Coal In the U.S.

The Future of Coal in Ontario Conference

Kenneth E. Markel, Jr.

Director of the Office of Major Demonstrations

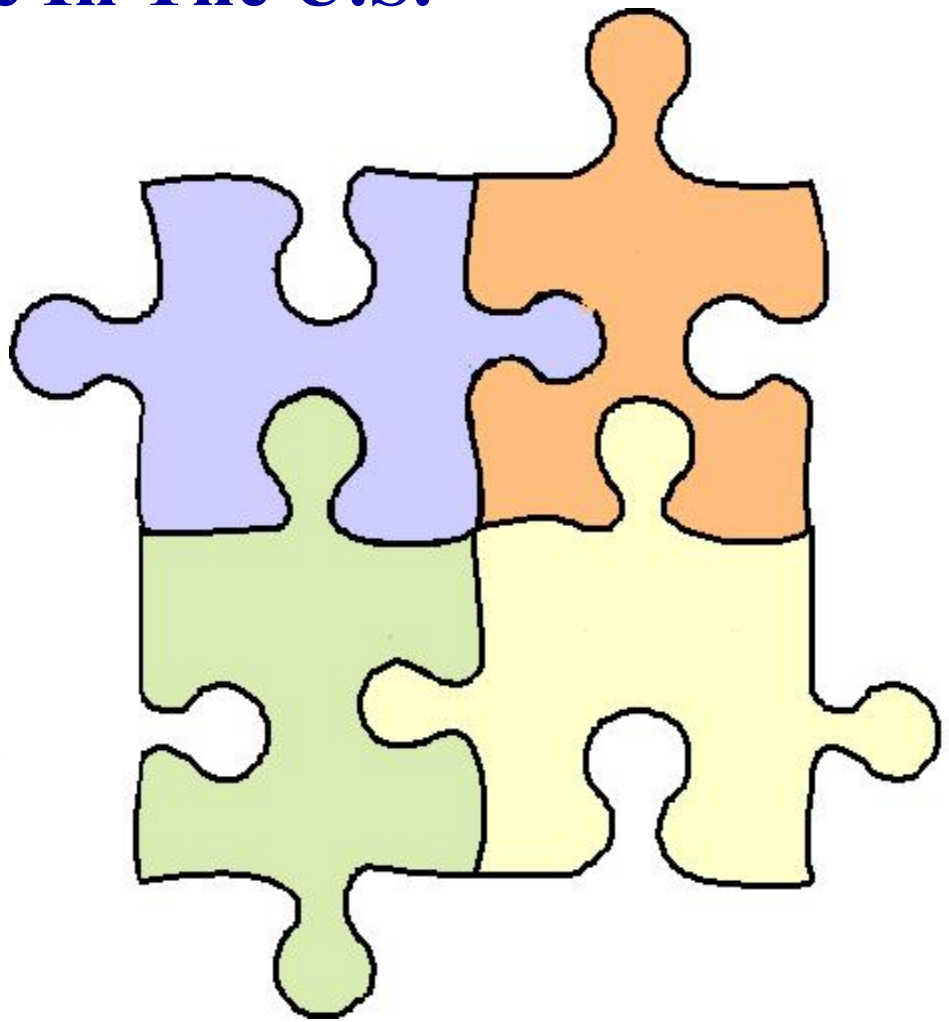
5-10-07

National Energy Technology Laboratory

Office of Fossil Energy

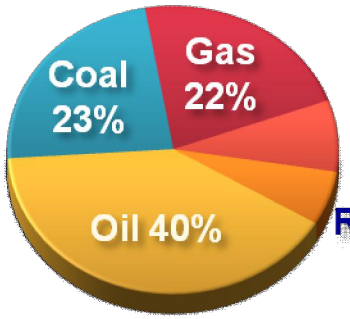
Coal Use In The U.S.

- Why Coal?
- Challenges?
- Response?
- What is NETL?



Energy Demand Today

101 QBtu / Year
85% Fossil Energy



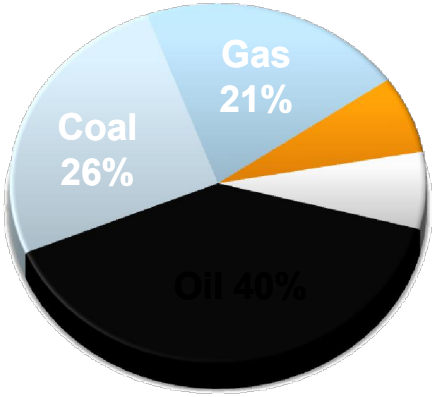
Nuclear
8%

Renewables
6%

United States

Energy Demand 2030

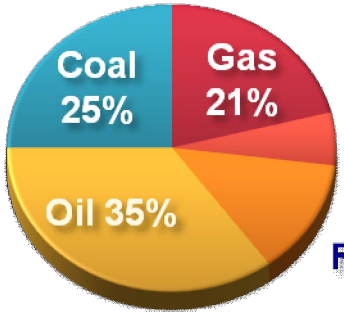
131 QBtu / Year
86% Fossil Energy



Nuclear
7%

Renewables
7%

475 QBtu / Year
80% Fossil Energy

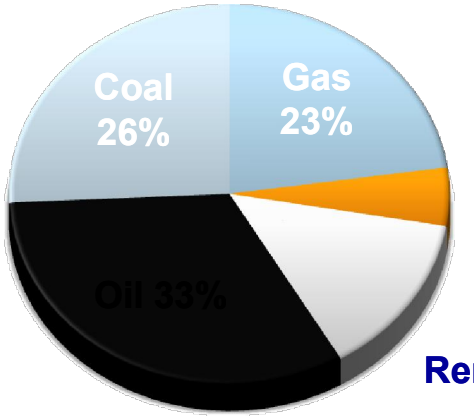


Nuclear
6%

Renewables
13%

World

725 QBtu / Year
81% Fossil Energy



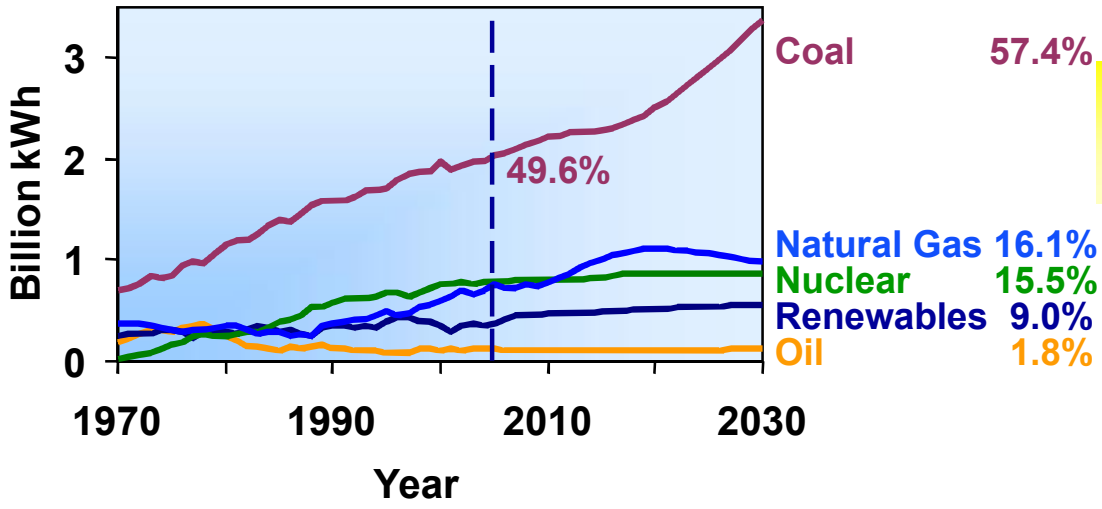
Nuclear
5%

Renewables
14%

Fossil Energy Will Continue to Dominate

U.S. data from EIA, Annual Energy Outlook 2007, years 2006 and 2030; world data from IEA, World Energy Outlook 2006, years 2004 and 2030

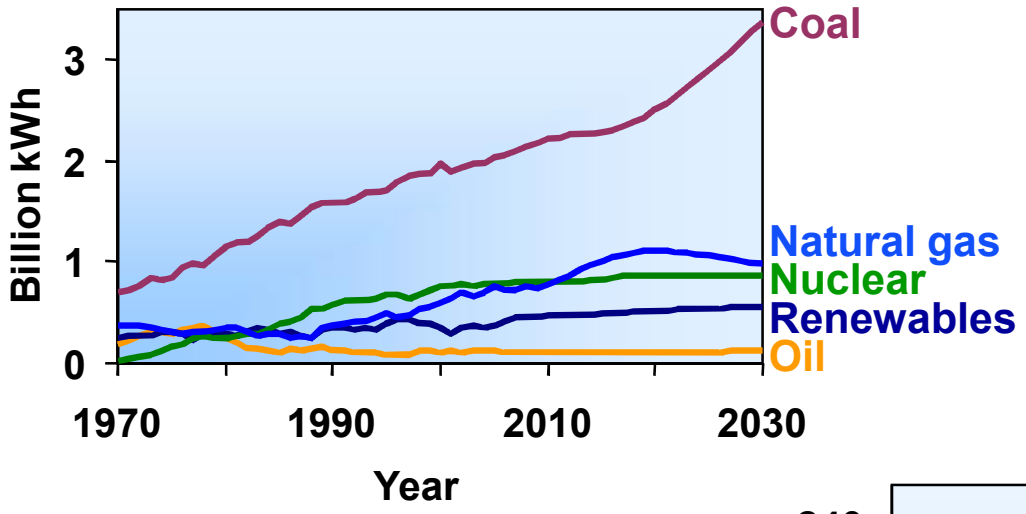
U.S. Coal Utilization Outlook



Coal dominates electricity generation

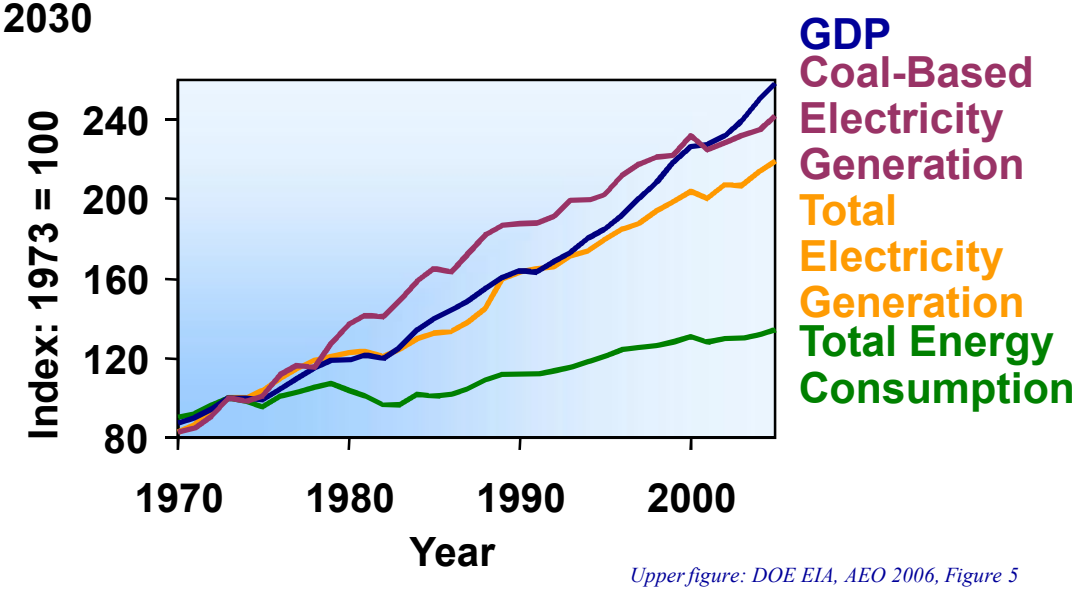
Upper figure: DOE EIA, AEO 2006, Figure 5
Lower figure: Energy & Electricity per DOE EIA, AER 2004
GDP per U.S. DOC, Bureau of Economic Analysis

U.S. Coal Utilization Outlook



Coal dominates electricity generation

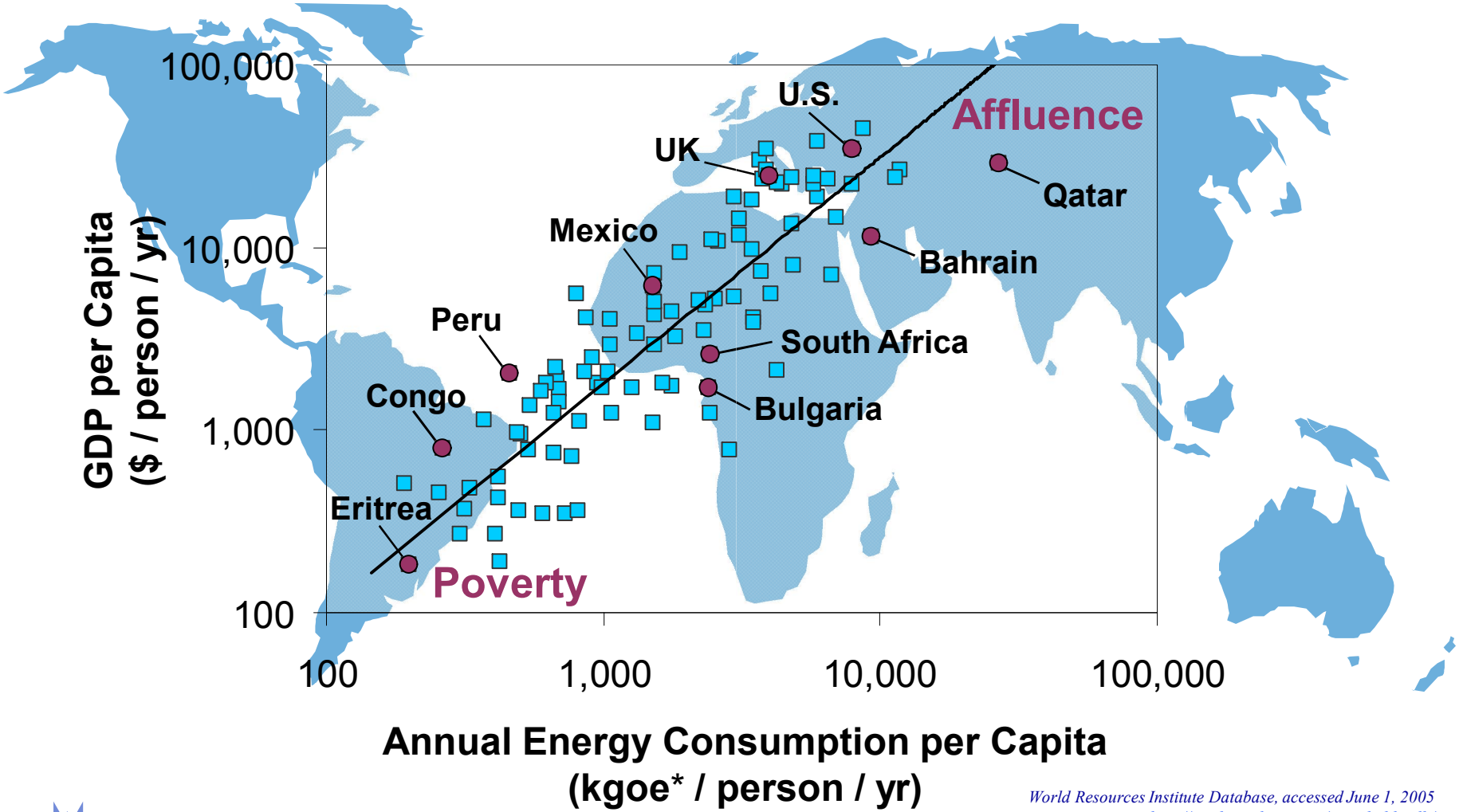
Coal use linked to economic growth



Upper figure: DOE EIA, AEO 2006, Figure 5
Lower figure: Energy & Electricity per DOE EIA, AER 2004
GDP per U.S. DOC, Bureau of Economic Analysis

Energy = Quality of Life

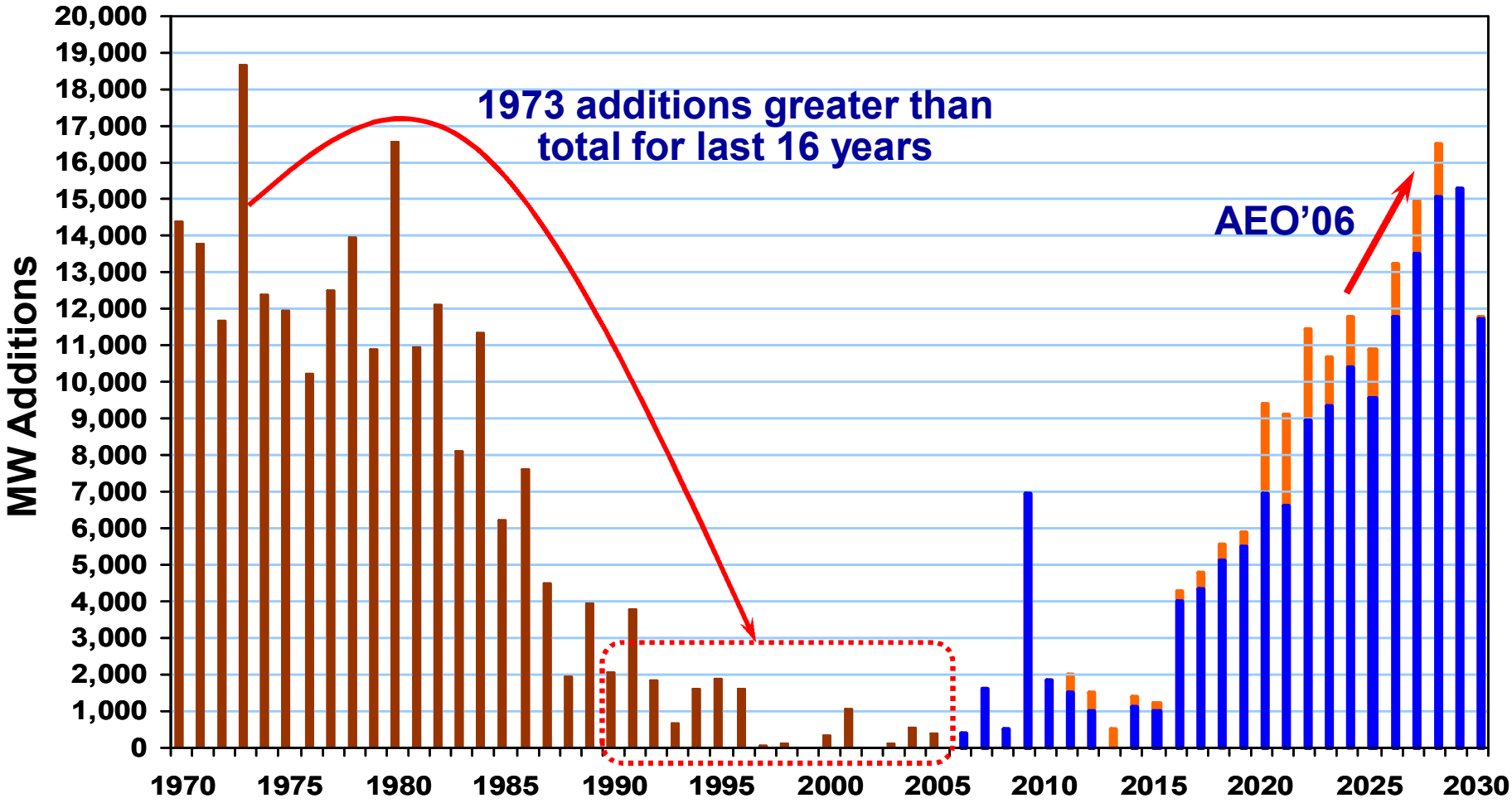
Poverty Reduces Global Security



World Resources Institute Database, accessed June 1, 2005
http://earthtrends.wri.org/searchable_db/
**kilograms of oil equivalent*

174 Added GW - Double the 87 GW in AEO'05

(Reference case with 5 additional years to 2030)



Coal Adds 154 GW New Capacity Plus 19 GW of CTL

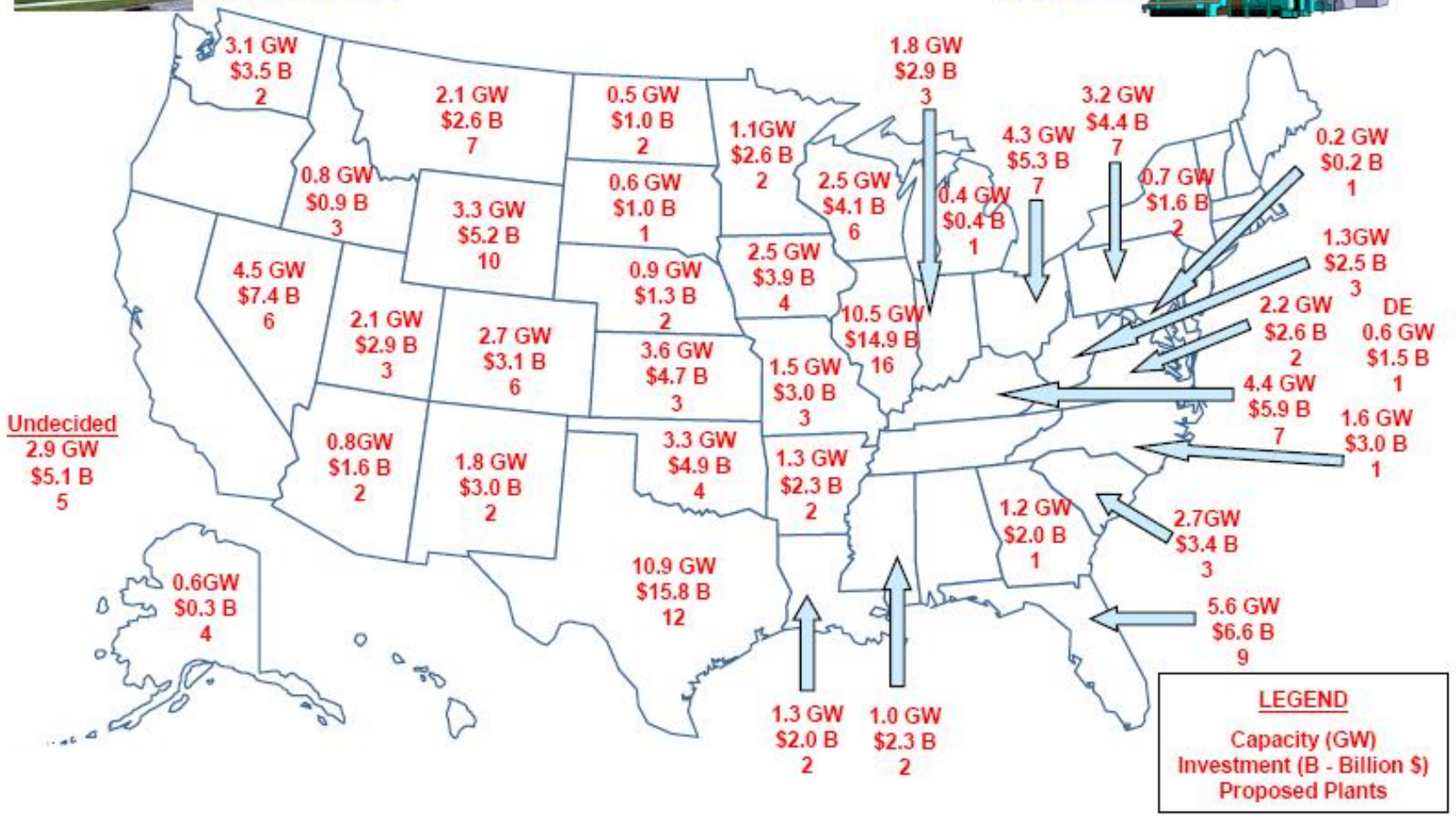
EIA, Annual Energy Review 2004, Annual Energy Outlook 2006

Coal's Resurgence in Electric Power Generation

Equivalent Power
for
96 Million Homes

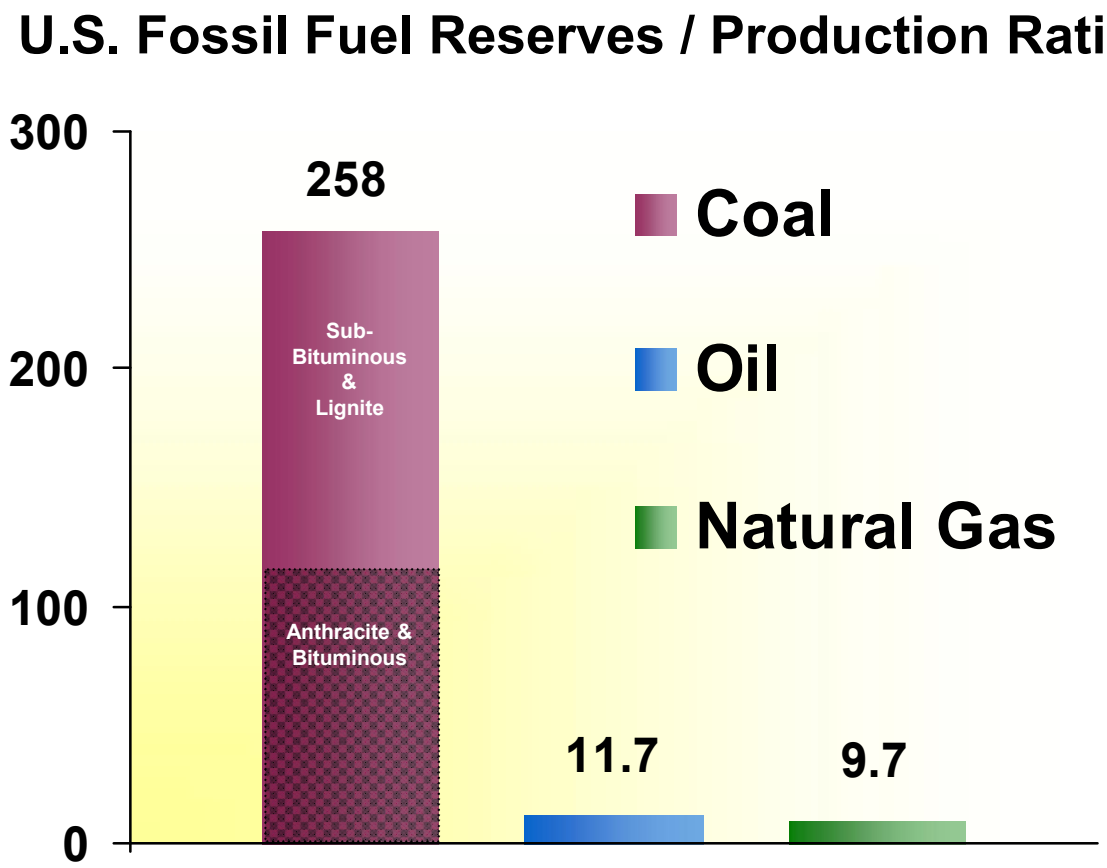
Proposed New Plants

159 Plants
96GW
$ 141 Billion



"Tracking New Power Plants. Coal's Resurgence in Electric Power Generation"
NETL, January 24, 2007, www.netl.doe.gov

250 Year Supply at Current Demand Levels !



Sources: BP Statistical Review, June 2004, - for coal reserves data (World Energy Council)
EIA, Advance Summary U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 2003 Annual Report, September 22, 2004 - for oil and gas reserves data

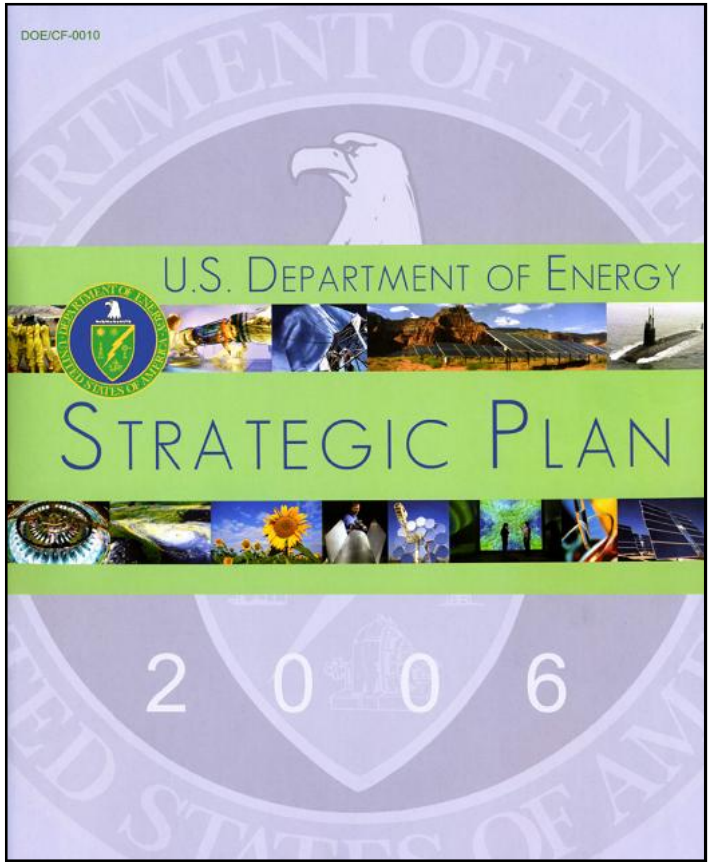
DOE Strategic Plan

1.1 *Energy Diversity* – Increase our energy options and reduce dependence on oil, thereby reducing vulnerability to disruption and increasing the flexibility of the market to meet U.S. needs.

1.2 *Environmental Impacts of Energy* Improve the quality of the environment by reducing greenhouse gas emissions and environmental impacts to land, water, and air from energy production and use.

1.3 *Energy Infrastructure* – Create a more flexible, more reliable, and higher capacity U.S. energy infrastructure

1.4 *Energy Productivity* – Cost-effectively improve the energy efficiency of the U.S. economy.



Recent Activities

- **2007 U.S.-EU Summit Statement -** April 30, 2007
  - **Key Priorities: 1. Advanced commercial deployment of clean coal and carbon capture and storage technologies including. . . advanced, clean, and near zero emissions coal technologies are critical in tackling global C02 emissions, given coal's importance in meeting current and future energy needs for developed and developing countries;**

- **U.S. - Japan Joint Statement on Energy Security, Clean Development, and Climate Change** – April 27, 2007
  - **We are accelerating the development and deployment of these technologies by providing policy incentives to reduce the cost barriers to their full commercialization. We especially note the importance of advancing: energy efficiency and renewable energy, alternative and renewable fuels, hydrogen, near-zero emissions coal, nuclear energy, and fusion energy.**

Difficult to Postulate Affordable, Secure Alternatives to Coal

Nuclear

Cost,
Permitting,
Waste Disposal?

Wind / Solar

Cost,
Land use,
Intermittency?

Biomass

Cost,
Gigantic,
Infrastructure?

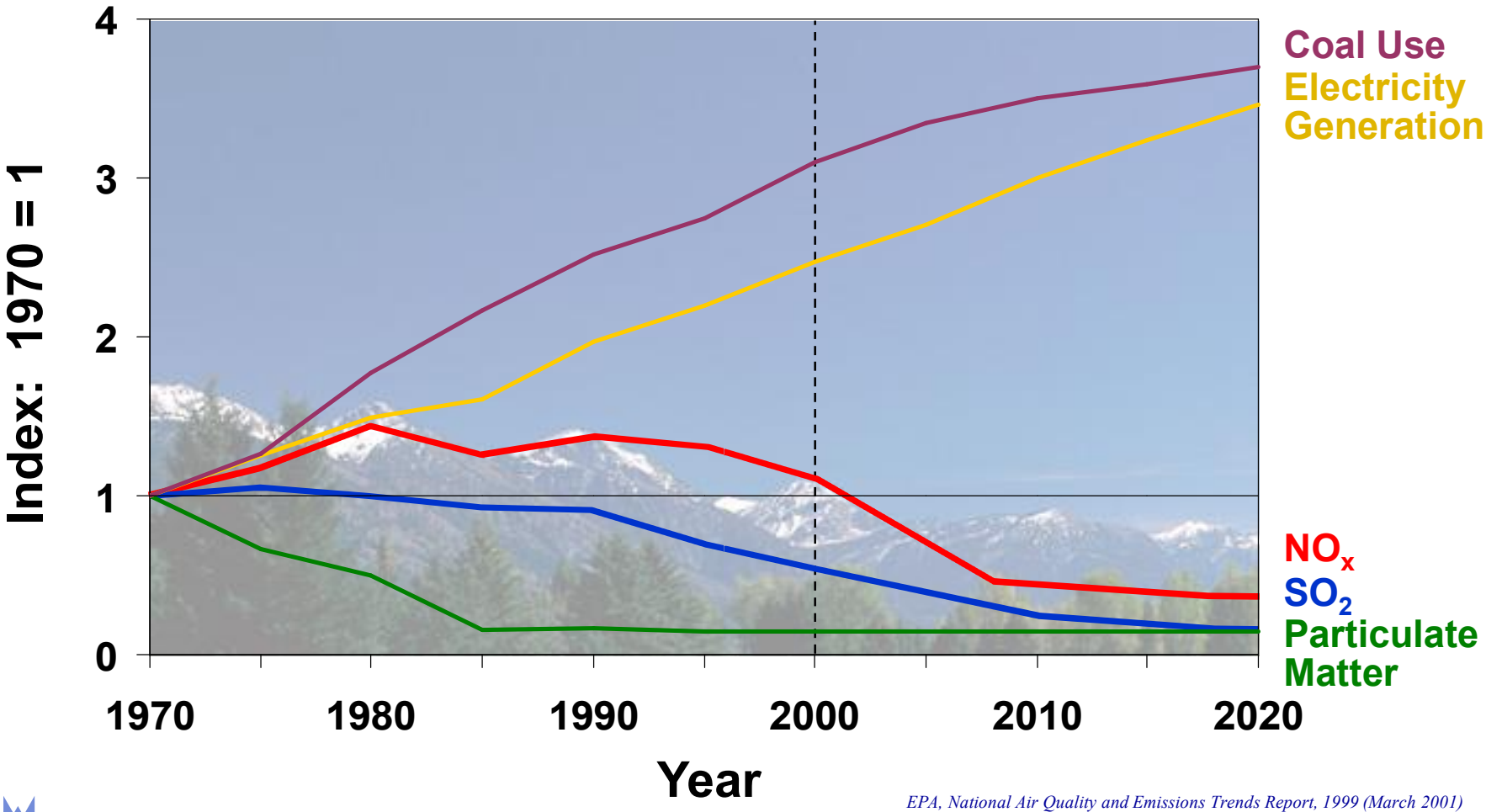
Hydro / Geothermal

Availability of sites?

R&D Challenges for Coal Technology

- "Near-zero" emissions
- CO_2 management
- High efficiency
- Water use
- By-product utilization
- Flexible (feedstocks, products, siting)
- Cost competitive with other energy choices

Coal Getting Cleaner While Demand Increases !



EPA, National Air Quality and Emissions Trends Report, 1999 (March 2001)
DOE, EIA Annual Energy Review
Projections for NO_x and SO_2: Clear Skies Initiative

DOE's Office of Fossil Energy

Advanced (Coal) Power Systems Goals

- **2010:**
  - 45-50% Efficiency (HHV)
  - 99% SO_2 removal
  - NOx< 0.01 lb/MM Btu
  - 90% Hg removal
  - $1,000/kW (2002 $)
- **2012:**
  - 90% CO_2 capture
  - *<10% increase in COE with carbon sequestration*
- **2015**
  - Multi-product capability (e.g, power + H_2)
  - 60% efficiency (measured without carbon capture)

Strategic Center for Coal

Demonstration Program

- Clean Coal Power Initiative

All Programs Support Presidential Initiatives:

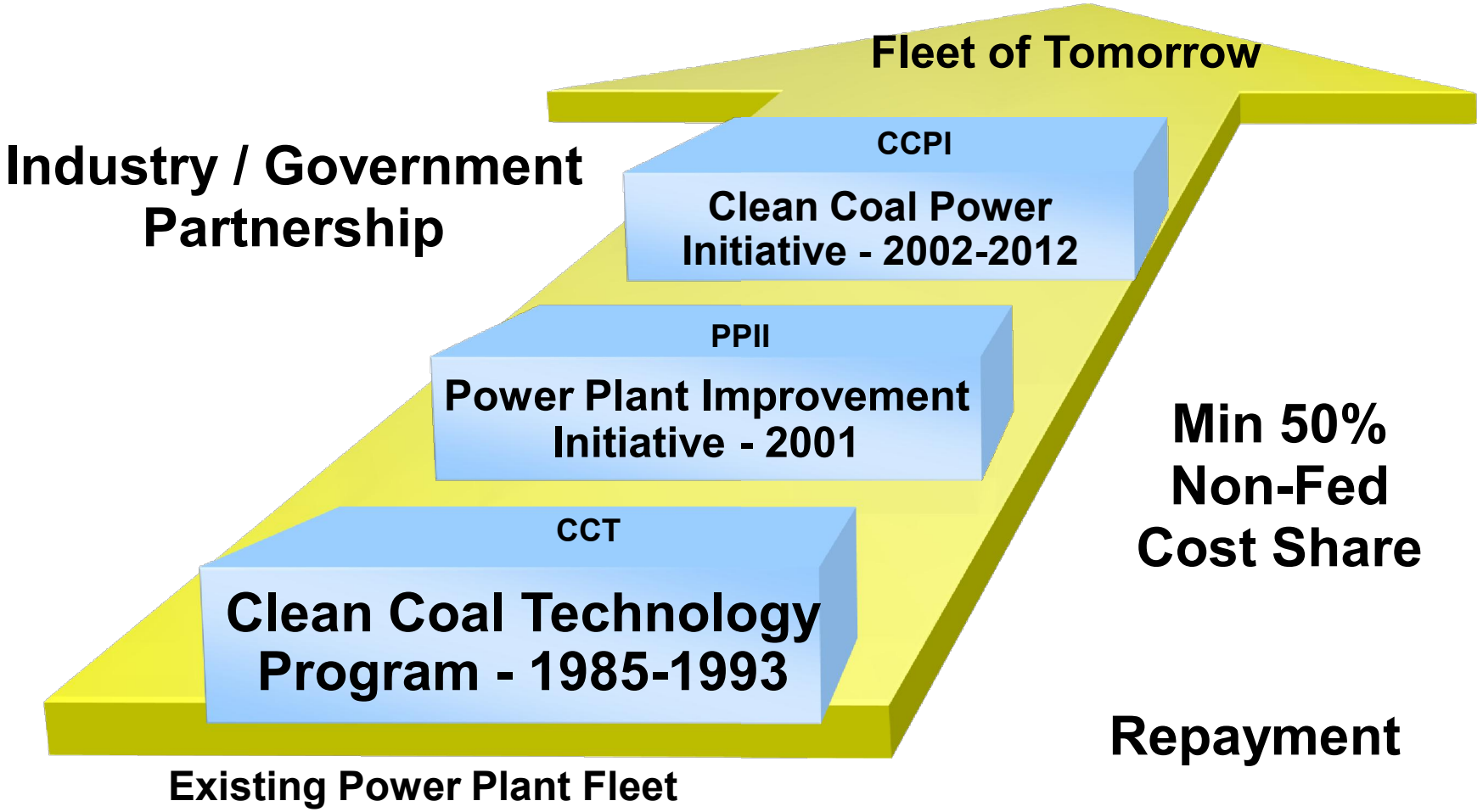
- Clear Skies
- Climate Change
- Energy Security

FutureGen

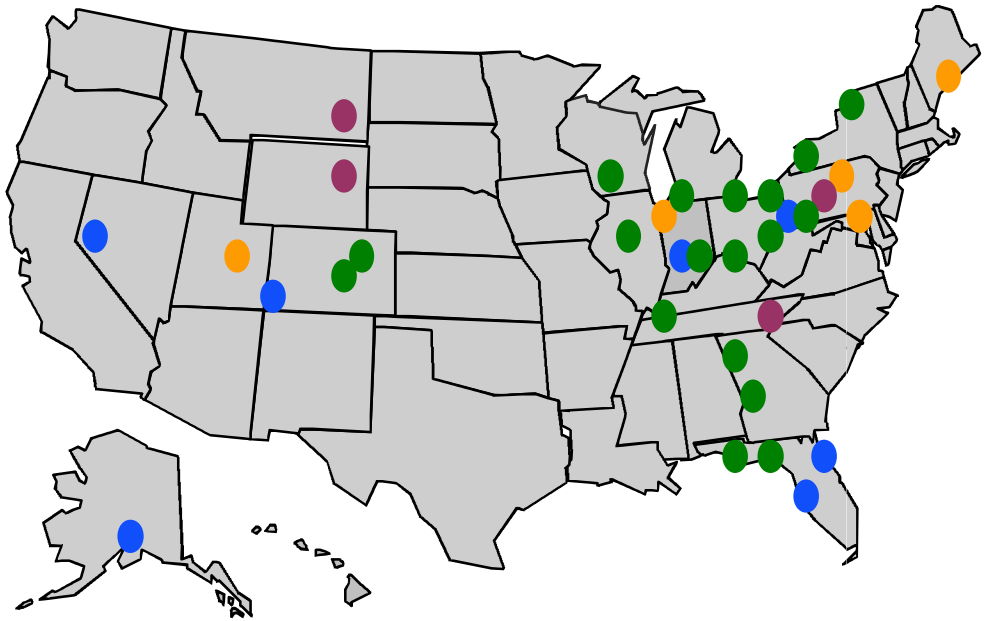
- Integrated sequestration, hydrogen, and power research facility

DOE's Coal Demonstration Programs

Implemented Through Competition



Clean Coal Technology (CCT) Program



- Power generation
- Environmental control
- Coal processing
- Industrial applications

- Five competitive solicitations, 1985 - 1993
- All 33 projects completed
- $1.3B DOE and $1.9B industry cost share

CCT Program Success Stories

Advanced Pollution Controls

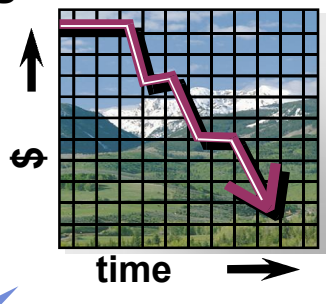
- Installed on 75% of U.S. coal plants
- 1/2 to 1/10 cost of older systems

FGD Scrubbers

Low-NO_x Burners

Hazardous Air Pollutants (HAPS) & Mercury Data

- Quantified HAPS Levels
- Basis for Mercury Regulations



Advanced Coal Power Systems

- World's largest circulating fluidized bed combustion (CFBC) power plant
- Two "super-clean" coal-based IGCC

Tampa IGCC

Wabash IGCC

JEA CFBC

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

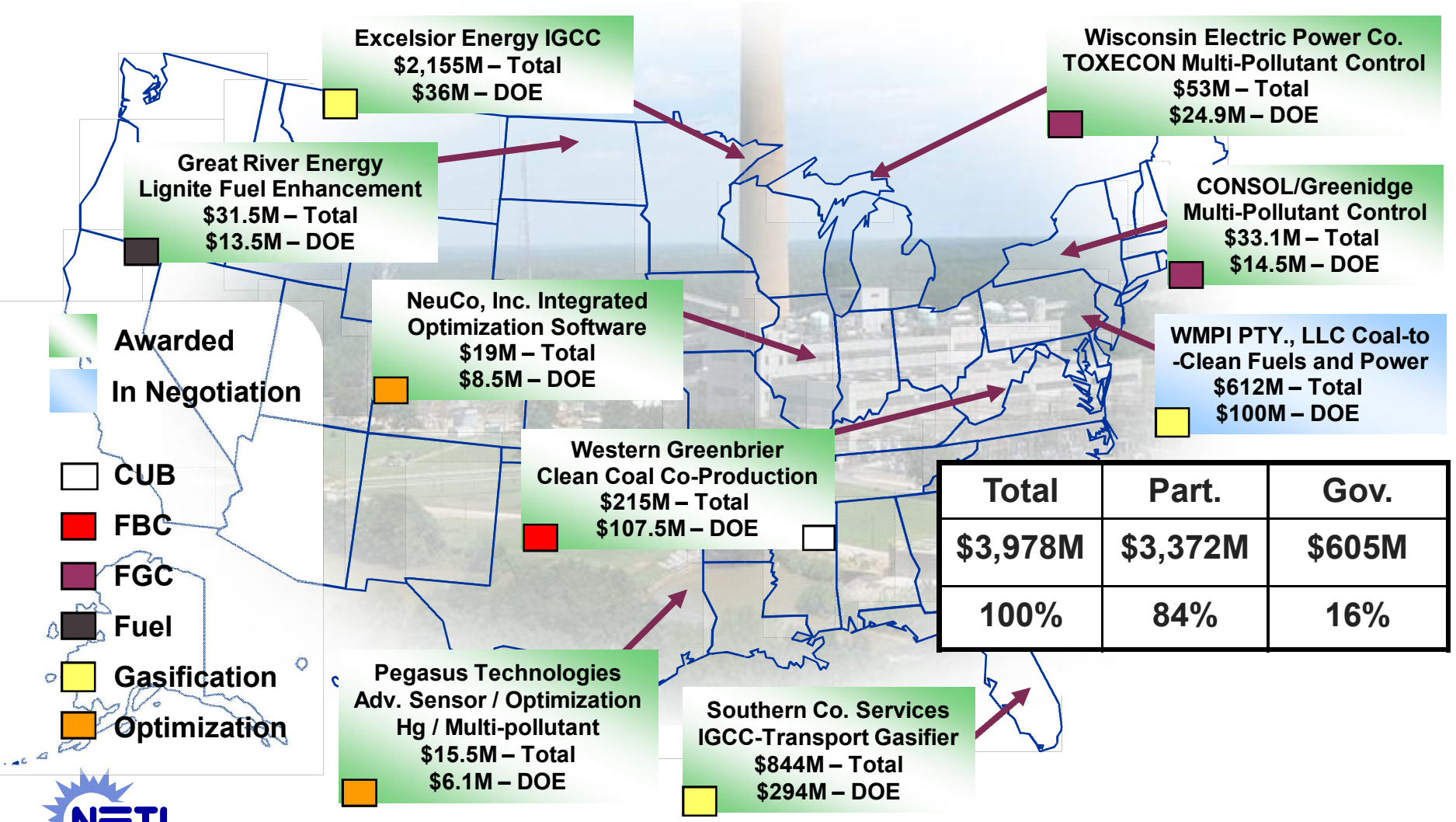
Nation's first commercial-scale IGCC plants, each achieving
> 95% sulfur removal
≥ 90% NO_X reduction

*Power Magazine

Clean Coal Power Initiative

- **10 yr**
- **4 rounds of solicitations**
- **Drivers**
  - **Overall**
    - Clear Skies Initiative
    - Reduced carbon intensity
    - Zero emissions technology target
    - Energy/economic security
  - **Round 1 (Broad)**
    - Advanced coal-based power generation
    - Efficiency, environmental & economic improvements
  - **Round 2 (Prioritized)**
    - Gasification
    - Hg control

Demonstration Projects
Locations and Cost Share



Total	Part.	Gov.
$3,978M	$3,372M	$605M
100%	84%	16%

Tentative Priority Technologies
Future CCPI Rounds

- **Emission control**
  - Mercury
  - NO_X
- **Integrated Gasification Combined Cycle**
  - Improved efficiency/lower capital cost
  - CO2 capture friendly
- **CO2 Capture and Storage**

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

$250M

Technologies for Clear Skies Compliance

Technologies For Zero-Carbon Emission Plants

Program Goals

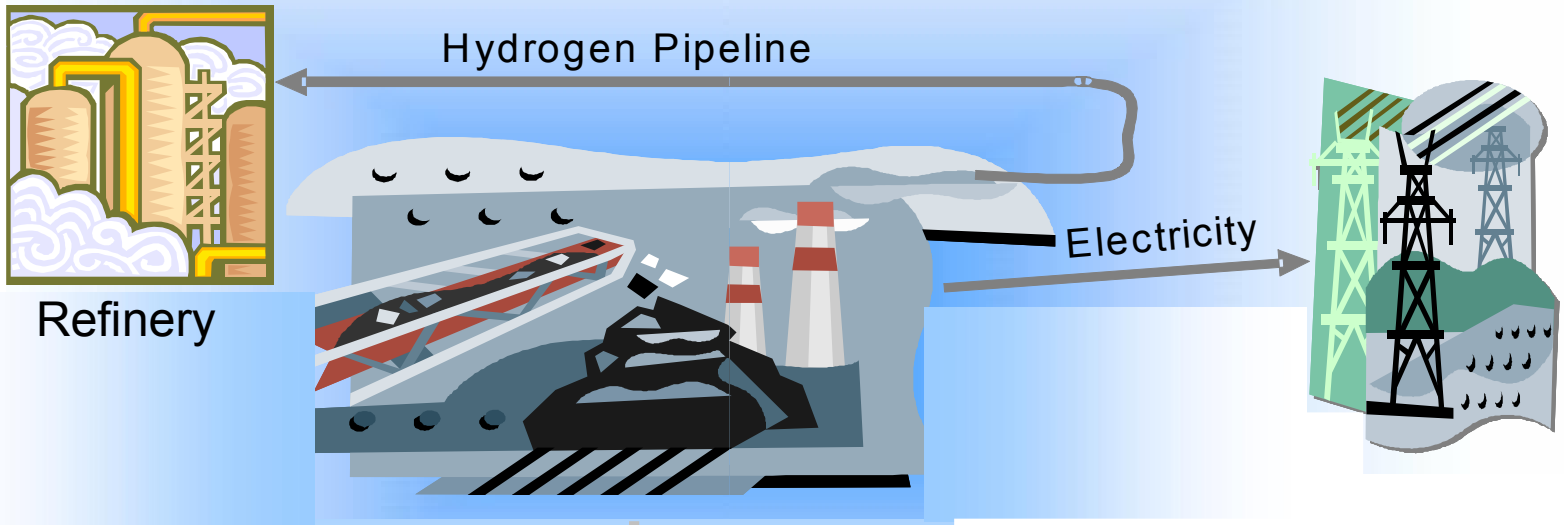
FutureGen: A Global Partnership Effort

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

President Bush, February 27, 2003

- **Broad U.S. participation**
  - DOE contemplates implementation by consortium
- **International collaboration**

FutureGen Concept



- H_2- 10lb/sec
- Electricity - 275 MW

- Virtually no air pollutants
- Capture & store CO2 - 10^6 tons/yr
- Full-scale Integrated operations

FutureGen Uses Cutting-Edge Technologies

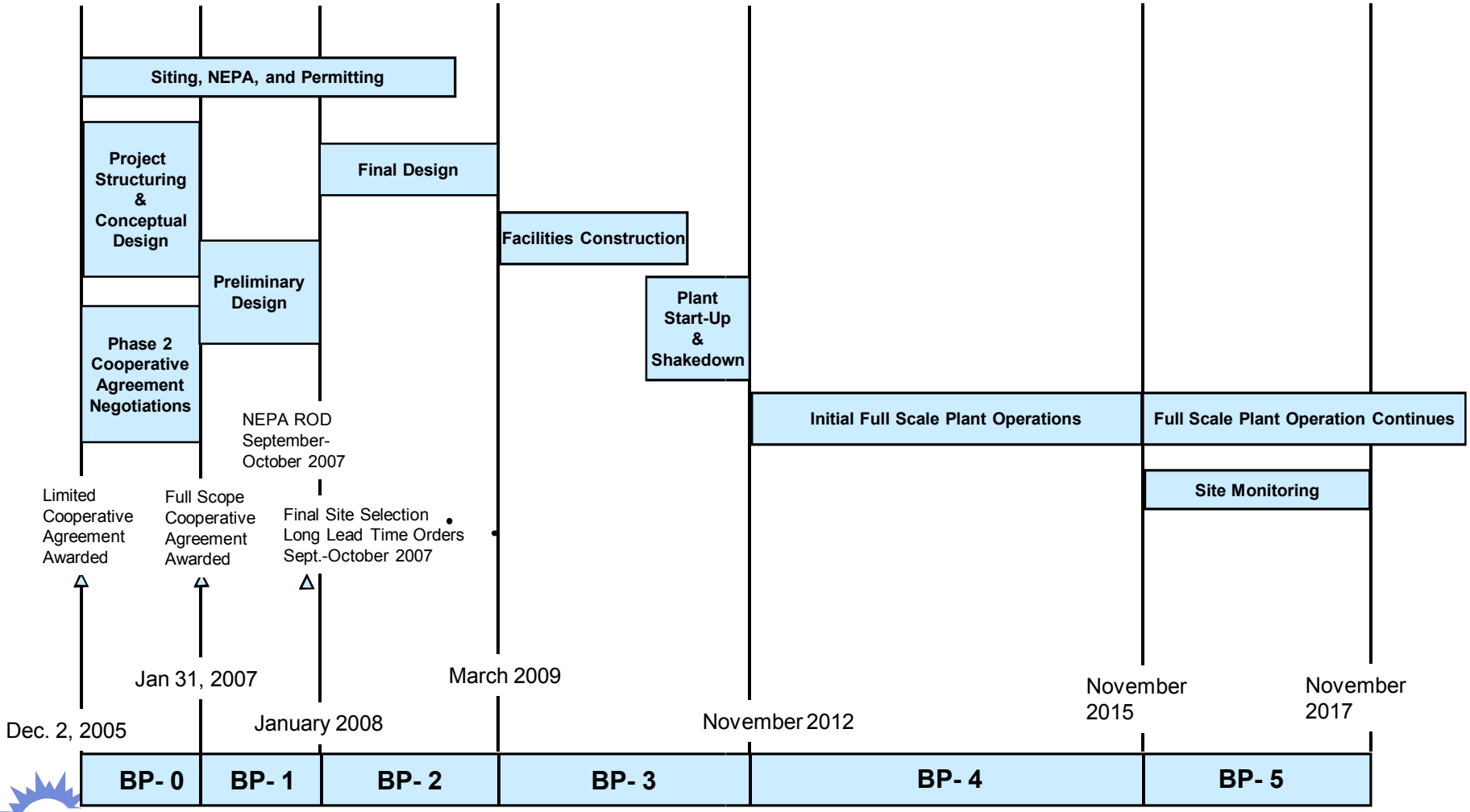
- **Can accommodate technology innovations with minimal modifications**
  - Emerging from national or international R&D pipelines
  - Slipstream or full-scale tests
  - Over life of project
- **Some emerging new technologies**
  - Membrane-based O_2 and H_2 separation
  - High-efficiency hydrogen turbines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

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

FutureGen Industrial Alliance, Inc.
Signed Cooperative Agreement with DOE on Dec. 2, 2005

- American Electric Power
- AngloAmerican
- BHP Billiton
- China Huaneng Group
- CONSOL Energy
- E.ON U.S.
- Foundation Coal
- Peabody Energy
- PPL
- Rio Tinto Energy America
- Southern Company
- Xstrata Coal

FutureGen Project Schedule

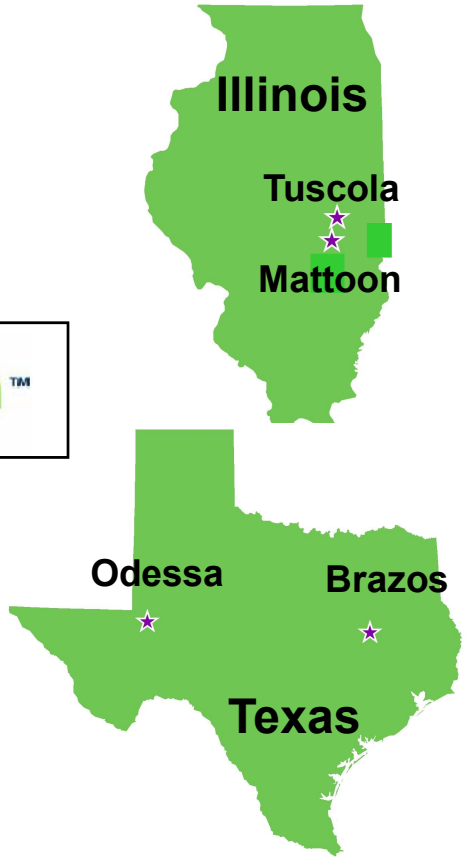


FutureGen Project

Supporting FutureGen is a Major Goal of the R&D Programs

- **Industry-led project with government oversight & international participation**
  - Signed Cooperative Agreement with DOE on Dec. 2, 2005
  - Project structuring to Jan. 2007
  - Design to July 2009
  - Construction to July 2012
  - Operations to July 2016
  - Site monitoring to July 2018

FutureGen™ ALLIANCE



- **Industry will choose project site & backbone technologies**
  - Down-selected to four potential sites

AEP · bhpbilliton · Peabody · FOUNDATION COAL · xstrata coal · 中国华能集团公司 CHINA HUANENG GROUP · RIO TINTO ENERGY AMERICA · ppl · SOUTHERN COMPANY · CONSOL ENERGY · ANGLO AMERICAN · e·on U.S.

Core R&D Program

- Carbon Sequestration
- Innovations for Existing Plants
- Advanced Integrated Gasification Combined Cycle
- Hydrogen & Syngas
- Fuel Cells
- Advanced Research
- Advanced Turbines

Carbon Storage – How does it work?

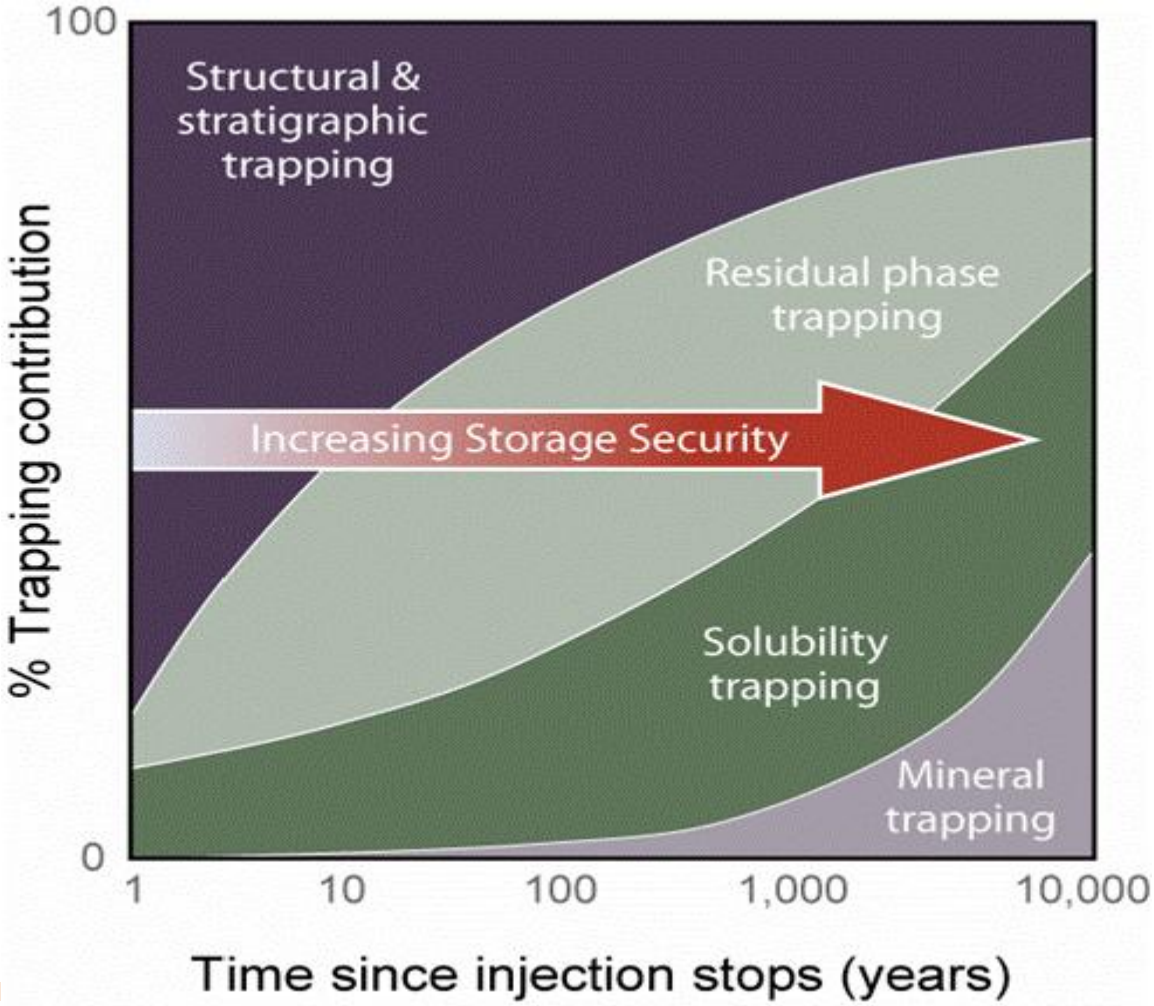
Storage mechanisms vary by target class; generally multiple processes which improve over time

Physical trapping
- **Impermeable cap rock**
- **Either geometric or hydrodynamic stability**

Residual phase trapping
- **Capillary forces immobilized fluids**
- **Sensitive to pore geometry (<25% pore vol.)**

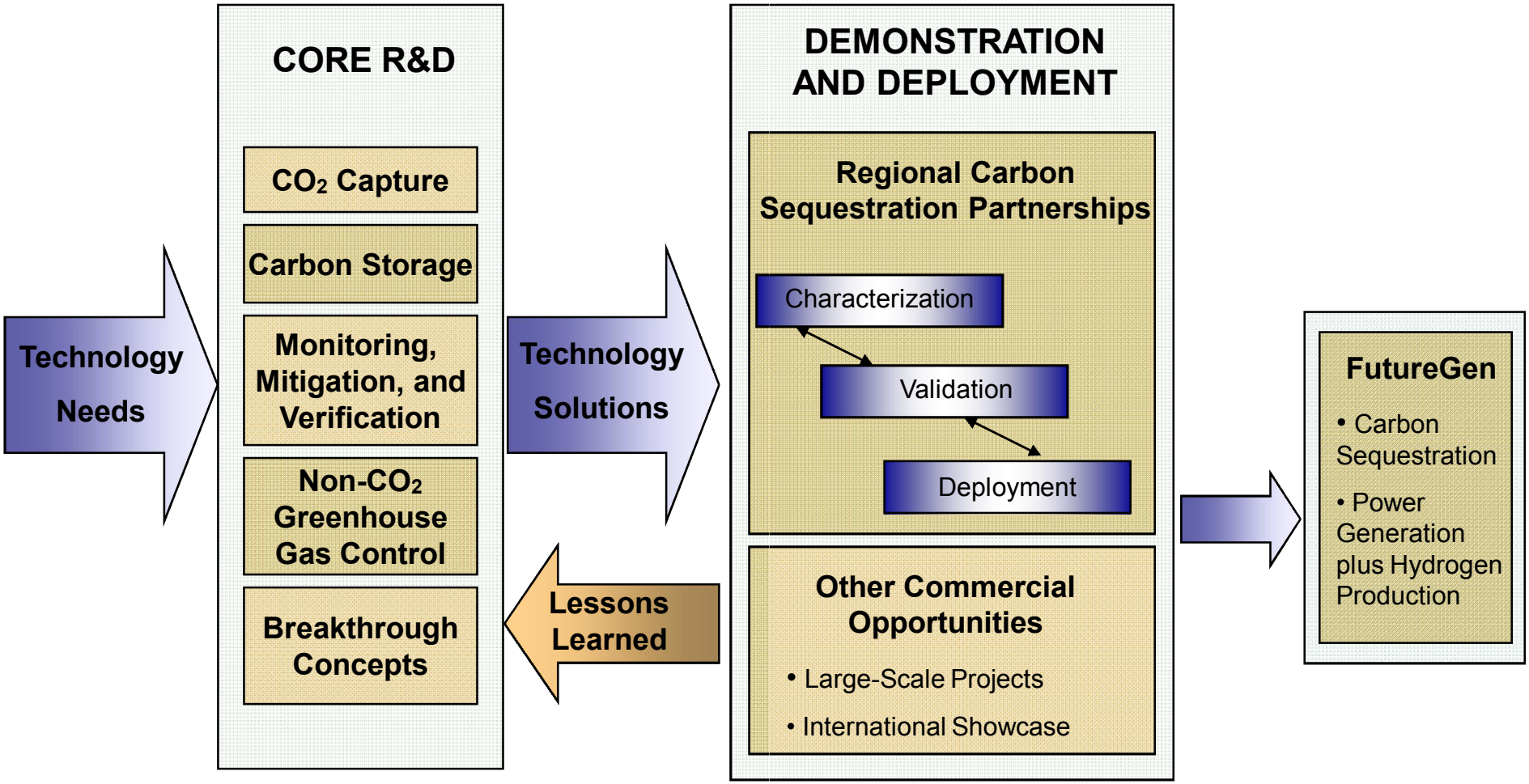
Solution/Mineral Trapping
- **Slow kinetics**
- **High permanence**

Gas adsorption
- **For organic minerals only (coals, oil shales)**



Source: S Benson, LBNL

DOE's Carbon Sequestration Program



Benefits of the RCSP Initiative

- **Better understanding of regional opportunities**
  - Match sources and sinks
  - Define scenarios for implementation
- **Test and refine geologic models**
- **Measure fate of CO_2 and compare technologies**
- **Best management practices to address site selection, well design, operations, monitoring, and closeout**
- **Engagement of regional stakeholders**
  - Implement public outreach and education

Regional Carbon Sequestration Partnerships

Characterization Phase

- 24 months (2003-2005)
- $16M DOE funds

Validation Phase

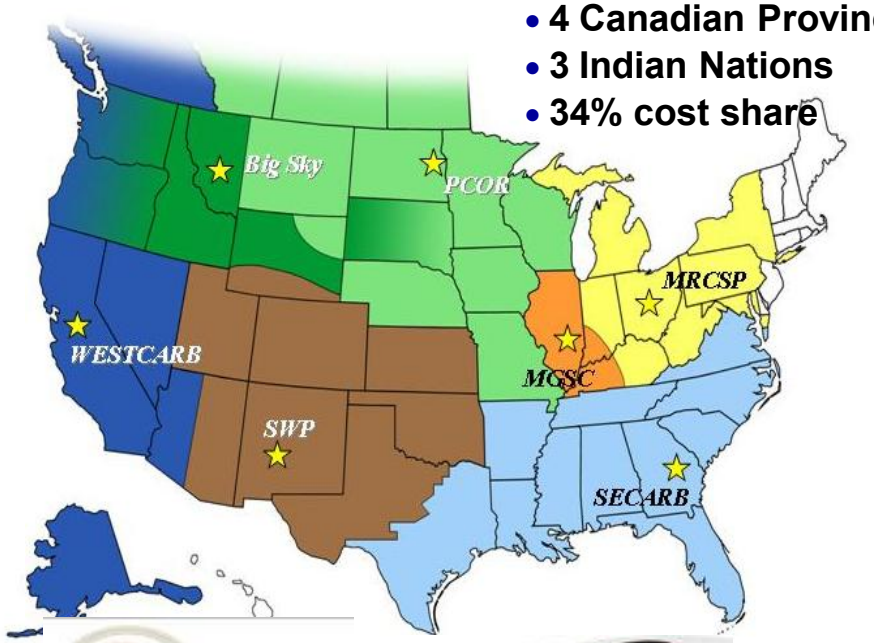
- 4 years (2005 - 2009)
- 7 Partnerships (41 states)
- 25 Geologic field validation tests
- $112M DOE funds

Deployment Phase

- 10 years (2008-2017)
  - FY07 Initiated
- Several large injection tests in different geology

Representing:

- **>340 Organizations**
- **41 States**
- **4 Canadian Provinces**
- **3 Indian Nations**
- **34% cost share**



BigSkyCarbon Sequestration Partnership

The Plains CO2 Reduction Partnership PCOR Partnership

West Coast Regional Carbon Sequestration Partnership
westcarb.org

MGSC

MRCSP Midwest Regional Carbon Sequestration Partnership

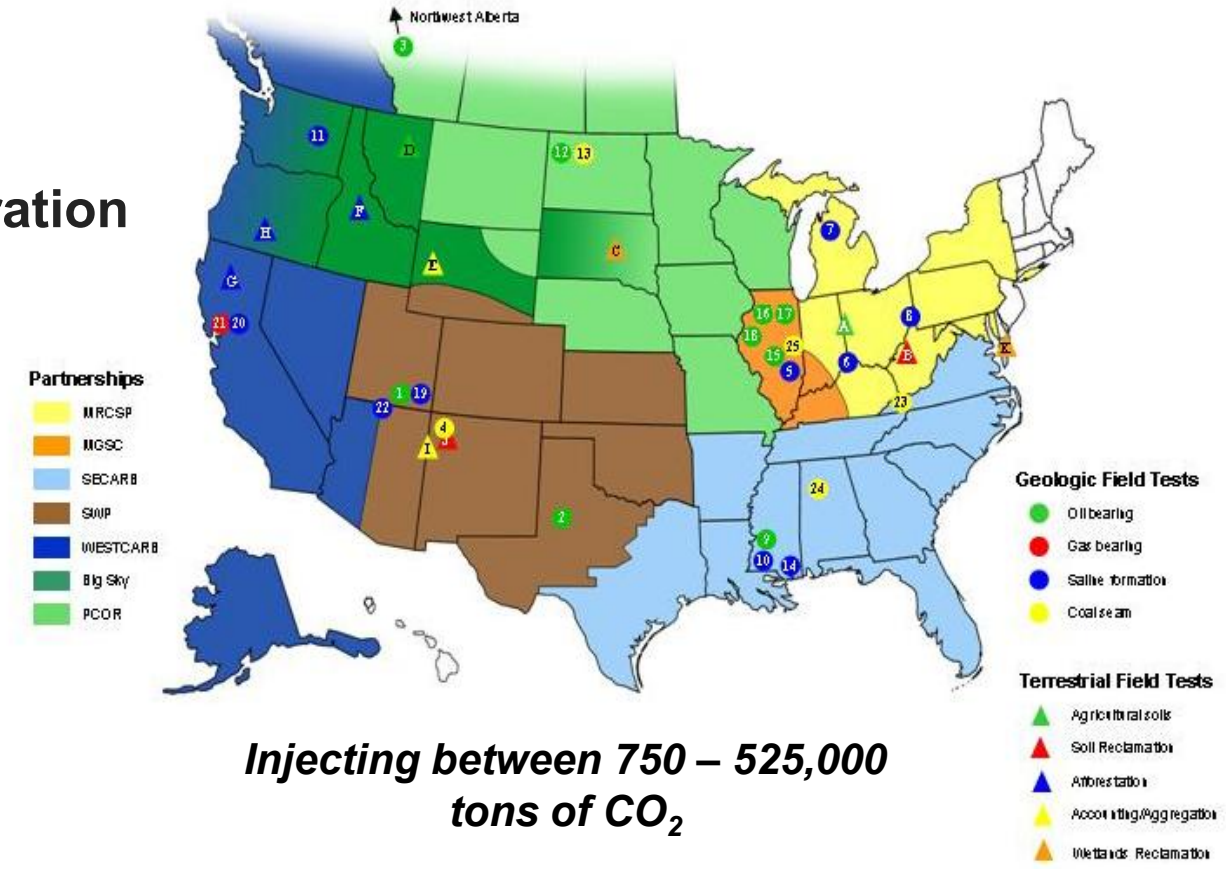
SWP Southwest Partnership CO2 Sequestration

Southeast Regional Carbon Sequestration Partnership

Validation Phase Field Tests

- **25 Geologic Sequestration Injection Tests**
  - 10 Saline Formation Tests
  - 9 EOR Tests
  - 5 ECBM Tests
  - 1 EGR Test
- **11 Terrestrial Sequestration Tests**
  - Croplands
  - Rangelands
  - Wetlands
  - Forestlands

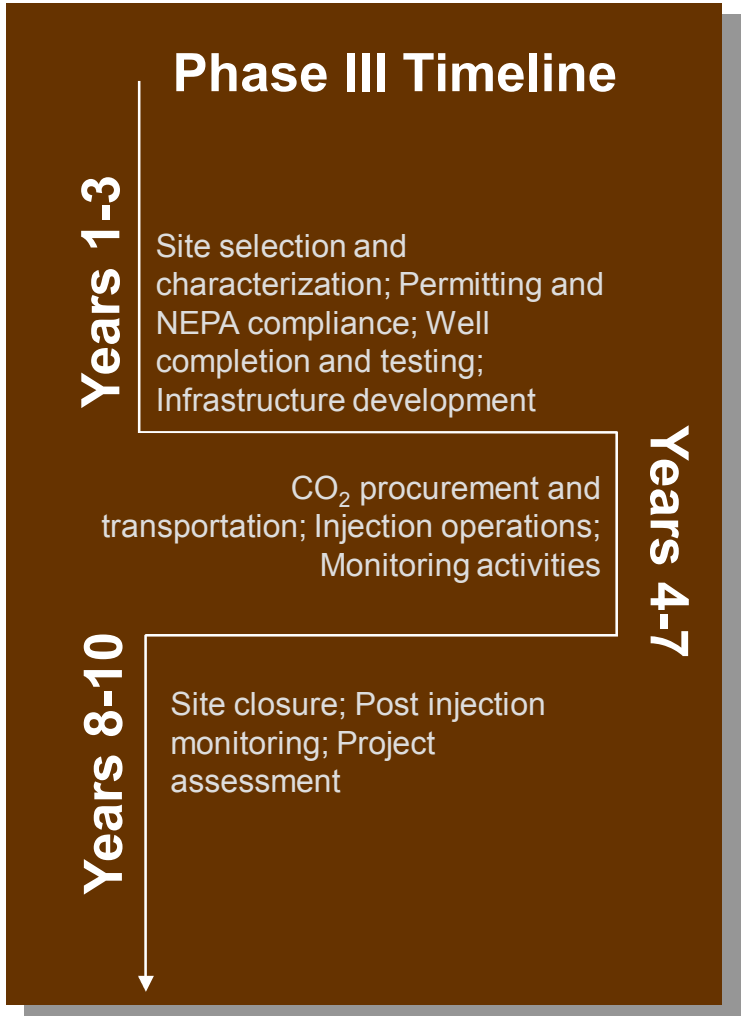
Validating Storage Options Throughout the U.S.



Injecting between 750 – 525,000 tons of CO_2

Deployment Phase
Scaling Up Towards Commercialization

- FY 2008-2017 (10 years)
- Several Large Volume Sequestration tests in North America
- Injection rates up to 1,000,000 tons per year for several years
- Scale up is required to provide insight into several operational and technical issues in different formations



Summary of RCSP Phase II Field Activities

Partnership	Geologic Field Test	FY 2006				FY 2007				FY 2008				FY 2009			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Big Sky - MSU	Basalt and Mafic Rock Field Validation Test																
MRCSP Battelle	Appalachian Basin Geologic Test																
	Cincinnati Arch Geologic Test																
	Michigan Basin Geologic Test																
MGSC ISGS	Saline Formation Tests																
	Enhanced Oil Recovery Tests (Huff 'n Puff)																
	Enhanced Coalbed Methane Tests																
PCOR EERC	Lignite in North Dakota Field Validation Test																
	Zama Field Validation Test																
	Beaver Lodge EOR Field Test																
SECARB SSEB	Gulf Coast Stacked Storage Project																
	Black Warrior Basin Coal Test																
	Central Appalachian Basin Coal Test																
	Saline Reservoir Field Test: Mississippi Test Site																
SWPCS UNMIMT	Paradox Basin, Utah: Aneth EOR/ Deep Saline Tests																
	Permian Basin, Texas: SACROC-Claytonville EOR-																
	San Juan Basin, New Mexico: ECBM Test																
WESTCARB CEC	Rosetta Resources Stacked Gas/Saline Project																
	Northern Arizona Saline Formation CO2 Pilot																

- Baseline - Drilling - Injection - MMV

Technical Working Groups

- Geologic and Infrastructure
- Capture and Transportation
- GIS and Database
- Public Outreach
- Regulatory Working Group
- Economics and Markets
- MMV Working Group

- **Benefits**
  - Developing standards for capacity
  - Sharing information on project implementation
  - Developing common messages

National Carbon Sequestration Database

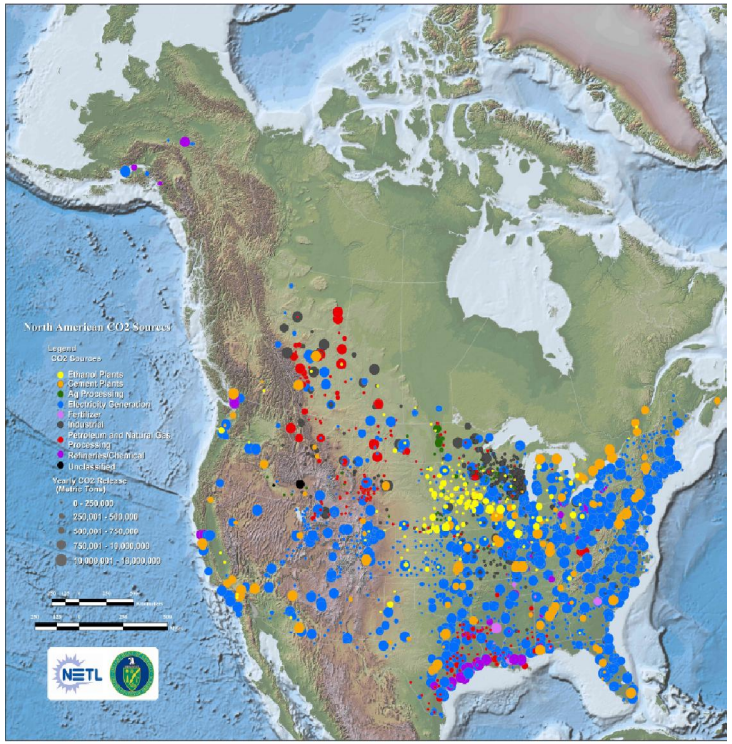
- **Integrate data across Partnerships**
- **National perspective of sequestration potential**
  - Identifies CO_2 sources
  - Identifies sequestration opportunities
  - Incorporates data from 15 servers
- **Outreach tool**
  - Web-site gets 400+ unique visitors / month

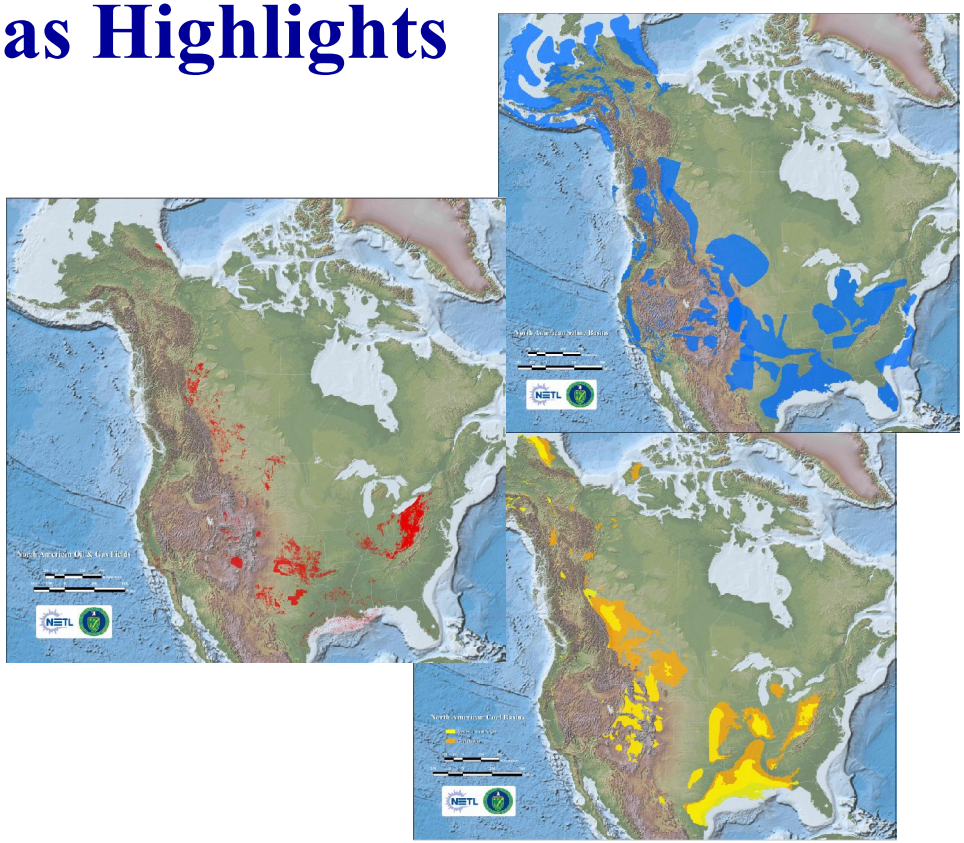
www.natcarb.org

National Atlas Highlights

CO_2 Sources Documented in NatCarb

	CO_2 Emission (Million Tons)	Number of Facilities
CO_2 Sources	3,809	4365



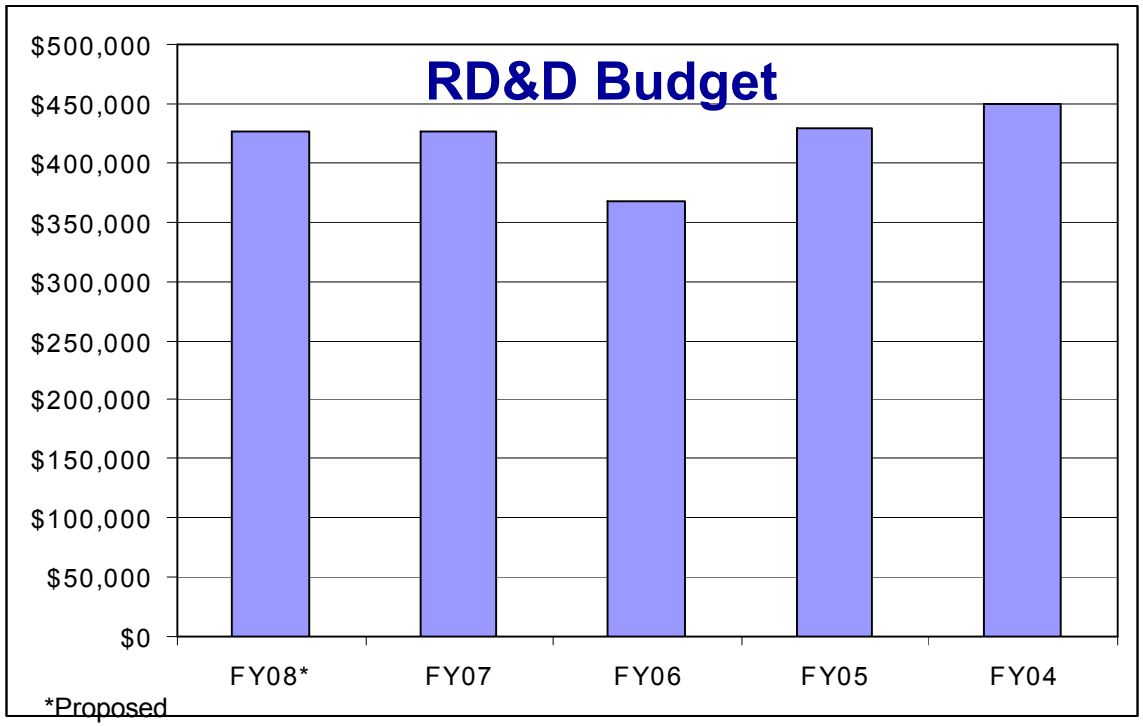


North American CO_2 Storage Potential (Giga Tonnes)

Sink Type	Low	High
Saline	969	3,223
Unmineable Coal Seams	70	97
Oil and Gas Fields	82	83

U.S. ~ 6 GT CO_2/yr all sources

Federal Support Advanced Coal Technology



Tax Credits

- $1.65 B Total
  - $1.3 B Power
  - $350 M Syn Gas
- $1.0 B Allocated
- 15% / 20%

Loan Guarentee

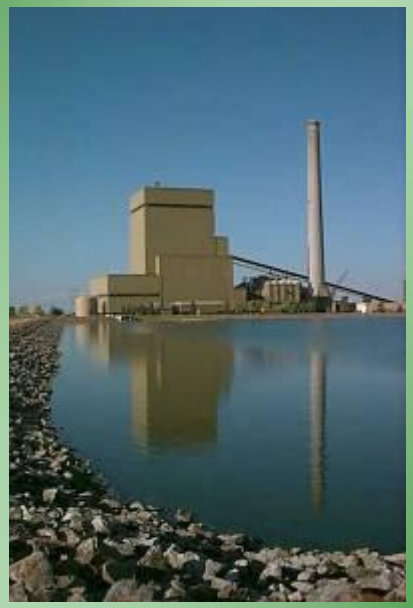
- Up to 80%
- 30 Years

National Energy Technology Laboratory Mission

Implement research, development, and demonstration programs to resolve the environmental, supply, and reliability constraints of producing and using fossil resources

NETL Mission Areas

Strategic Center for Coal

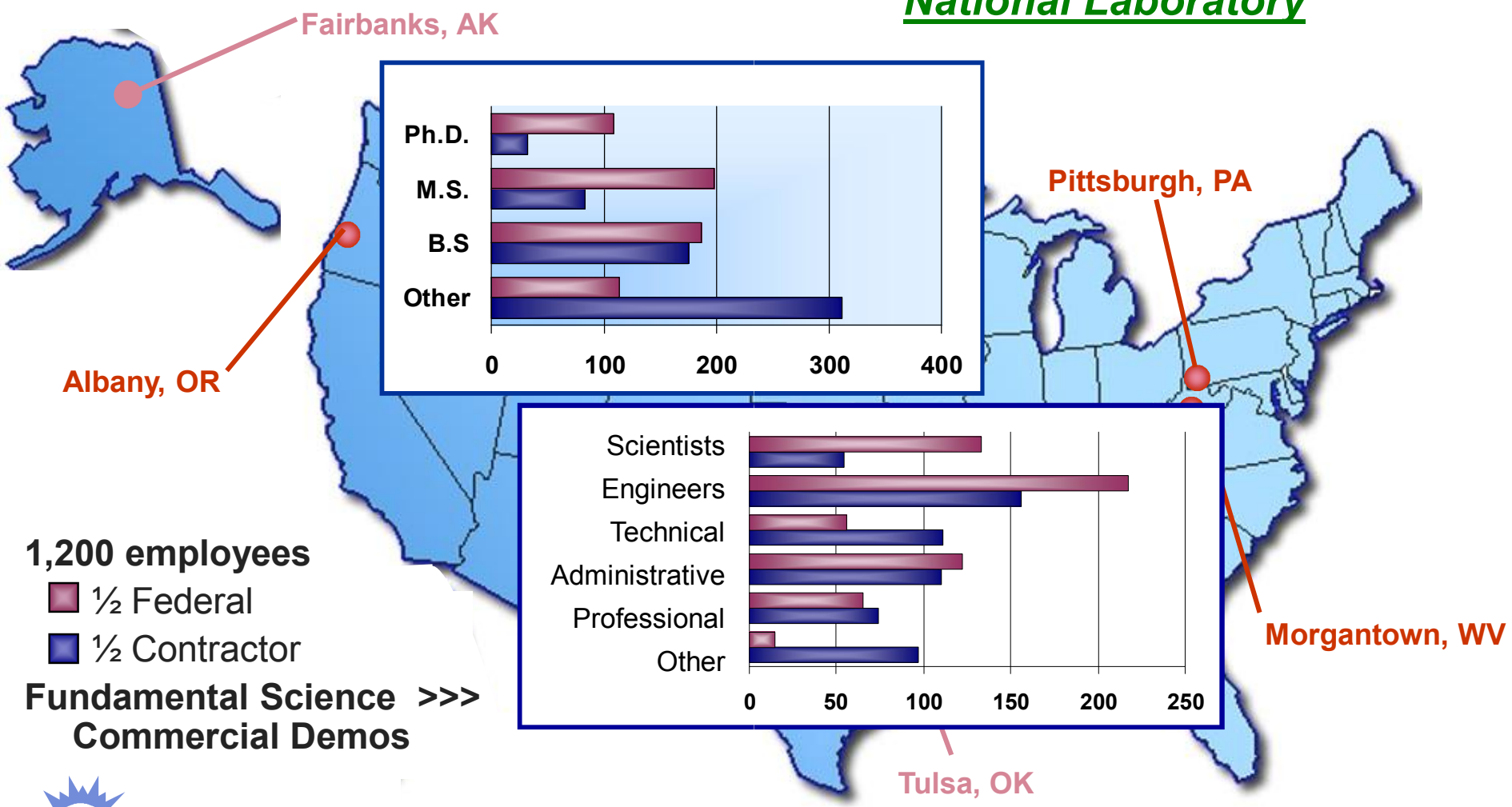


Strategic Center for Natural Gas and Oil

Project Management Center

National Energy Technology Laboratory

DOE's Fossil Energy National Laboratory

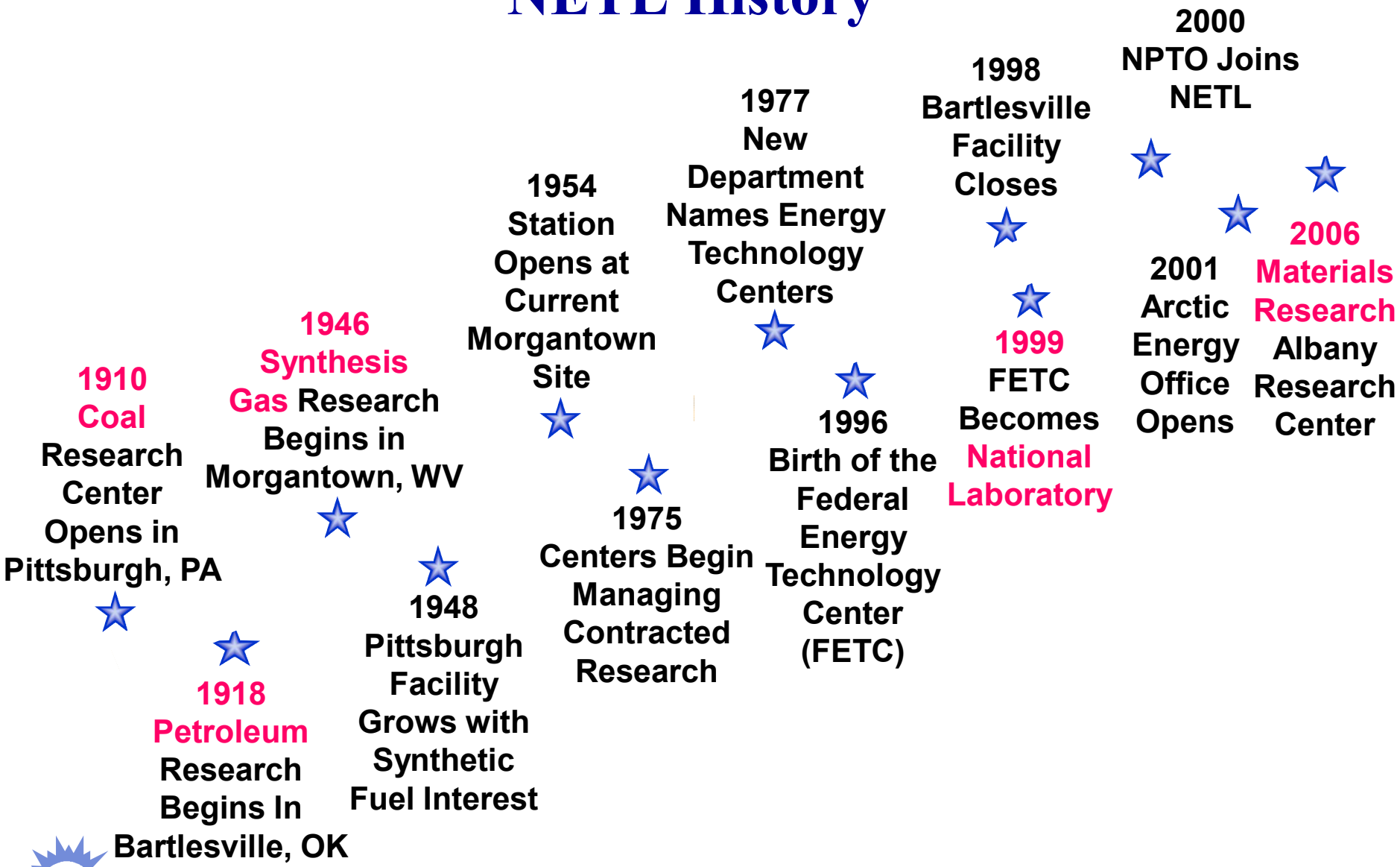


1,200 employees

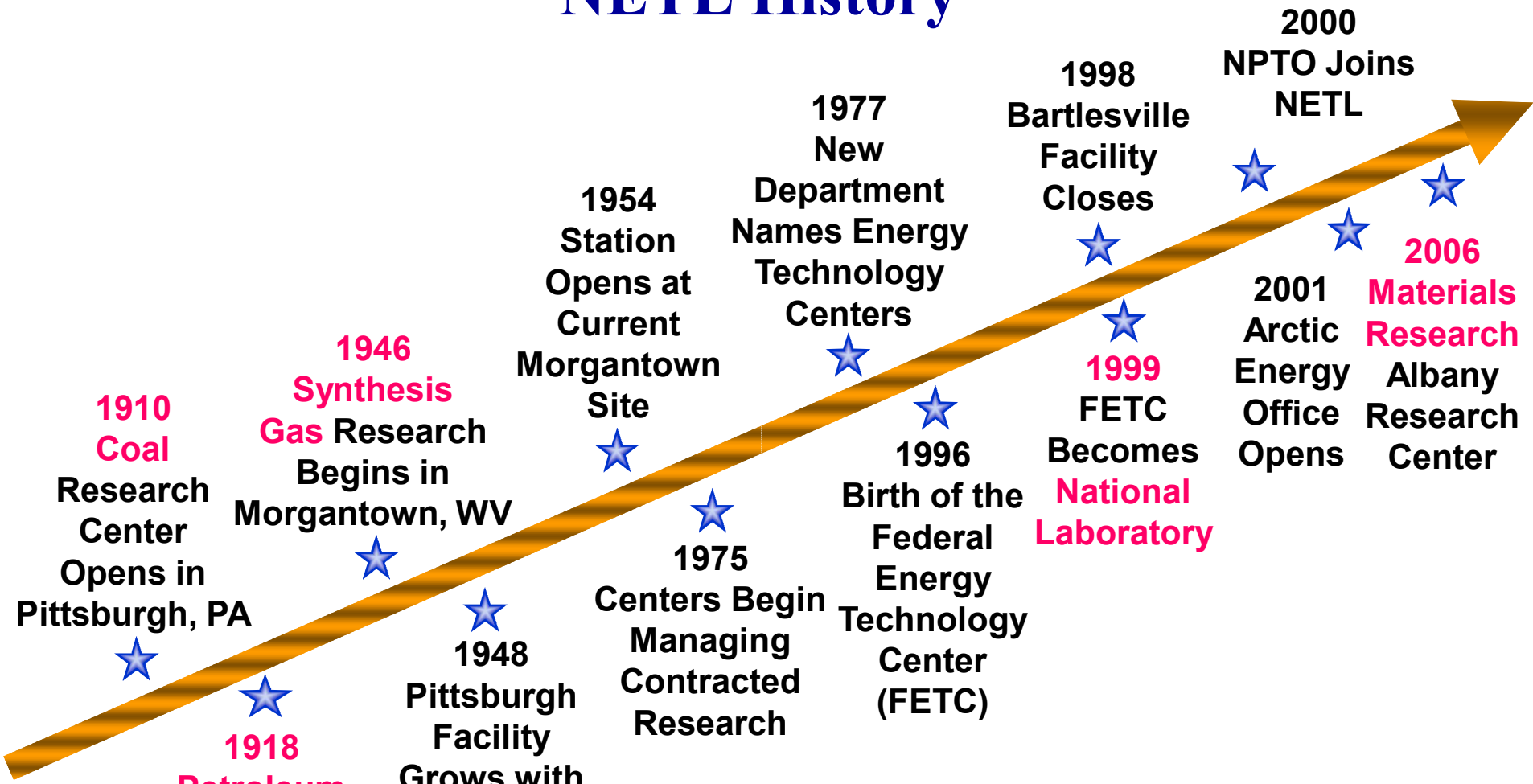
- ½ Federal
- ½ Contractor

Fundamental Science >>>
Commercial Demos

NETL History



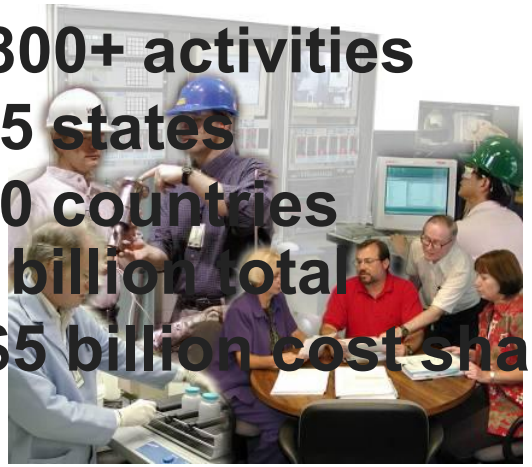
NETL History



Accomplishing NETL Mission

- **Extramural RD&D**

>1,800+ activities
45 states
40 countries
>$9 billion total
$5 billion cost share



- **Onsite research**

>Geological & Environmental Science
>Energy System Dynamics
>Material Science
>Computational & Basic Science

Research and Policy Guidance

> Systems a
> Life cycle a
> Benefits quantificat

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Research and Policy Guidance

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Research and Policy Guidance

> Systems analysis
> Life cycle analysis
> Benefits quantification
> Forecasts and trend analysis
> Technology-regulatory implications
> Assessment of natural resource requirements

Advanced Energy Technologies Can Resolve the Environmental, Supply, and Reliability Constraints of Producing and Using Fossil Fuels

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www.netl.doe.gov