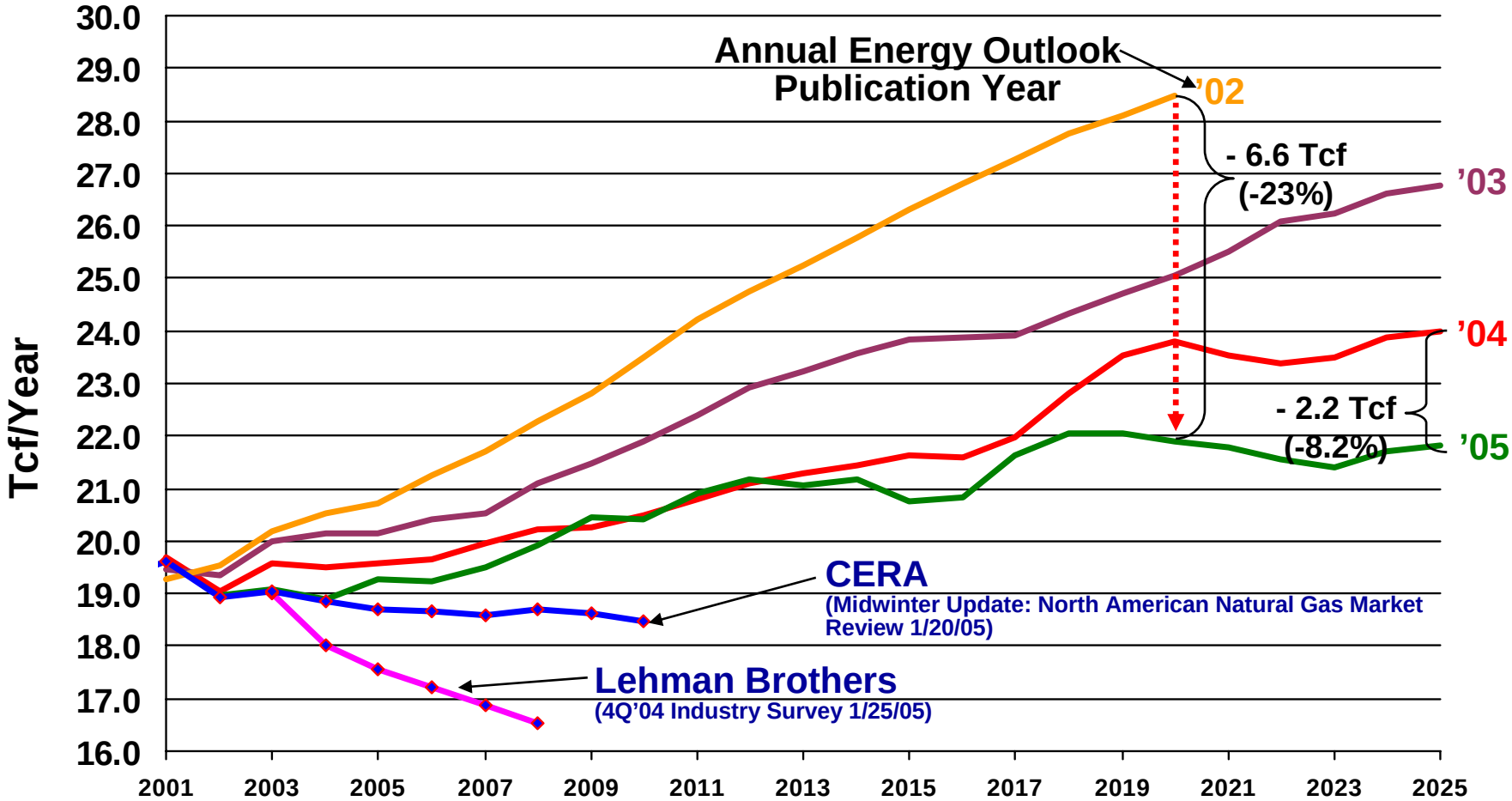
RAYMOND JAMES & ASSOCIATES, INC.



EIA Discrepancies in 12 Month Forecast
4 Year Average… Actual Price 25% Off Forecast (29% Last 3 Years)

Actual Henry Hub prices per January 2005 Short Term Energy Outlook
Raymond James "Stat of the Week", February 7, 2005

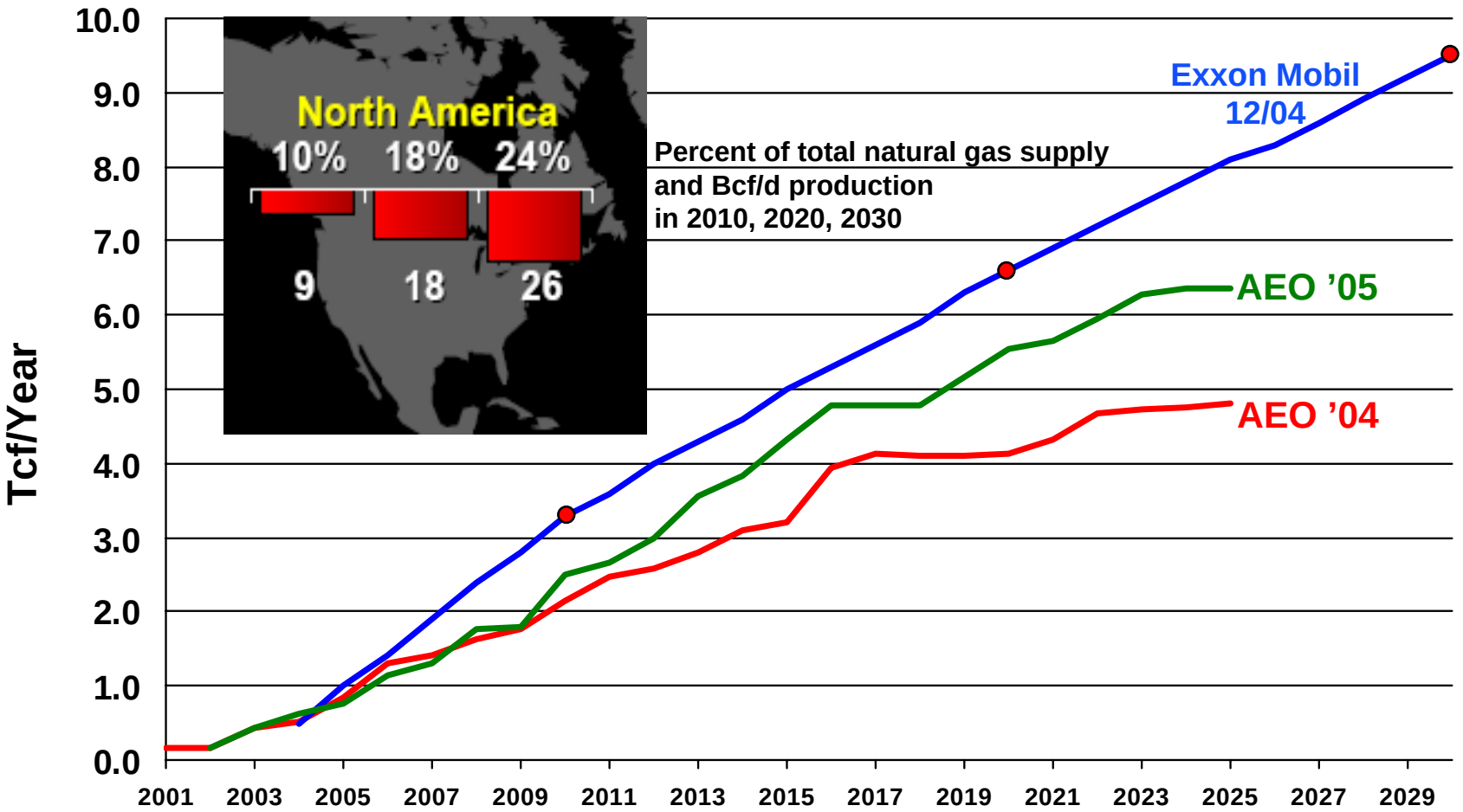
Declining Domestic Natural Gas Production Forecast



AEO'05 Domestic Production Reduced by an Amount Larger Than Alaskan Pipeline (>1.5 Tcf/yr in 2020)

Annual Energy Outlook 2002, 2003, 2004 and 2005

Exxon Mobil LNG Forecast

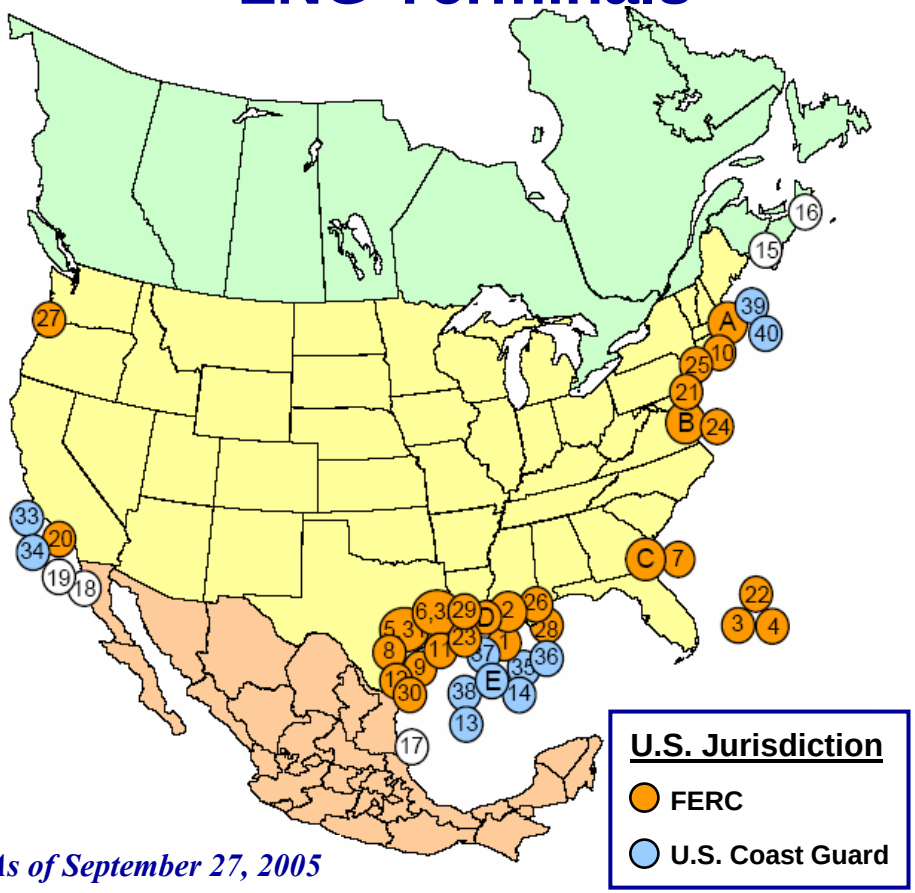


Developers' Perspectives Even More Aggressive

Reference: Exxon Mobil; The Outlook for Energy, A 2030 View; December 2004; http://media.corporate ir.net/media_files/irol/11/115024/presentations/xom_120204.pdf

Status of North American LNG Development

Existing and Proposed LNG Terminals



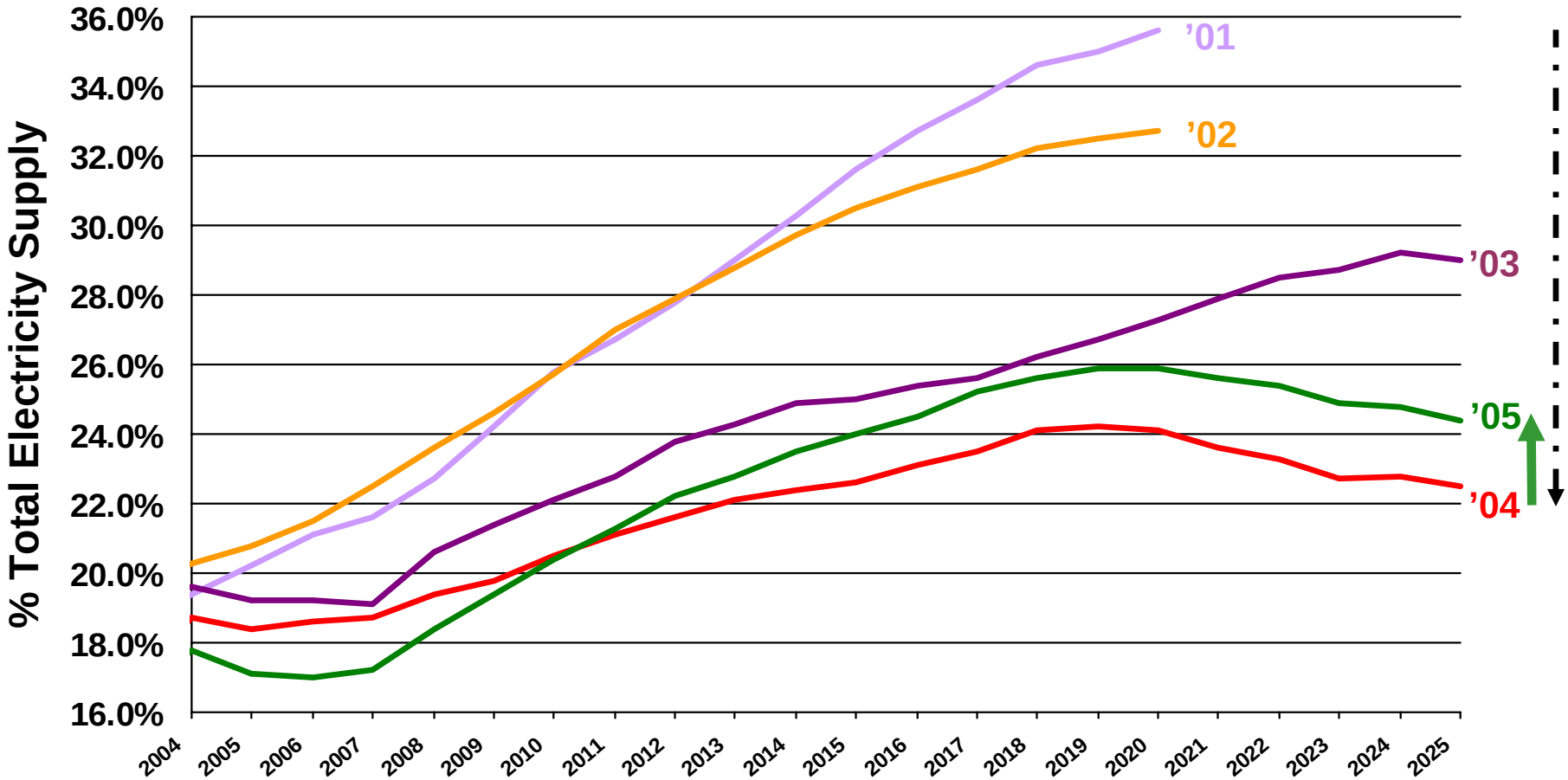
As of September 27, 2005

** U.S. pipeline approved; LNG terminal pending in Bahamas*

- 5 existing import terminals (including Energy Bridge)
- 19 FERC / Coast Guard / Canadian / Mexican approved sites
- 21 additional proposals
- 8.4 Tcf supply if all approved plants built
- EIA forecast for U.S. LNG = 6.4 Tcf by 2025

FERC Office of Energy Projects
http://www.ferc.gov/industries/lng/indus-act/exist-prop-lng.pdf

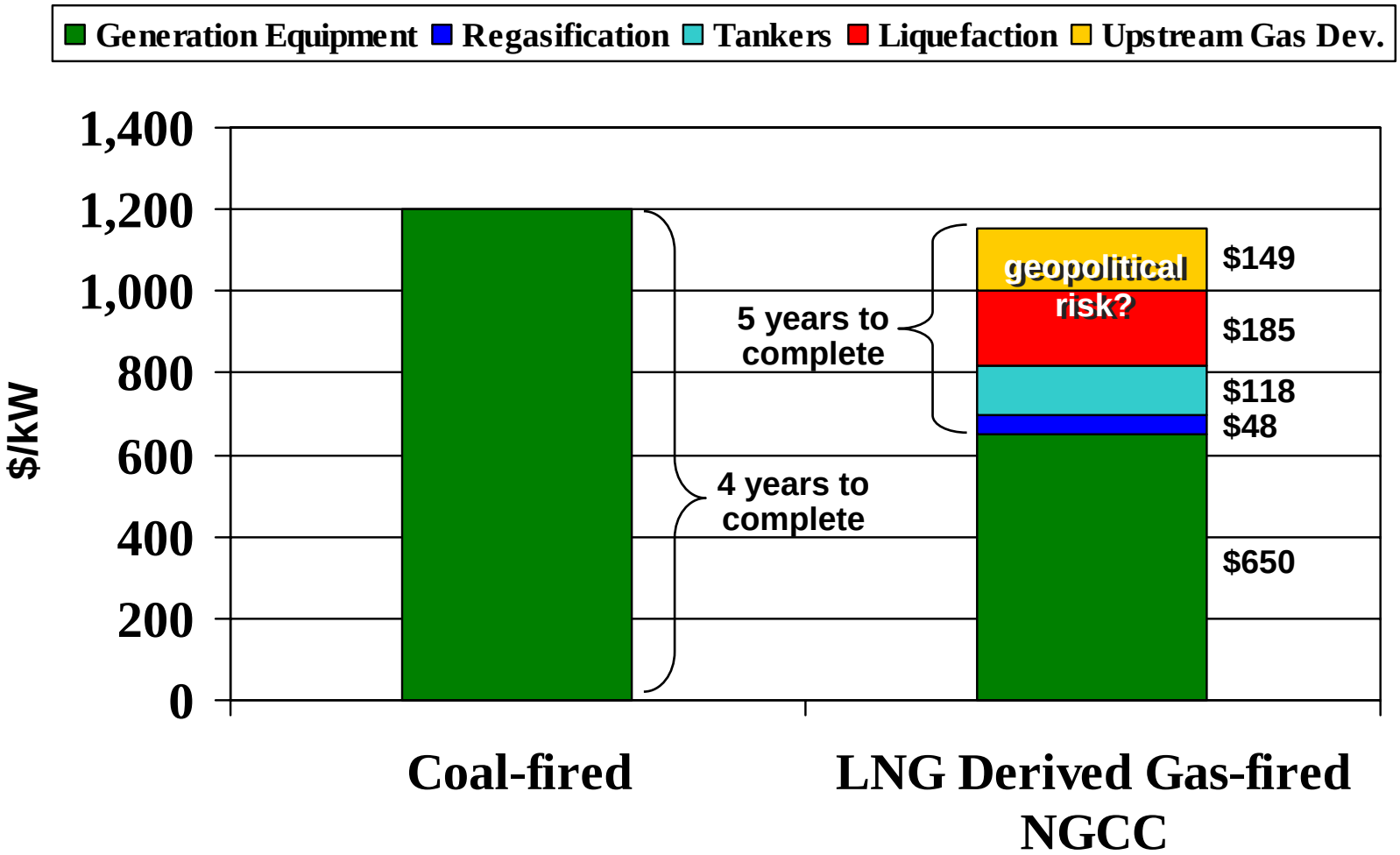
Resurgence In Gas-fired Generation's Contribution to Electricity Production



Increased Based on "Revisions in Relative Capital Costs and Efficiencies for New Coal- and Gas-fired Generating Capacity"

EIA, Annual Energy Outlook 2001, 2002, 2003, 2004 and 2005

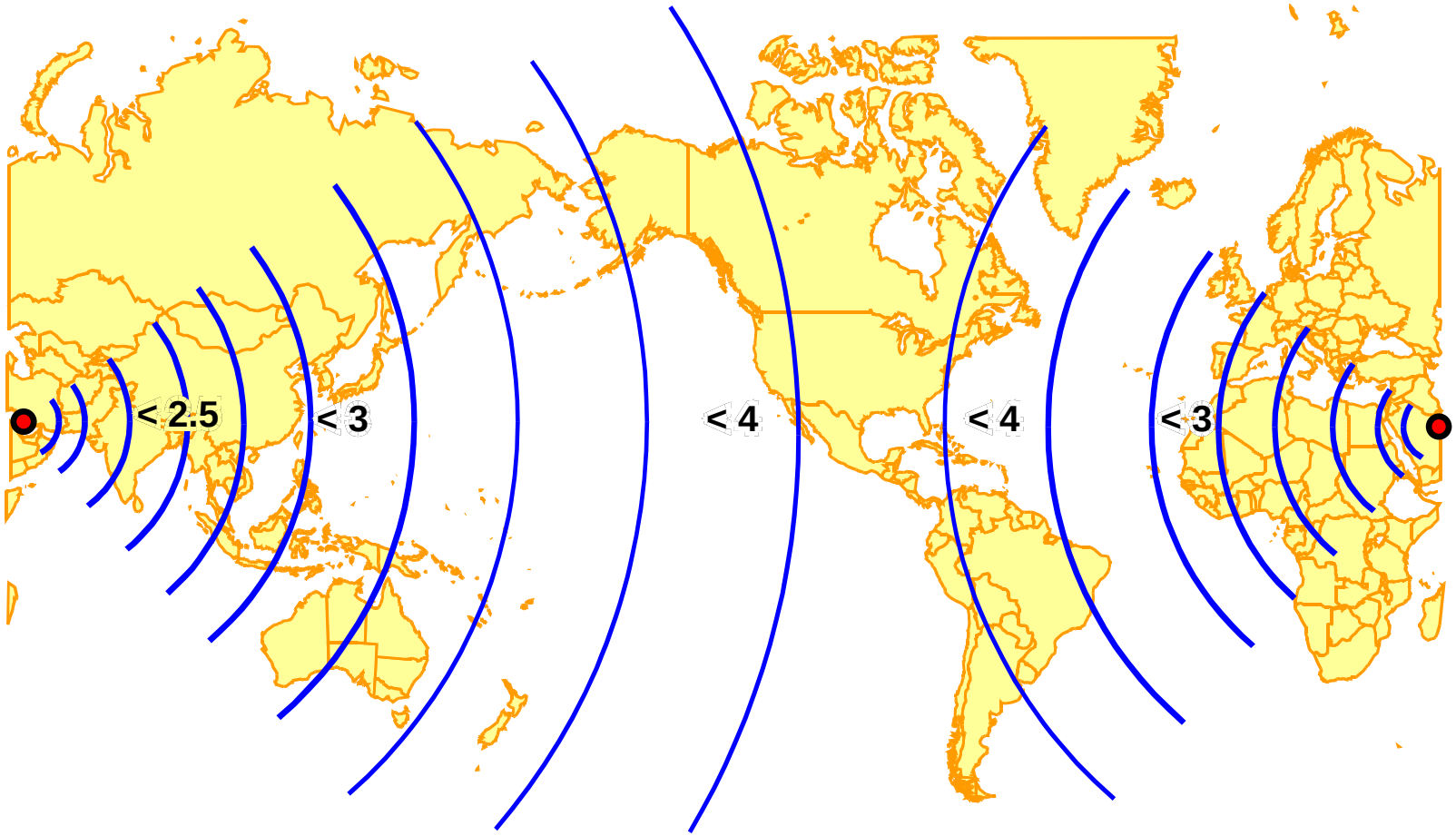
Are Risks of LNG Capital Costs Considered?



New Gas-fired Generation Will Be Increasingly Required to Secure a Reliable Fuel Source, Adding ≈ $500/kW

References: QatarGas III Costs, Gulf States Newsletter, April 19, 2004;
Calculated Based on 375 Bcf/y LNG Train per 10,000 MW Gas-fired Capacity;
Deutsche Bank, Global LNG, Exploding the Myths, July 22, 2004

U.S. is Poorly Positioned on Price for Delivery of LNG ($/mmbtu)



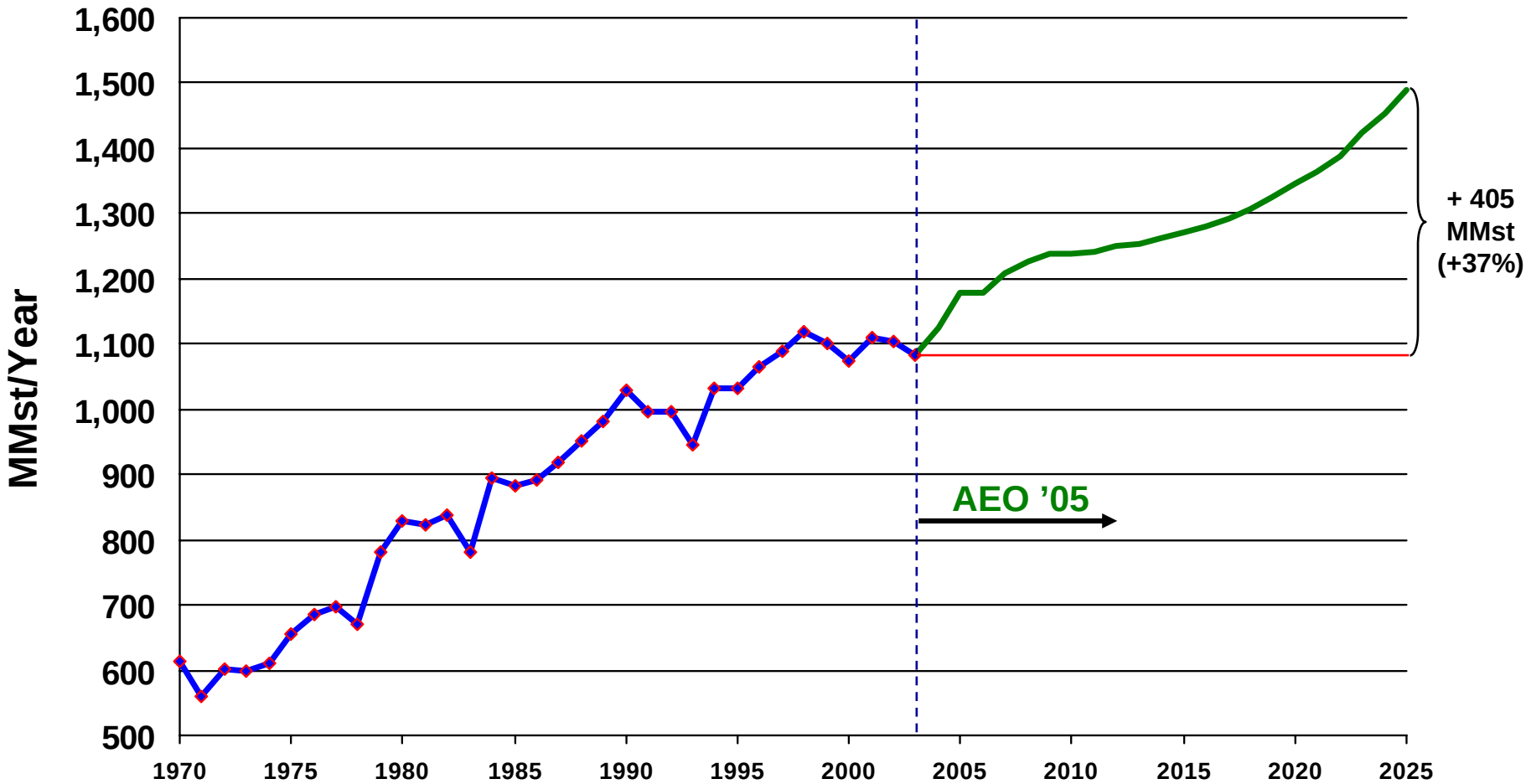
Graphic: Cambridge Energy Research Associates.
31001-10

Conclusion: Gas-fired Generation Growth Overestimated; Cost Underestimated

- Generation growth, at one time expected to represent 1,200 BkWh, reduced to 100 BkWh, absent imported LNG
- Costs, expected to represent significant advantage over coal at $500/kW, left out import costs-U.S. pays highest shipping-raises cost competitiveness concern
- Roughly 2 LNG supply systems (365 Bcf/year each) required to support 20,000 MW of NGCC
- ConocoPhillips Qatar Gas III: $5 billion for 1 Bcf/day of gas (in 2010)*
- Actual cost of gas-fired generation -- $500/kW for plant plus $500+/kW for fuel supply infrastructure

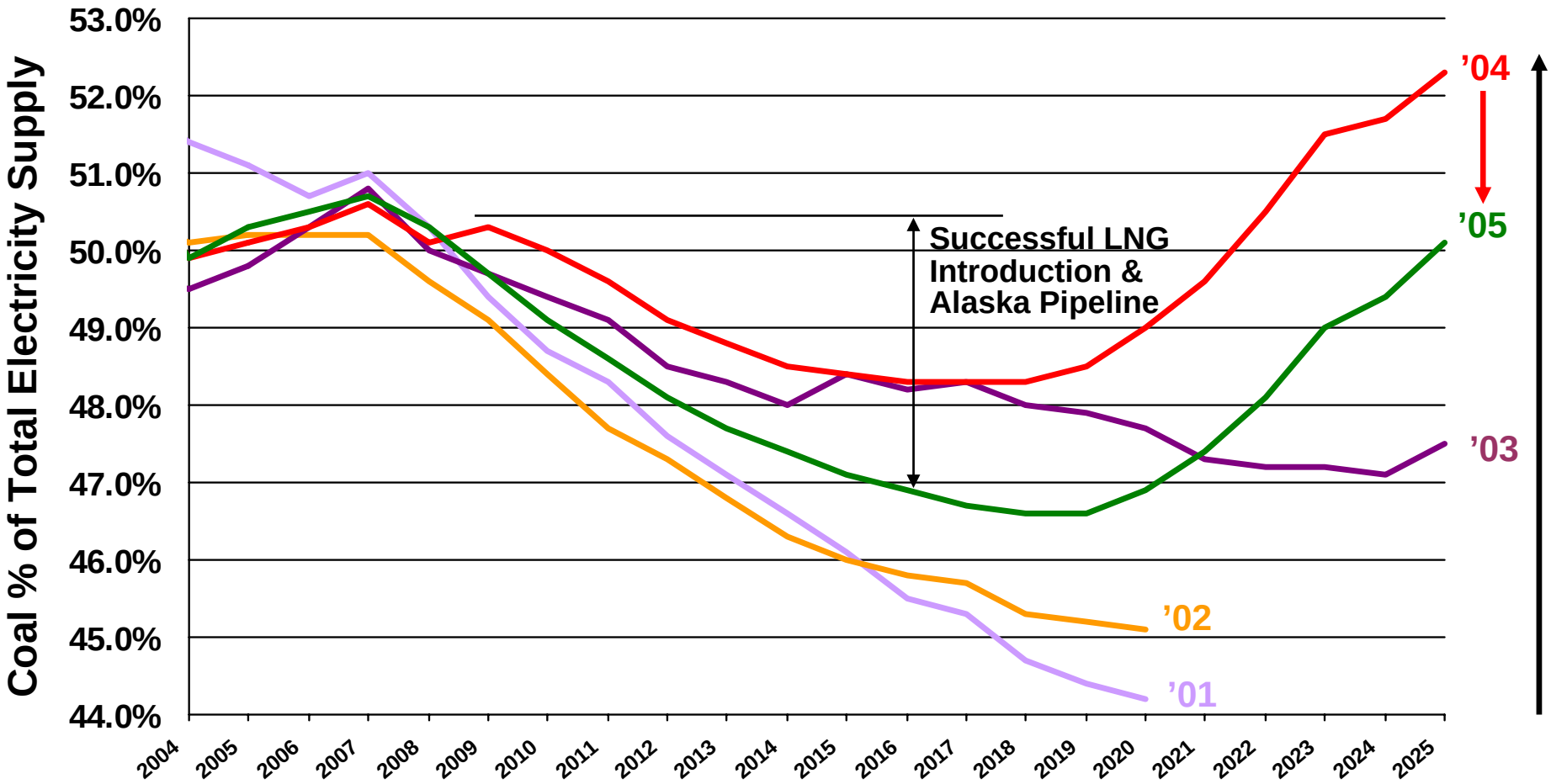
* *Matthew Simmons Coronado Club Speaker's Luncheon, Houston, Texas, June 9, 2004*

Coal Production History And Forecast



Still A Significant Challenge For Nation's Mining and Transport Industries

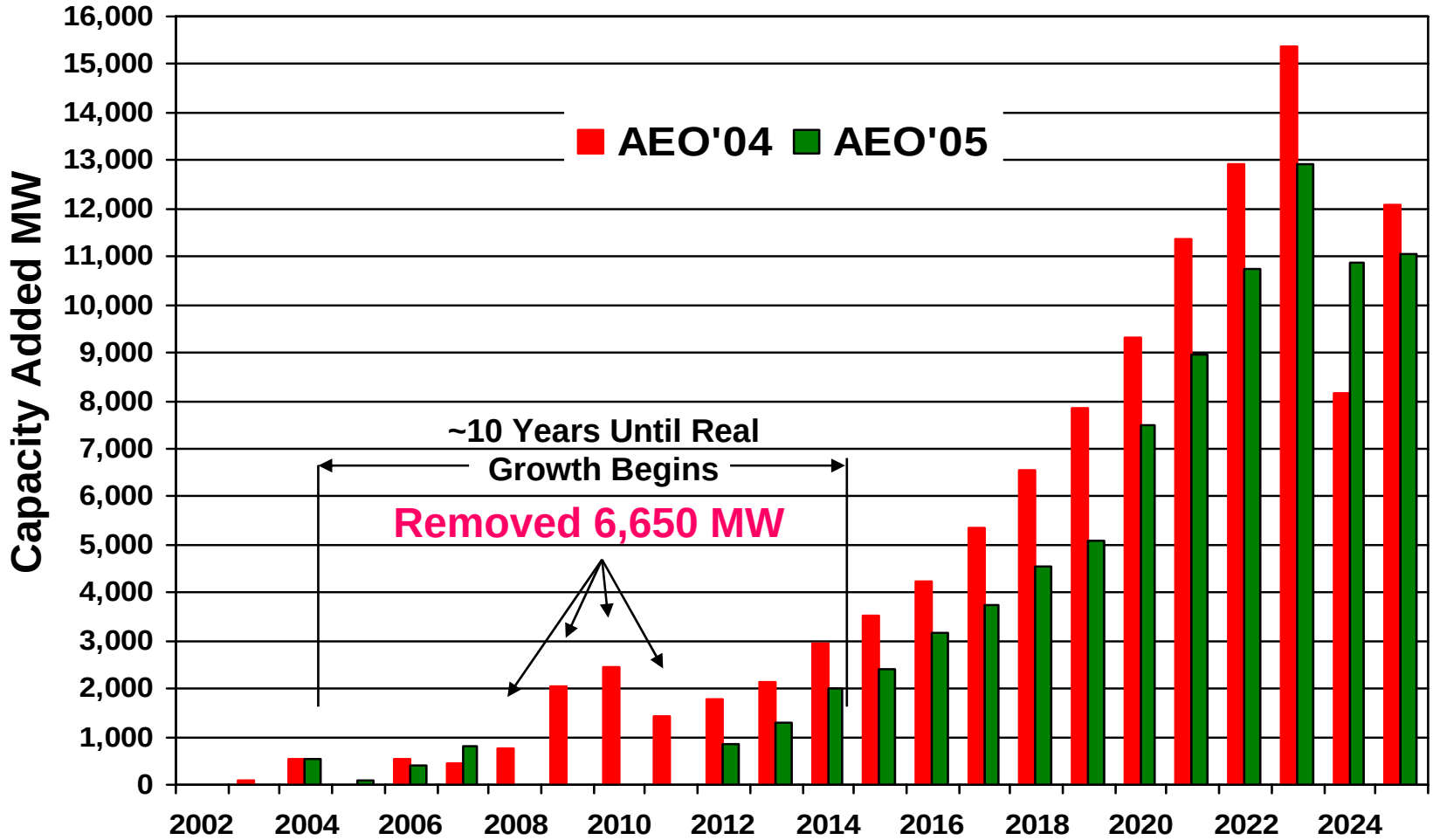
Pull-back In Coal-fired Contribution to Electricity Production



Reflects a (Model) Preference for Imported LNG Over Coal-fired Generation

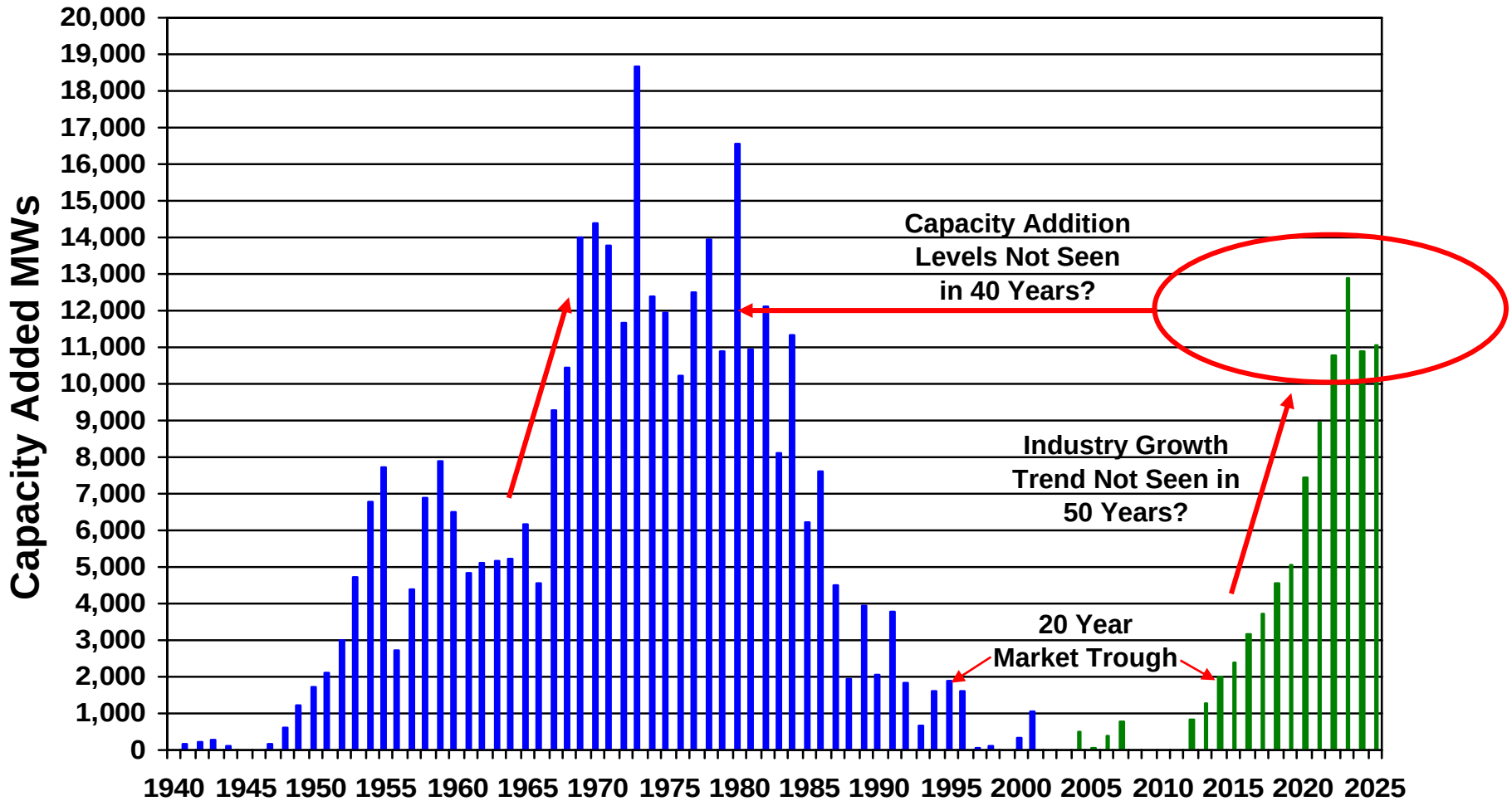
EIA, Annual Energy Outlook 2001, 2002, 2003, 2004 and 2005

New Coal-fired Capacity Forecast
AEO'04 vs. AEO'05



Another Decade of Insufficient Domestic Market Scale to Support 13,000 MW/Year Industry

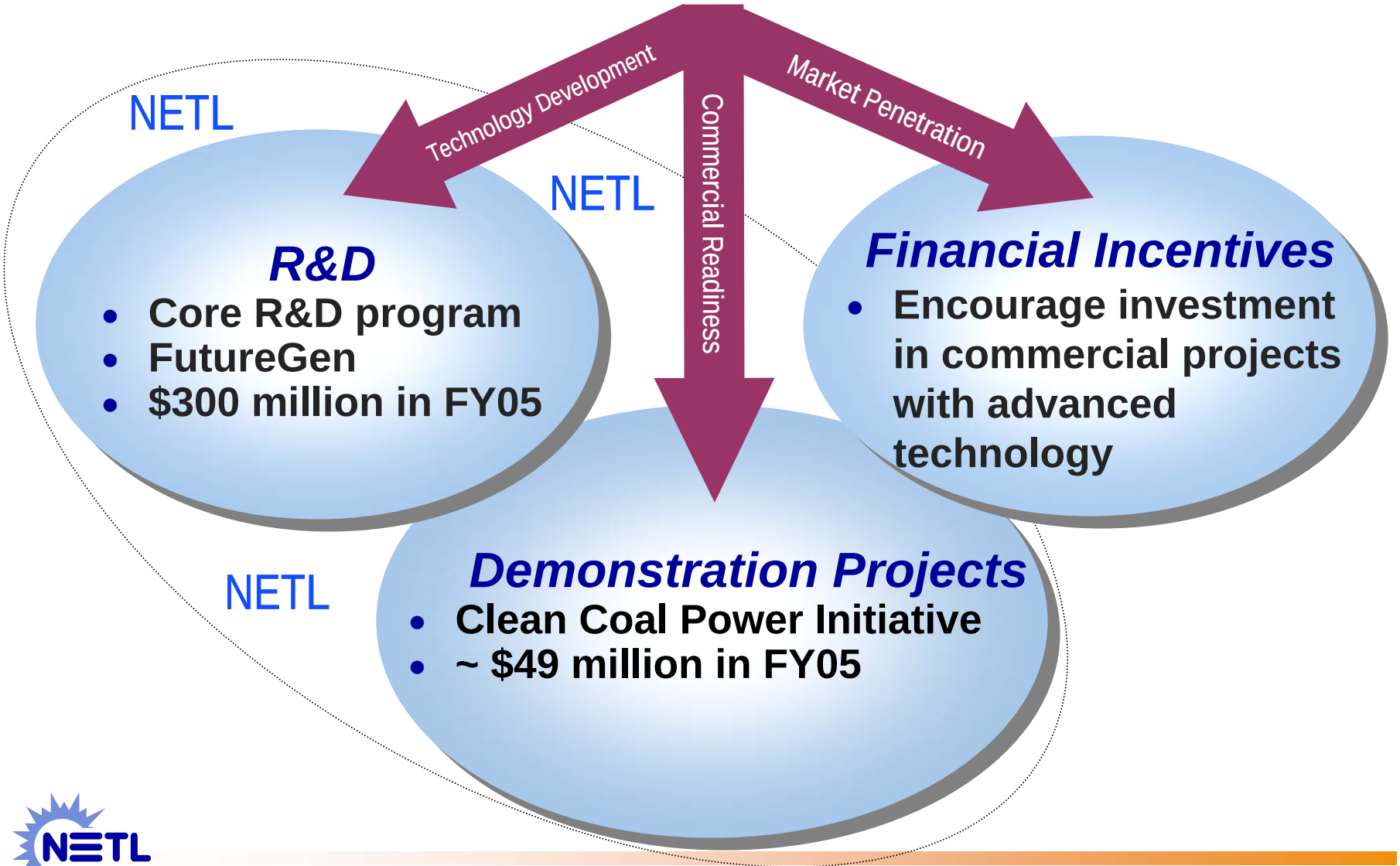
Coal Capacity History and Forecast AEO'05



Will Nation's Industry be Prepared and Capable of Meeting This Coal Plant Forecast?

Forecast - Annual Energy Outlook 2005
Historic Data - UDI 2001 Operating Data

Government's Coal R&D Investment Strategy



Clean Coal Technology Development Must Address Near and Long Term Energy Needs

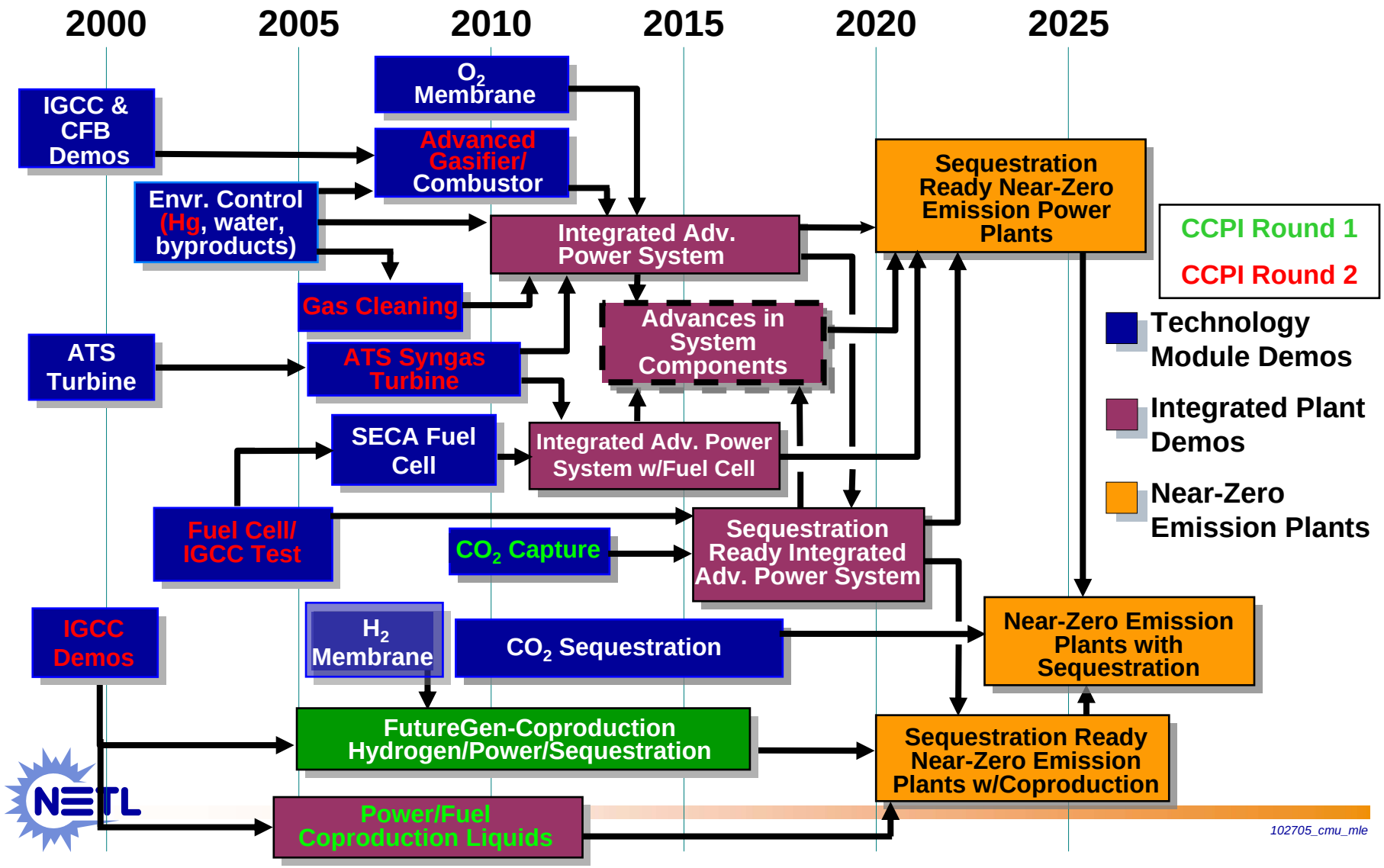
Short-term Needs:

- **Maximize existing fleet service**
- **Provide advanced technologies for new, near term plants**
- **Provide technology bridge to transition to future plants.**

Long-term Needs:

- **Zero emissions coal technology**
- **Reliable coal technology**
- **Cost competitive coal technology**
- **Technology for Hydrogen Economy**

Integrated Technology Roadmaps Drive R&D



Performance Targets Keep R&D Focused & On Track

(Represents best integrated plant technology capability)

	Reference Plant	2010	2020
Plant Efficiency (HHV)	40%	45-50%	50-60%
Availability	>80%	>85%	≥90%
Plant Capital Cost $/kW	900 – 1300	900 – 1000	800 – 900
Cost of Electricity ¢/kWh	3.5	3.1	<3.0

FE/NETL Coal Program Components

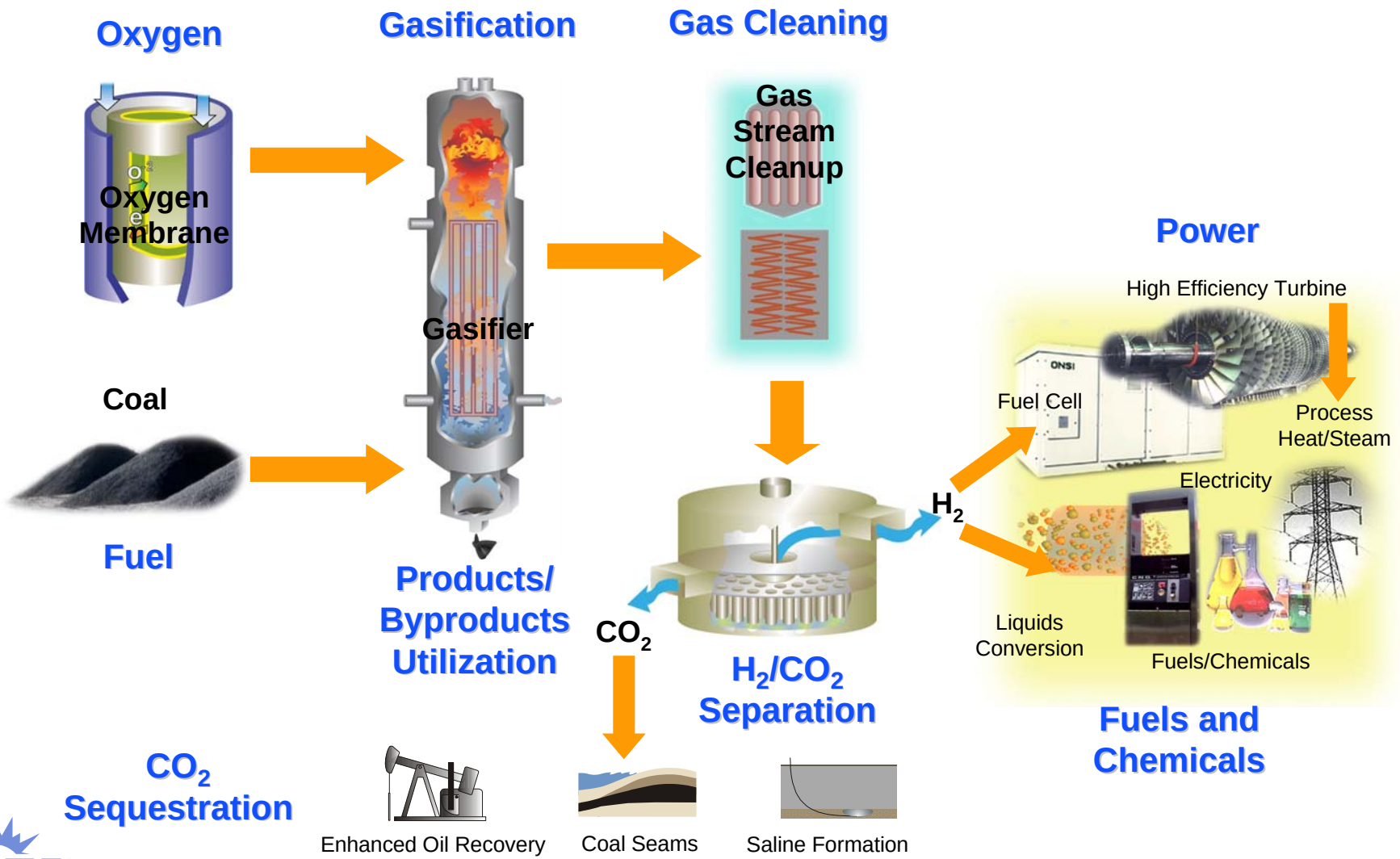
R&D Program FY05 ($300 M)

- ***Central Systems (~$85M)***
  - *Innovations for Existing Plants (~$19M)*
  - *IGCC (~$46M)*
  - *Combustion (~$5M)*
  - *Turbines (~$15M)*
- ***Distributed Generation (~$77M)***
- ***Sequestration R&D (~$45M)***
- ***Fuels (~$32M)***
- ***Advanced Research (~$43M)***
- ***FutureGen (~$18M)***

Demonstration Program

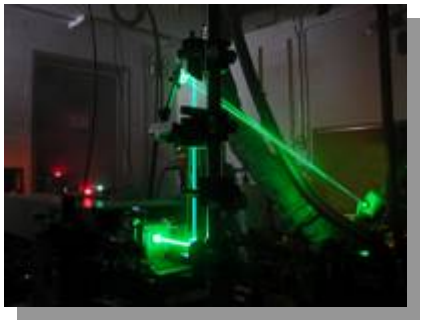
- ***Clean Coal Power Initiative (~$49M)***

Integrated R&D Developments Required for Zero-Emissions Coal Systems



Conduct Intramural Research

NETL Focus Areas



Energy System Dynamics

- Fuel Cells / Hybrids
- Gas Combustion
- Carbon Capture
- FutureGen

Geological and Environmental Systems

- Carbon Sequestration
- Clean Air Technology
- Water & Coal Utilization Byproducts

Computational and Basic Sciences

- Computational Chemistry
- Device Simulation
- Advanced Fuel Systems
- Gas Hydrates

University/NETL R&D Initiative

A New Collaborative R&D Effort

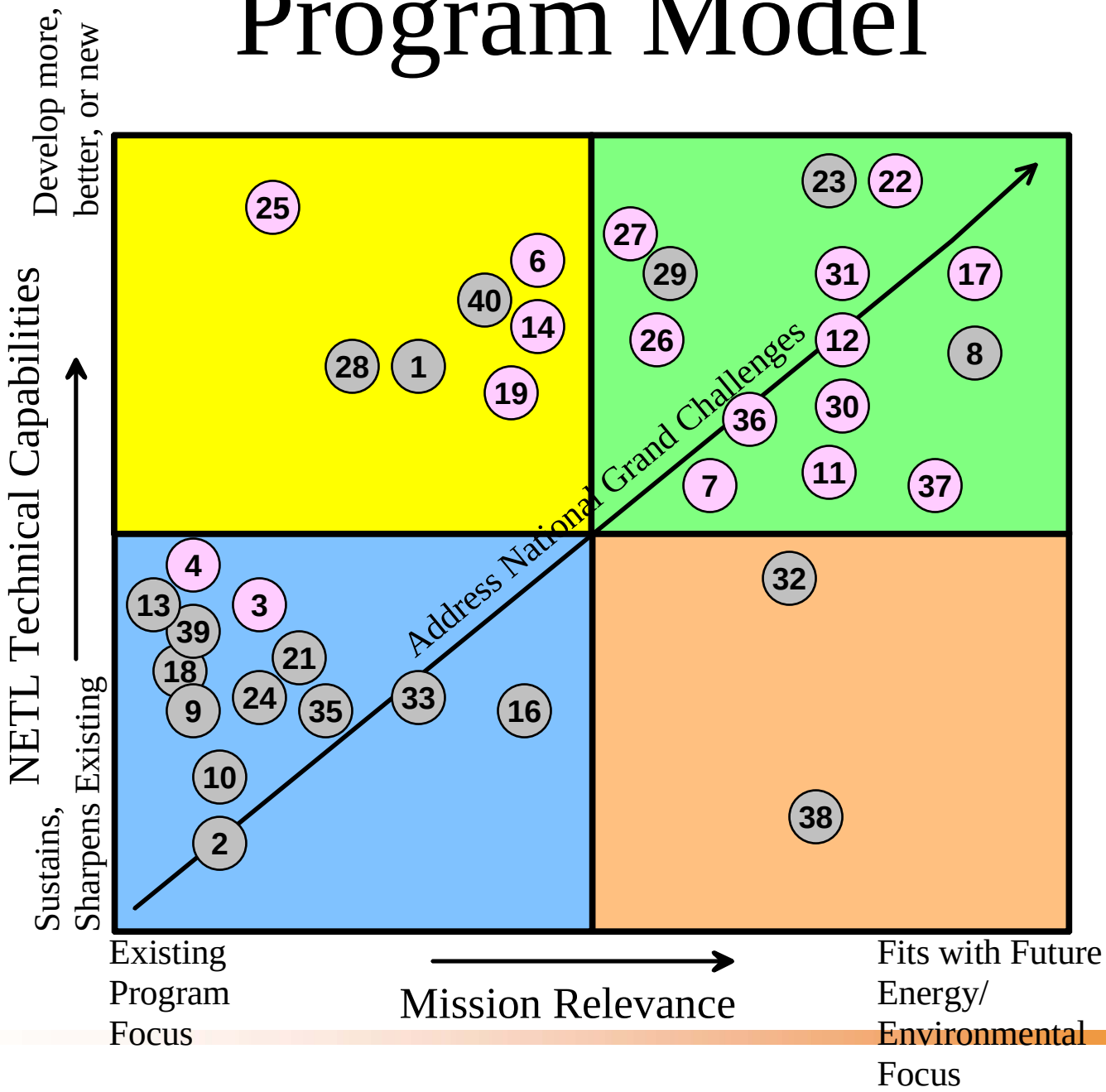
Collaboration ≠ Grant Program

<u>Relationships</u> that provide opportunities for mutual benefit and results beyond what any single organization or sector could realize alone.

Leader to Leader Institute-2005

17 Projects Recently Selected
~ $2.5M; CMU gets 5

Program Model



Advanced Research - Power Systems

Ingenuity, innovation and implementation

Objectives

- Bridge gap between basic and applied research
- Foster development of innovative systems
- Improve efficiency and environmental performance, reduce cost

Computational Energy Sciences
Scientific Consortium, visualization, Modeling, and simulation

Advanced materials consortium for ultra-supercritical power plants

R&D Activities

- ***Advanced Materials***
- ***Novel Sensors & Controls***
- ***Adv Power Plant Simulations***
- ***Bioprocessing Technologies***
- ***Educational Foundation Programs***

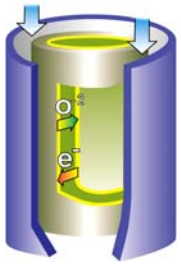
IGCC Future Challenges

- Lower *capital cost*
  - **$200 to $400 / kWe reduction**
- Greater *reliability*
  - **Single train availability > 85 to 90%**
- Improved *efficiency*
  - **60% HHV**

- Near- *zero emissions* (including CO_2)
  - **Improved separation/capture technology**
  - **Low cost, safe, permanent sequestration options**

IGCC Technology Issues

Oxygen Membrane



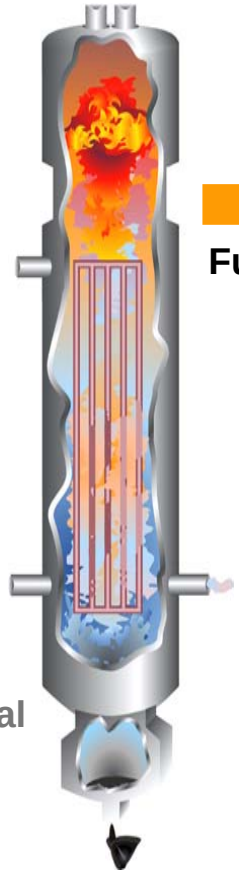
Oxygen

Durability of Membrane
Integration with Overall Process

Low-rank Coal

Coal

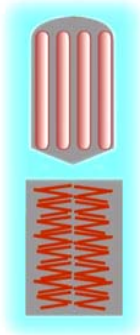
Injector Reliability
Single Train Availability
Durability of Refractory Material
Durability and Accuracy of Monitoring Devices
Alternative Feedstocks
Feed System Reliability
Heat Removal
Temperature Measurement & Control



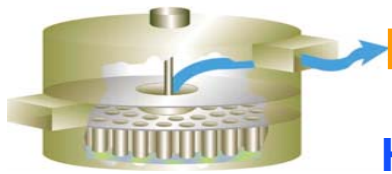
Gasification

Fuel Gas

Gas Cleaning



Cost-Effective Multi-Contaminant Control to Ultra-Clean Specifications
Moderate Temperature
Hg Removal at Elevated Temperatures
Integrated Specifications with Downstream Process Requirements
Integration with NOx Reduction Processes



Hydrogen

H_2/CO_2 Separation

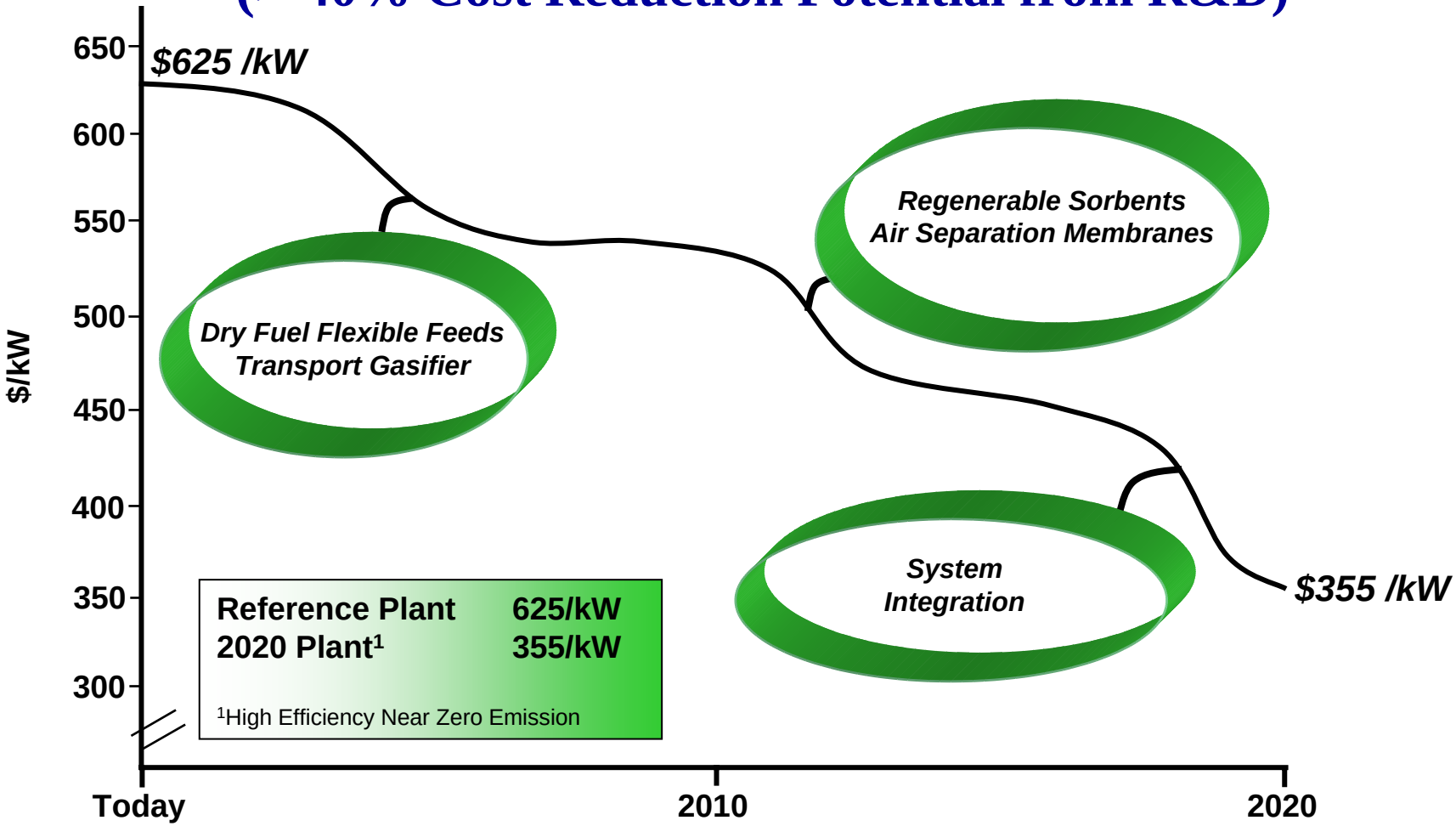
Durability of Membranes
Low Flux
Contaminant Sensitivity
Heat Removal

CO_2

Contributions to Program Targets
Gasification Systems

Projects	Cost	Efficiency	Reliability	H_2 Product & CO_2 Capture
Transport Gasifier	↓	↑	↑	
Compact Gasifier	↓	↑	↑	↑
Alstom Chemical Looping	↓	↑		↑
GE Chemical Looping	↓	↑		↑
Stamet Pump Dry Feed	↓	↑	↑	
Instruments & Materials		↑	↑	

Driving Down Cost For Gasification Systems(1)
(> 40% Cost Reduction Potential from R&D)



(1) Air Separation, Coal Feed, Gasification, Gas Stream Purification/Separation

Why Interest in IGCC is Rising

- Recognition of continuing high-price of natural gas
- Excellent environmental performance of IGCCs (SO_2, NOx, particulates and solid waste)
- Potential for economic control of mercury emissions
- Growing environmental community view of IGCCs as BACT for coal systems
- Consolidation of IGCC development companies
- Uncertainty of carbon management requirements and potential suitability of IGCC for CO_2 controls

CCT Program Success Stories

Advanced Pollution Controls

- **Now installed on 75% of U.S. coal plants**
- **1/2 to 1/10 cost of older systems**

Low-NO_x Burners

JEA CFBC Power Plant

PSI Energy Wabash River IGCC Power Plant

Proven Advanced Coal Power Systems

- **Two "super-clean" coal-based IGCC plants operating reliably**
- **World's largest CFBC power plant**

Tampa Electric IGCC Power Plant

IGCC Technology in Early Commercialization
U.S. Coal-Fueled Plants

- **Wabash River**
  - 1996 Powerplant of Year Award*
  - Achieved 95% availability
- **Tampa Electric**
  - 1997 Powerplant of Year Award*
  - First dispatch power generator

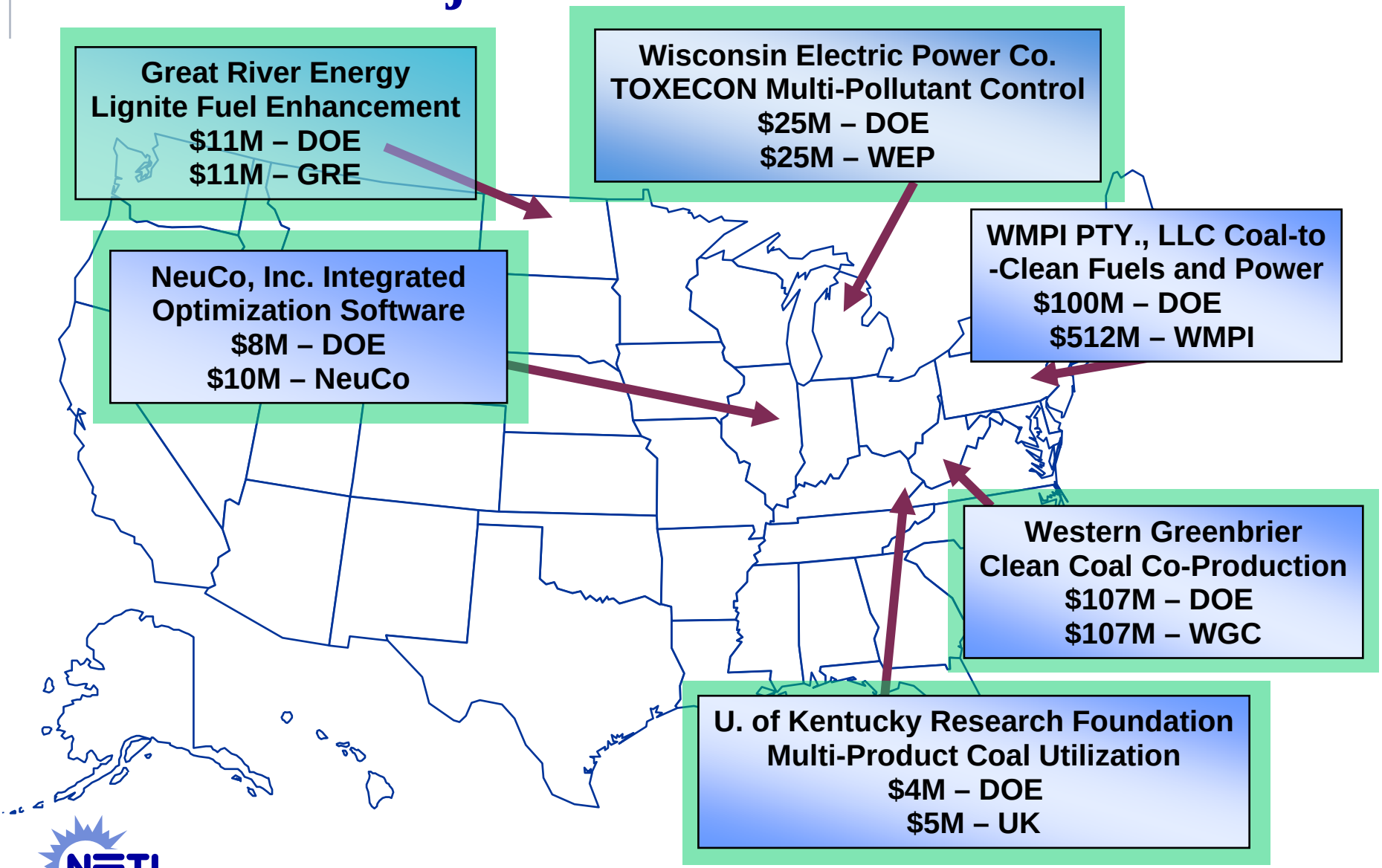
Nation's first commercial-scale IGCC plants, each achieving
> 95% sulfur removal
≥ 90% NO_x reduction

*Power Magazine

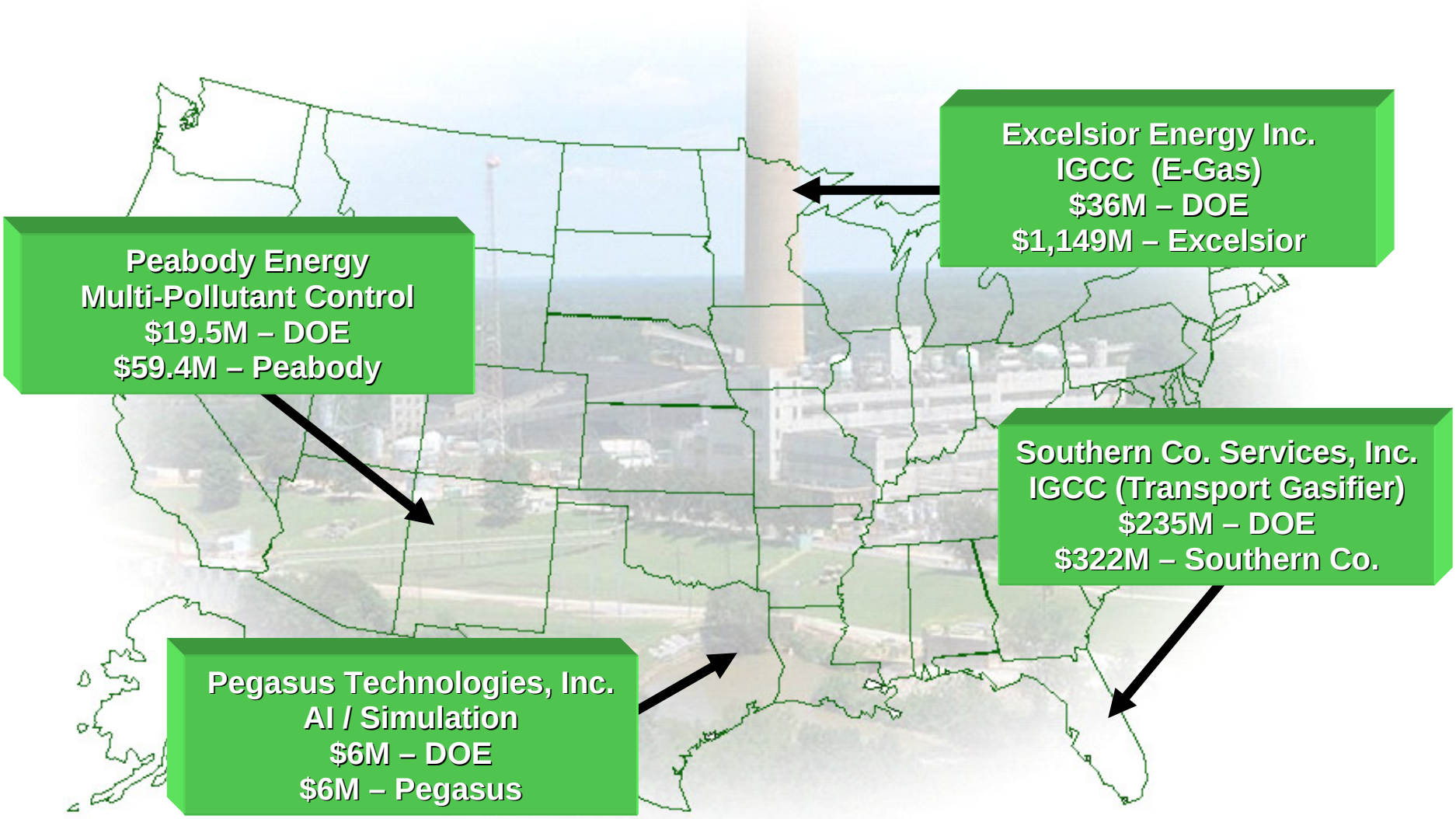
Clean Coal Power Initiative

- **Demonstrate emerging technologies in coal-based power generation**
  - $1-2 billion, 10-year program
  - 50/50 cost-shared
  - Government / industry partnerships
- **Coal key component of National Energy Policy**

Projects in CCPI – Round 1



Projects in CCPI – Round 2



CCPI Priority Technologies
($49 million in FY2005)

- **Emission control**
  - Mercury
  - NO_x
- **Advanced Power Technologies**
  - Improved efficiency / lower capital cost
  - Sequestration friendly
- **Sequestration**

Round 2 | **Round 3** | **Round 4**

Technologies for Clear Skies Compliance

Technologies for Zero-Carbon Emission Plants

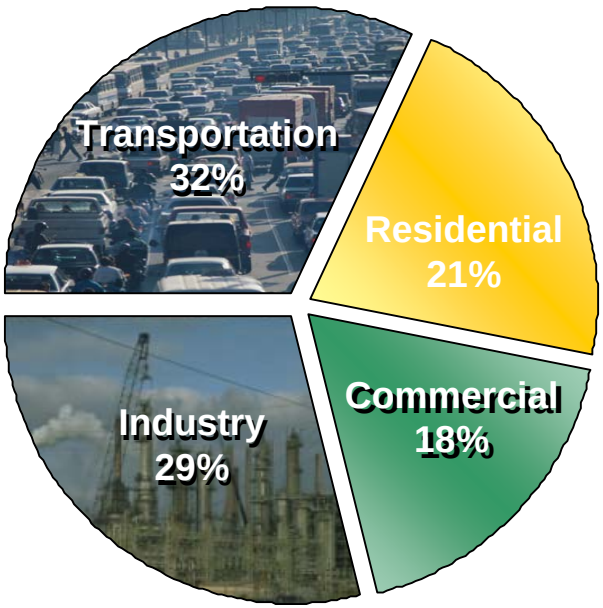
Program Goals

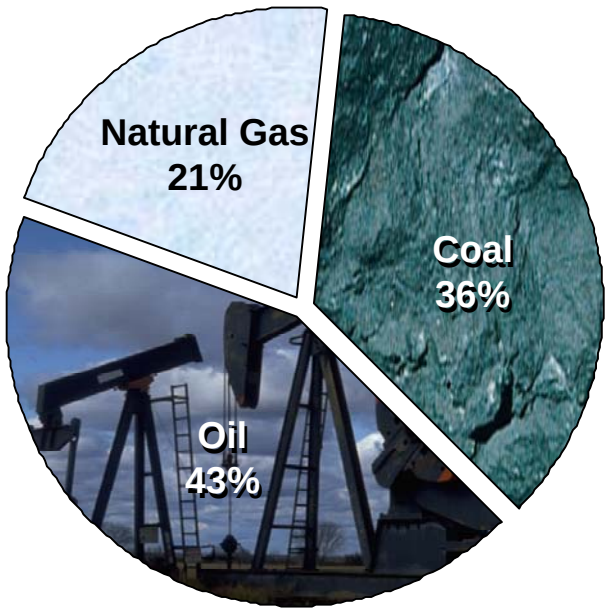
Reducing CO_2 Emissions

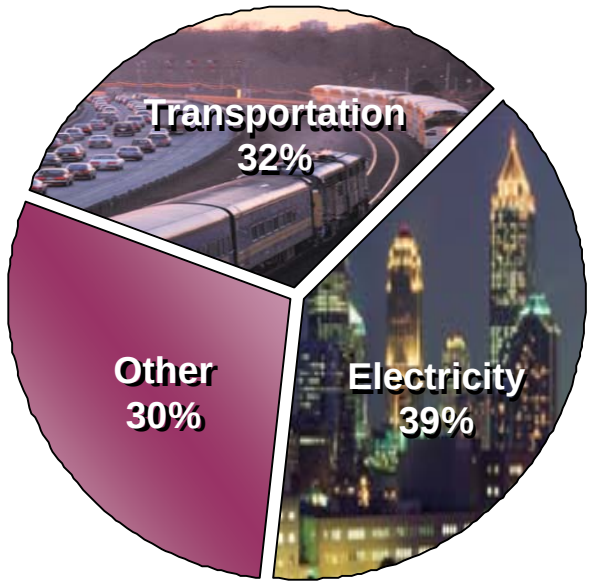
(All Fossil Fuels & Energy Sectors Contribute CO_2 Emissions)

United States Carbon Dioxide Emissions

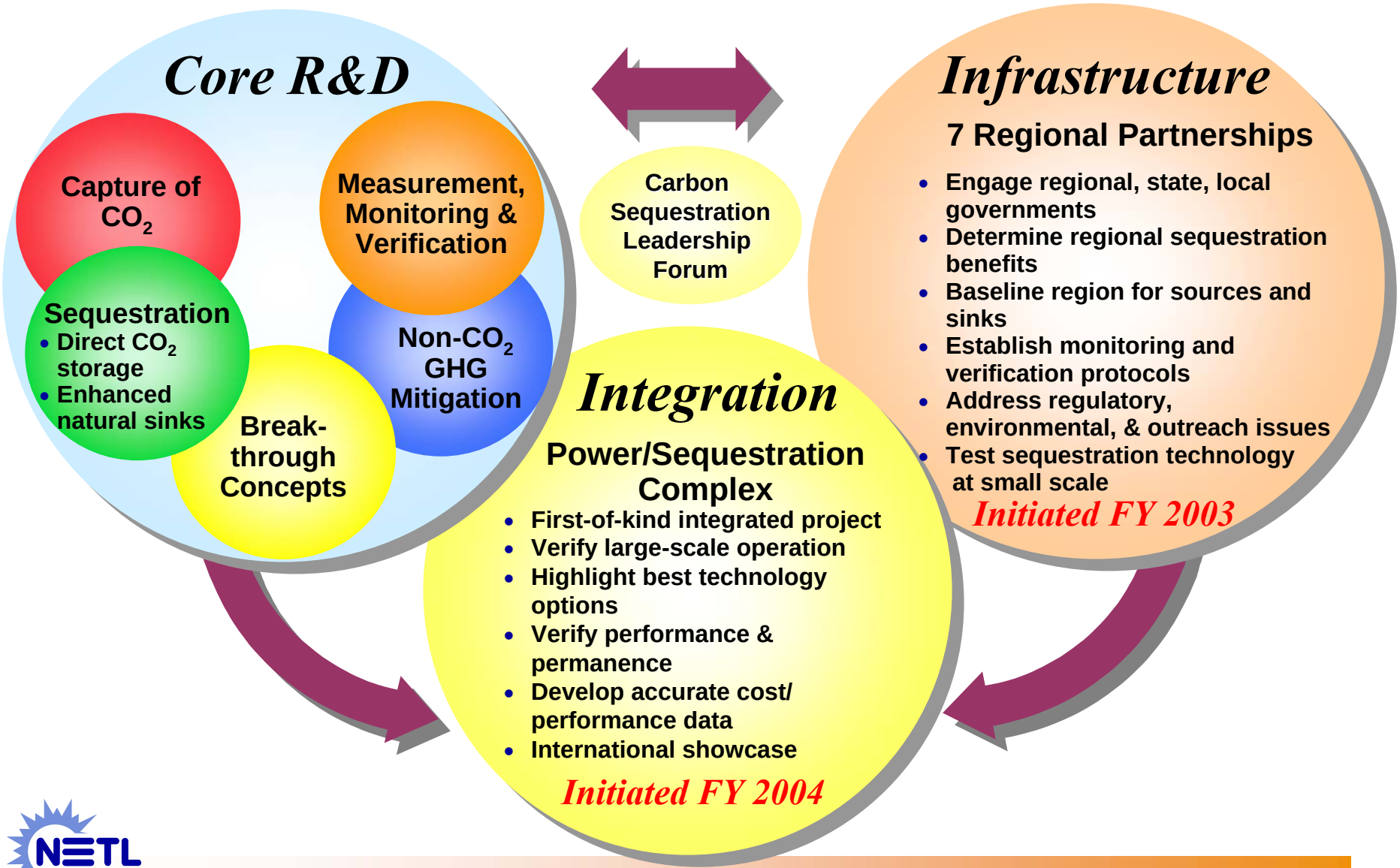
(By Source & Sector)





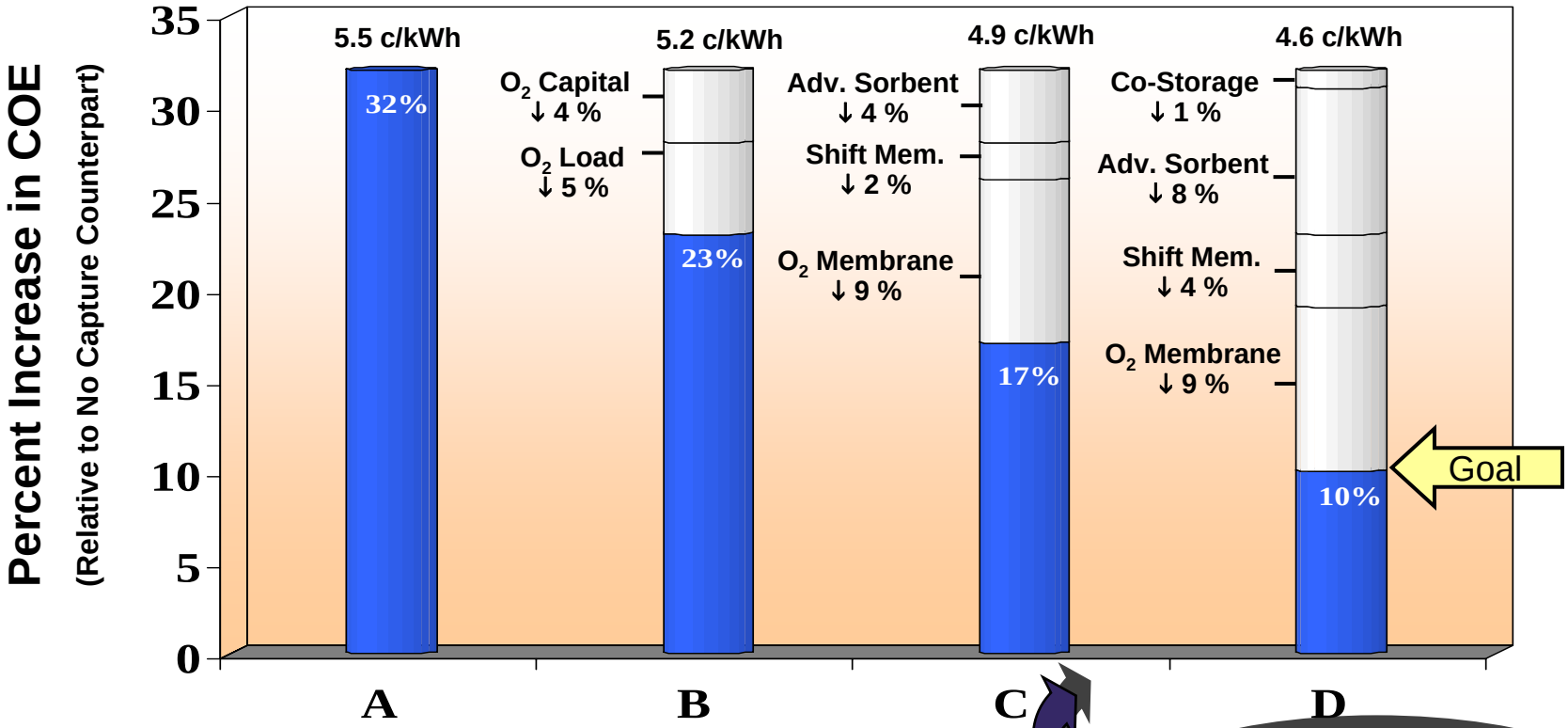


Carbon Sequestration Program Structure



Systems Analysis Used to Focus and Track R&D

(Example cost reduction potential for CO_2 capture developments)



Basis:

- No Capture COE 4.2 c/kWh
- 400 MW Net Output
- 90 % CO_2 Capture
- 80% Capacity Factor
- Saline Formation Storage

A—Current Scrubbing
B—Oxygen Membrane
C—O_2 Membrane + WGS Membrane + Adv. Sorbent
D—O_2 Membrane + WGS Membrane + Adv. Sorbent + Co-Storage H_2S/CO_2

…the results of NETL's systems, analysis and planning activity…

FutureGen: A Presidential Initiative

One-billion-dollar, 10-year demonstration project to create world's first coal-based, zero-emission electricity and hydrogen plant

President Bush, February 27, 2003

- **Produce electricity and hydrogen from coal using advanced technology**
- **Emit virtually no air pollutants**
- **Capture and permanently sequester CO_2**

FutureGen Uses Cutting-Edge Technologies

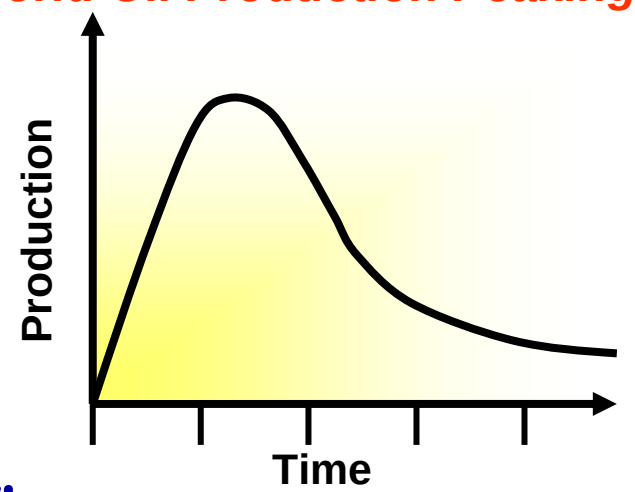
- **Can accommodate technology innovations with minimal modifications**
  - Emerging from national or international R&D
  - Slipstream or full stream tests
  - Over life of project
- **Some emerging new technologies**
  - Membrane-based O_2 and H_2 separation
  - High-efficiency hydrogen turbines
  - High-throughput gasifiers
  - Monitoring systems
  - Fuel-cell systems

FutureGen will be a global showcase of very best technology options for coal-based systems with zero carbon emissions

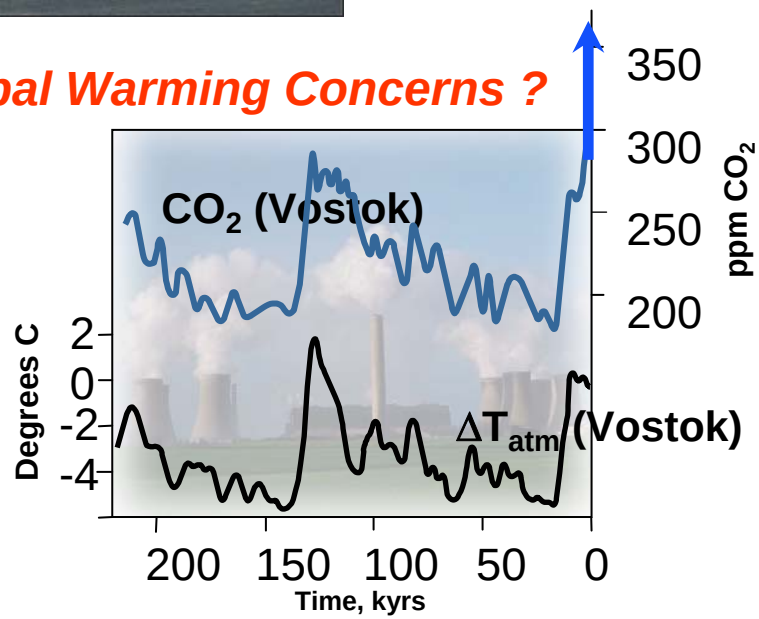
Energy Wildcards

Perceptions About LNG Safety ?

World Oil Production Peaking ?



Global Warming Concerns ?



Signals of an Economic Tipping Point or Opportunity for Coal

What to look for…

- **Serious Legislative commitment to expand domestic energy resources; Recognition of sharply declining energy security**
- **Continued high natural gas price; Evidence of declining supply**
- **Slow development for future LNG plants; More safety/security reports; Commercialization learning curve for offshore LNG; Current LNG business model (Expectation of Low Gas Prices, Independent of Oil) unproven**

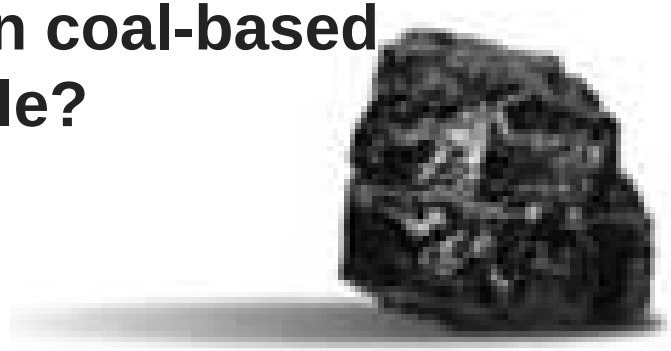
Signals of an Economic Tipping Point or Opportunity for Coal (continued)

What to look for…

- **Regional electricity shortages 2007-2010 due to insufficient fuel for gas-fired generation, lack of alternative generation**
- **Meaningful progress on new coal-fired or nuclear project(s), by respected industry leader, Shifts in industry philosophy (risk management); Academia and industry focus on human resource needs**
- **<u>Implementation</u> of Energy Policy Act (converting policy to actions)**

Closing Comments

- **Coal must continue play a key role in securing healthy U.S. economy**
- **Must maximize existing fleet performance as bridge to the future**
- **New clean coal plants needed soon – we see challenging but "do-able" path forward for coal**
- **R&D will show near-zero emission coal-based energy is possible…and affordable?**



Visit Office of Fossil Energy & NETL Websites

http://fossil.energy.gov/

www.netl.doe.gov