Energy and the <u>Environment</u>:

A Changing Emphasis in the Energy and Minerals Section?

Jim Drahovzal

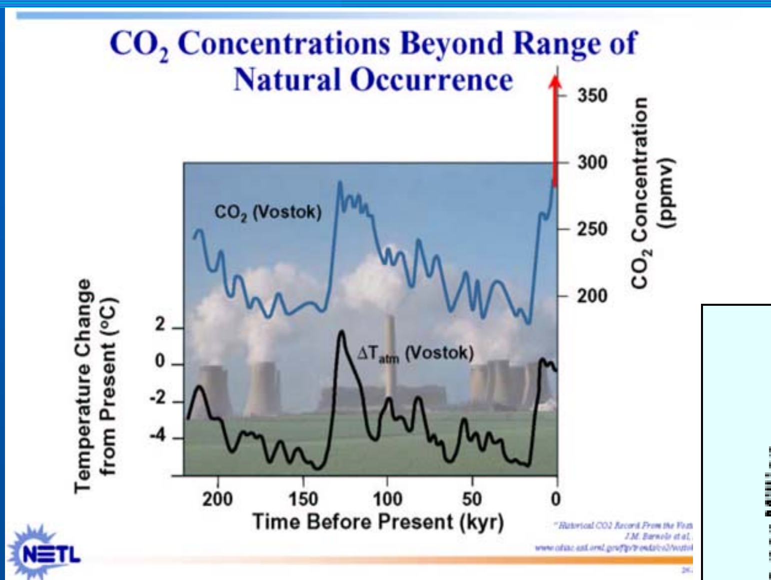
KGS Annual Meeting

May 16, 2003

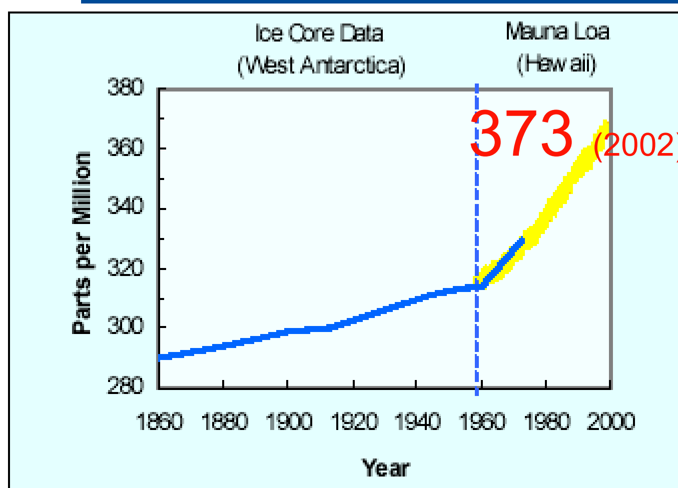
Outline

- Carbon Sequestration
  - What we think we know about climate change
  - Fossil fuel future
  - Technological options to manage carbon
  - DOE's carbon sequestration programs
  - KGS responses and interests
- Coalbed Methane
- Deep Gas
- Other Programs

Global Climate Change: Current Understanding



Unprecedented
<u>23% higher than the highest in the last 420k years</u>



Data sources: Ice core data obtained at the Siple Station, published by Neftel, et al., 1985; Data from the Mauna Loa Observatory obtained from the NOAA web page.

<u>18% in 2002 than in 1959</u>

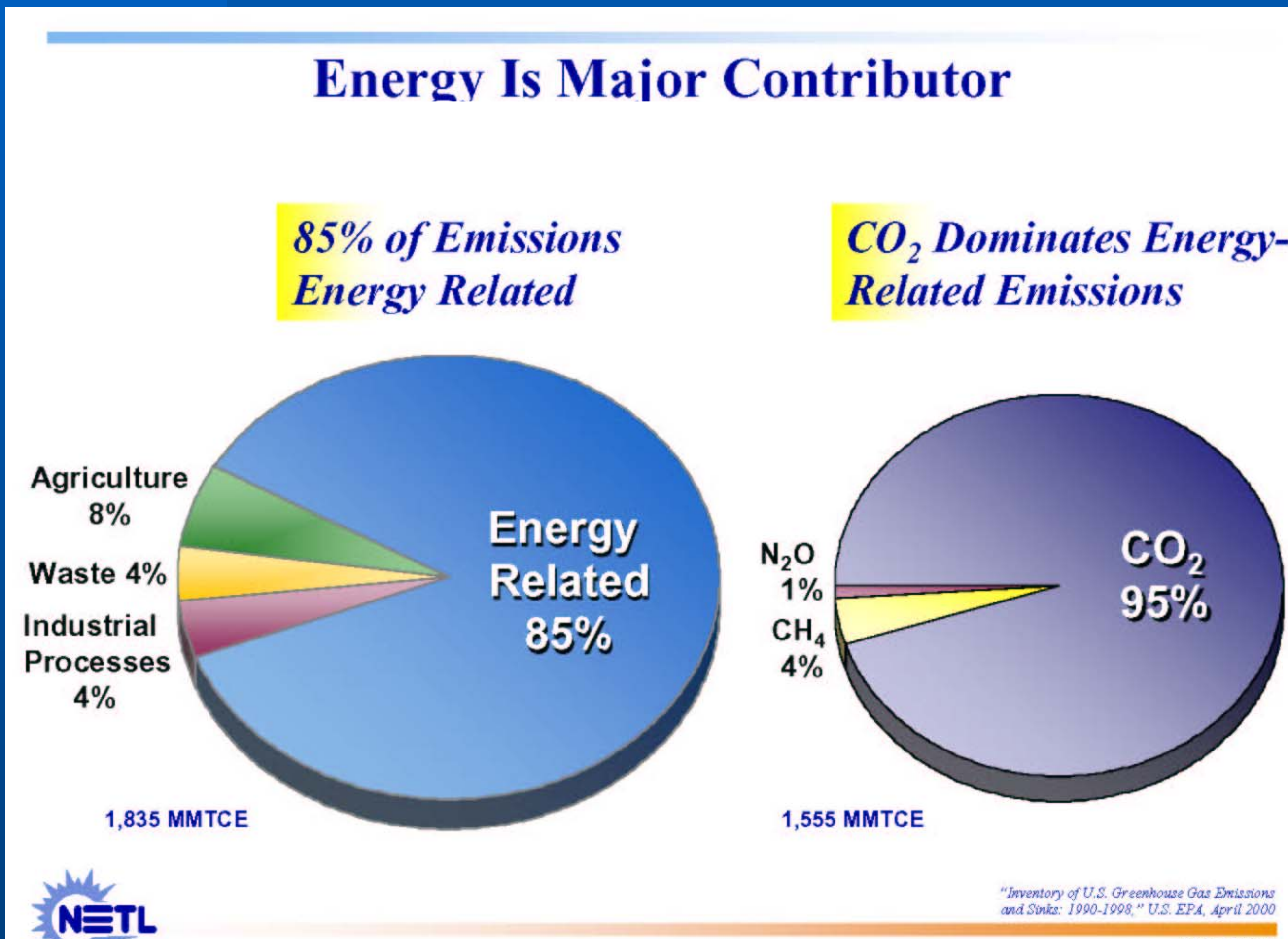
- Global temperatures are rising: GHG CO_2
- Impact on global climate/warming
  - sea level rise
  - extreme weather
  - human health
  - agricultural patterns
  - ecological change

Scientific questions
  - Adequacy of models
  - Which is the driver?
  - Other factors?

Global Climate Change: Public Policy Response

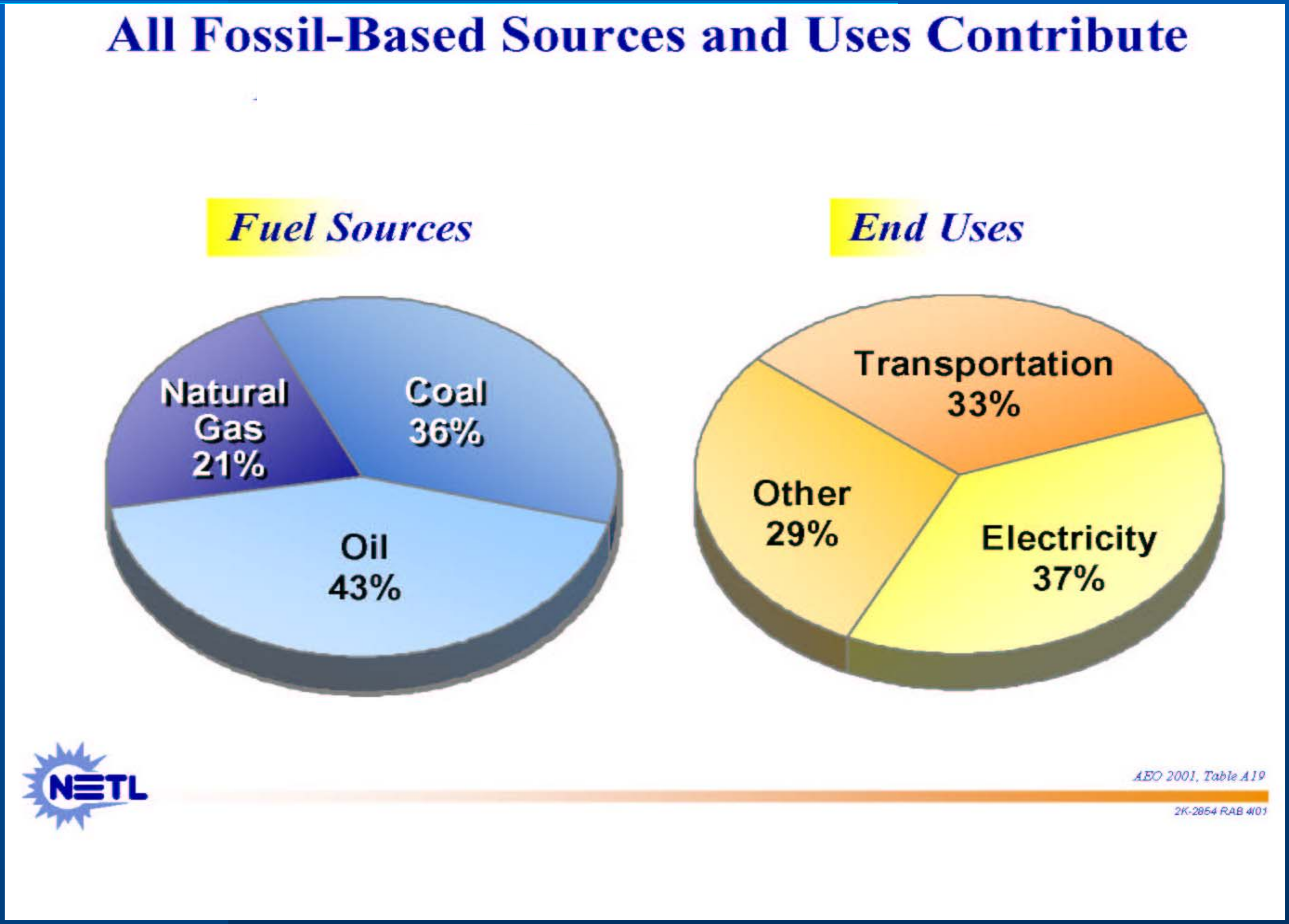
- 1992 Rio Treaty: "… stabilization of of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." (161 countries)
- 1997 Kyoto Accords: "… the vast majority of scientists now believe that rising concentrations of 'greenhouse gas' in the earth's atmosphere … are overriding this natural variability and leading to potentially irreversible climate change." (106 countries; not United States)
- 2000 Former President Clinton: "… one of the two or three major issues facing the world over the next 30 years."
- 2001 Christine Todd Whitman: "… one of the greatest environmental challenges we face, if not the greatest."
- 2002 President Bush: Global Climate Change Initiative (GCCI) "… we need to dramatically reduce our greenhouse gas emissions in the longer term."

U.S. Anthropogenic GHG Emissions



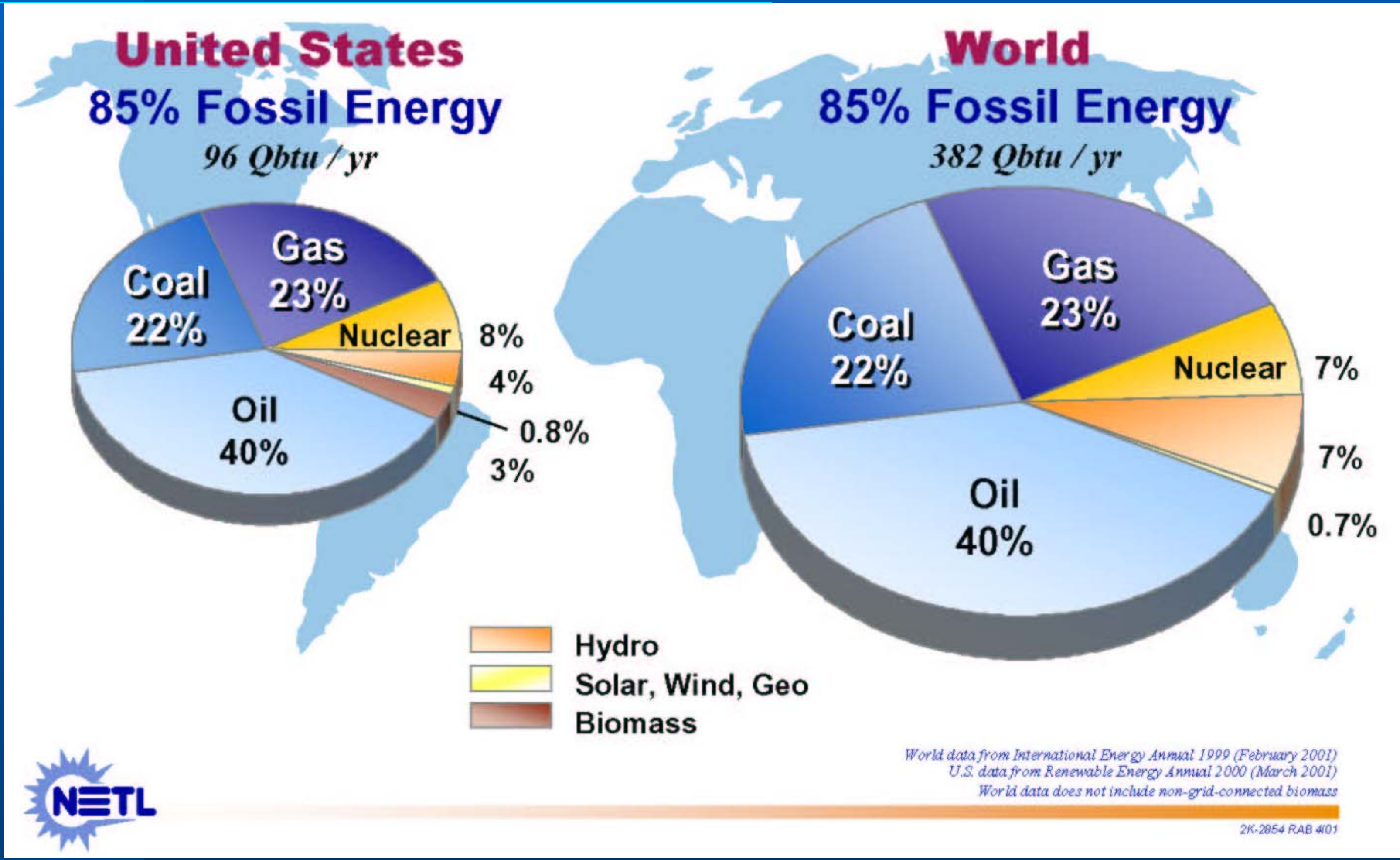
- Note: Anthropogenic emissions = 3% of total global CO_2 emissions
- But anthropogenic emissions are changing the balance and CO_2 is increasing in atmosphere
- Global climatic effects

U.S. CO_2 Emissions from Energy

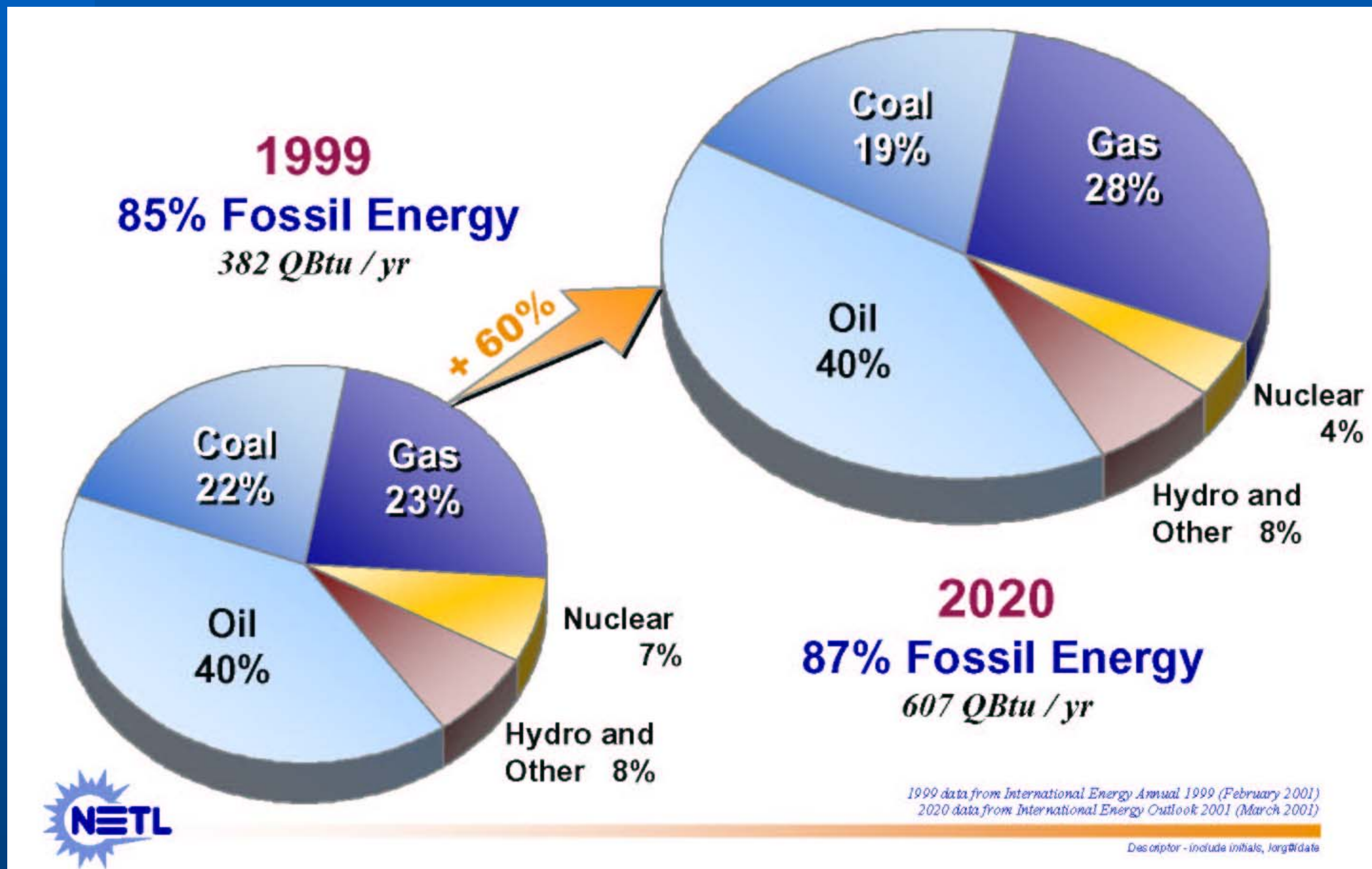


- CO_2 emissions involve all fossil fuels and end user sectors

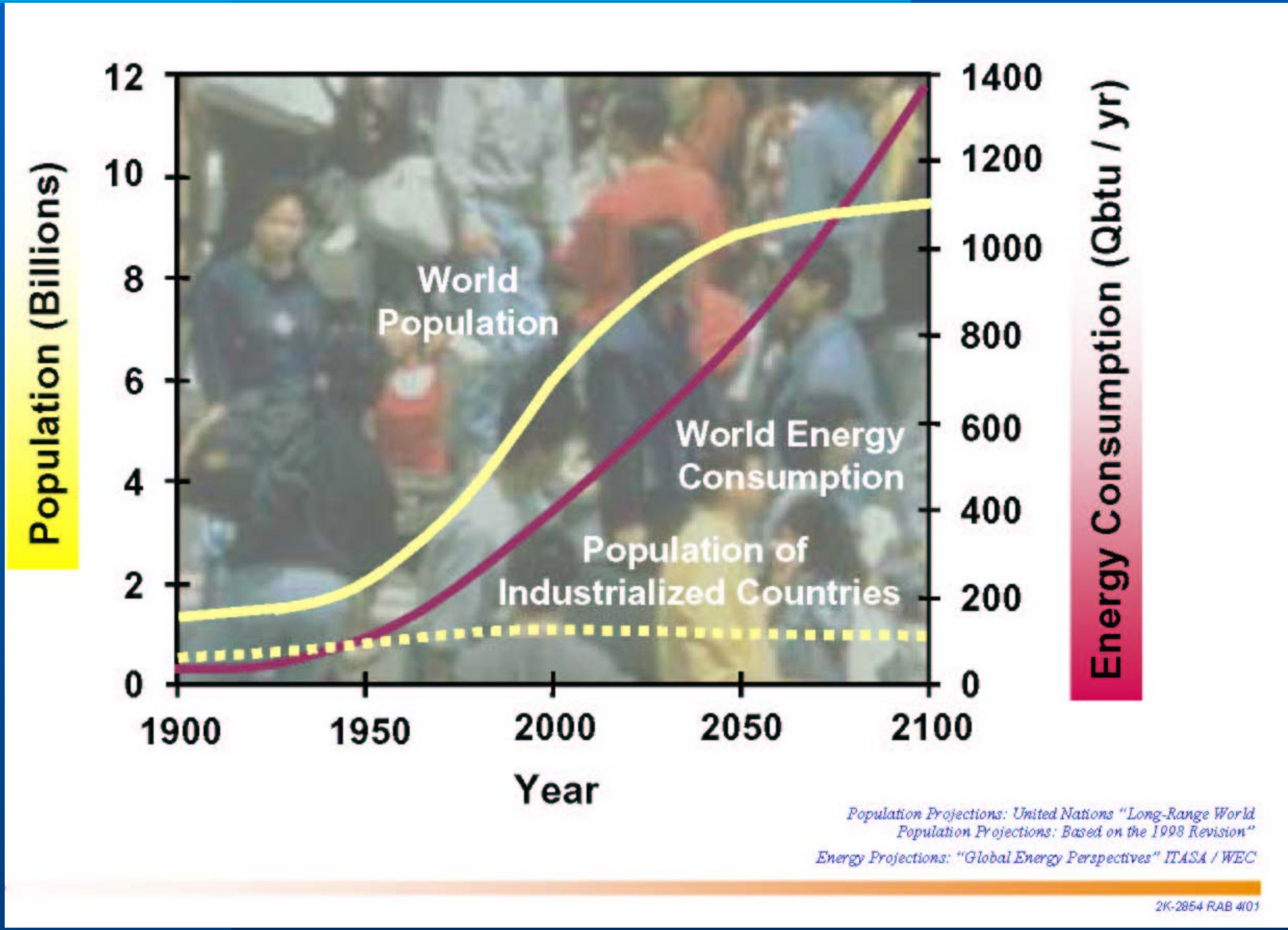
U.S. and World Economies based on Fossil Fuels



Fossil Fuels Will Continue as Key to World Economy

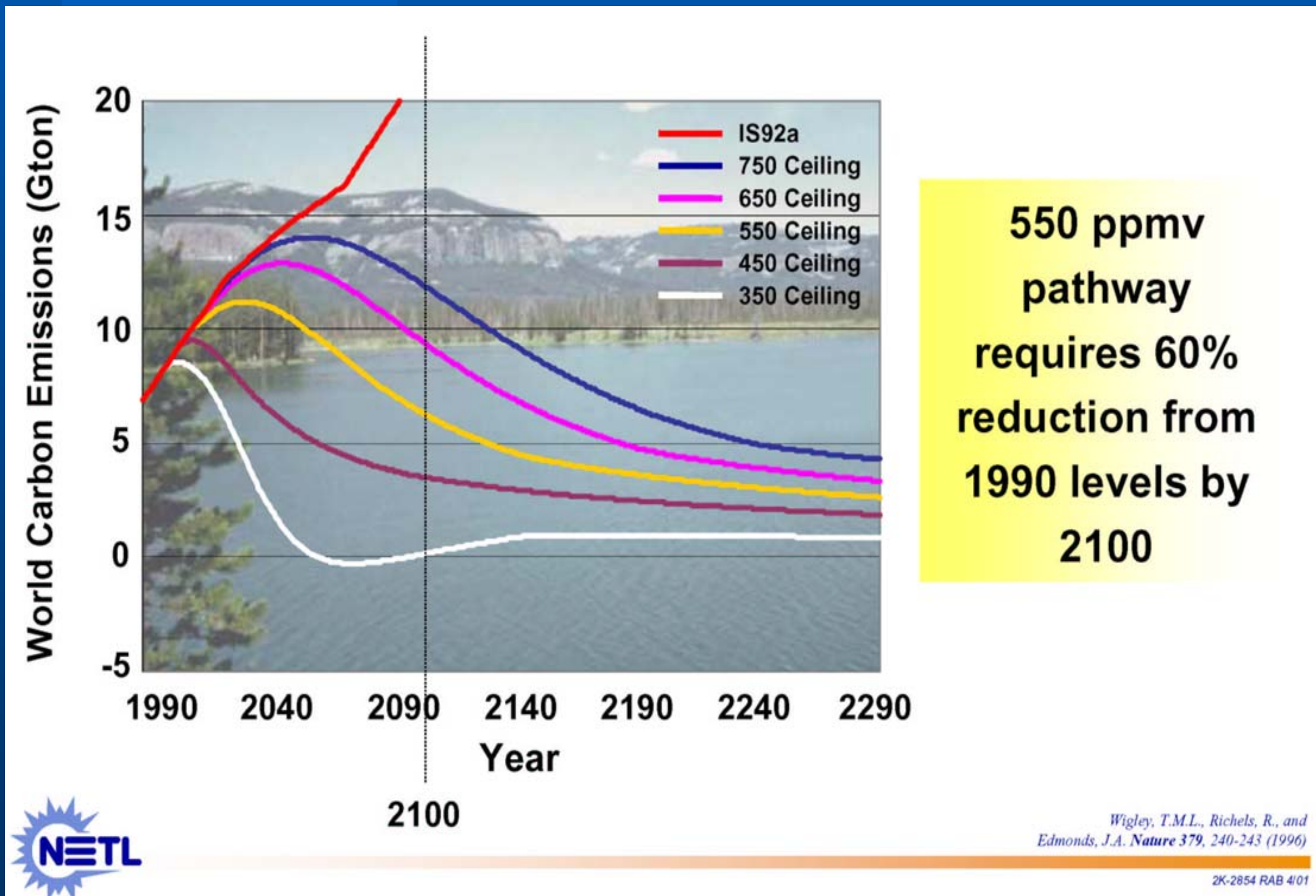


Looking Farther Out at World Energy Demand



- World Energy Council predicts a rise of 2 to 5 times by 2100
- This graph shows rise of about 3 times
- What will happen with CO_2 concentrations?

Scenarios to Stabilize CO_2 Concentrations



- Current 7.4 GtC/yr
- Even if:
  - moderate population growth
  - moderate economic growth
  - >40% energy from non-fossil sources
- Growth could expand up to 26 GtC /yr by 2100
- Fear of major global consequences
- 550 ppmv is achievable, but 2x pre-industrial
- How do we stabilize atmospheric CO_2 ?

KGS

The Situation

- Fossil fuels will remain the mainstay of energy production well into the 21st century
- Without mitigation, anthropogenic CO_2 emissions to the atmosphere are predicted to more than double during the 21st century
- Global environmental consequences
  - Climate change
  - Health issues

Technical Approaches to and Factors in CO_2 Management

- Increase the efficiency of primary energy conversion systems
- Use lower carbon or carbon-free fuels
- Sequestration (Disposal)
  - Geologic
  - Critical Factors
    - Cost
    - Safety
- Federal Rationale: *Begin Research Now*

Technological Carbon Management Options

Reduce Carbon Intensity	Improve Efficiency	Sequester Carbon
• Renewables • Nuclear • Fuel Switching	• Demand Side • Supply Side	• Capture & Storage • Enhance Natural Processes

All options needed to:

- Supply energy demand
- Address environmental objectives

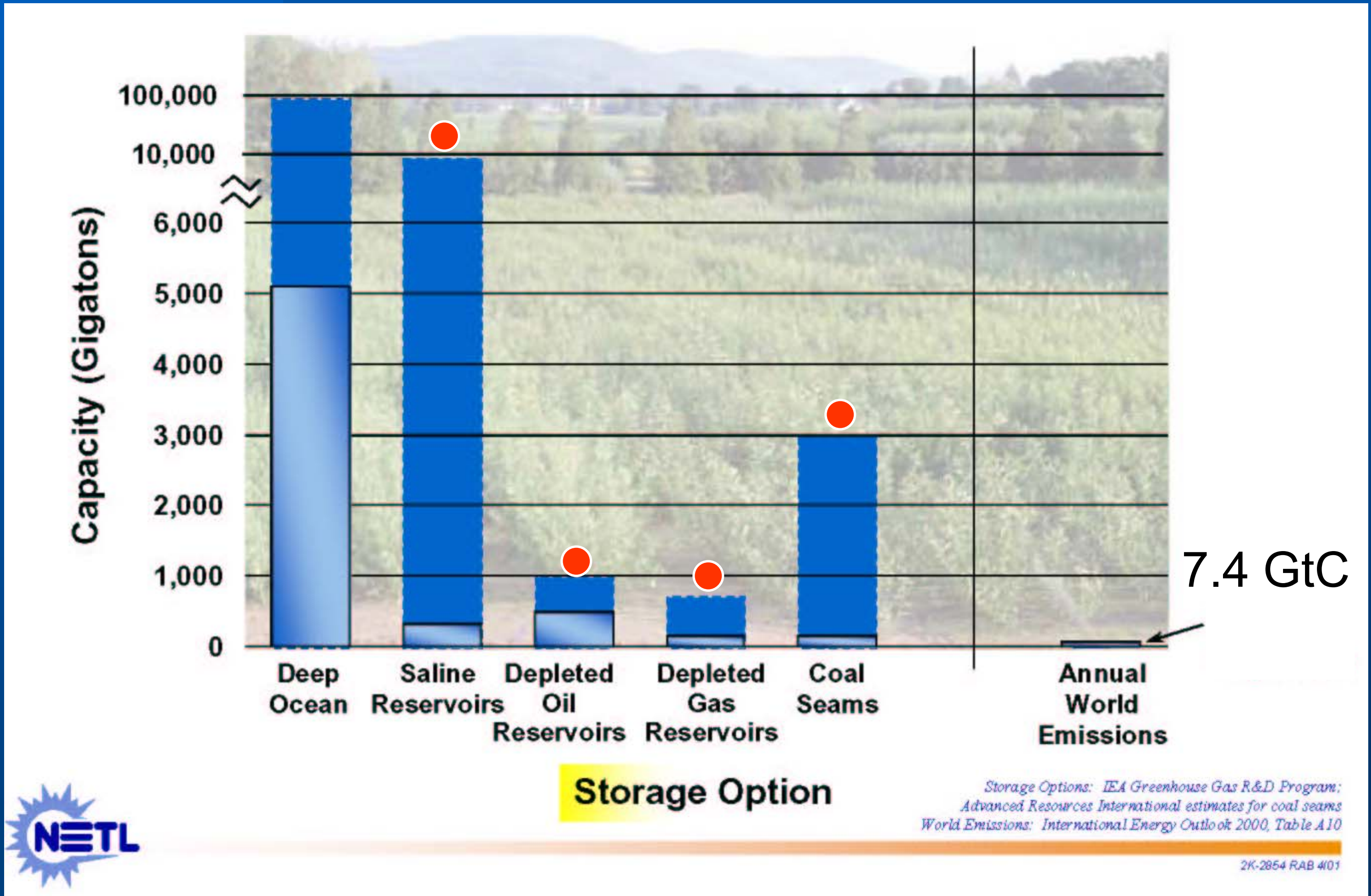
NETL

2K-2854 RAB 4/01

KGS

Approaches in Sequestering Carbon

Large Worldwide Potential Storage Capacity



Organic shale?

Capacity should not be an issue*

*Given that we move to a non-carbon (hydrogen) economy in a reasonable timeframe

Requirements for Sequestration to be Viable Public Policy Option

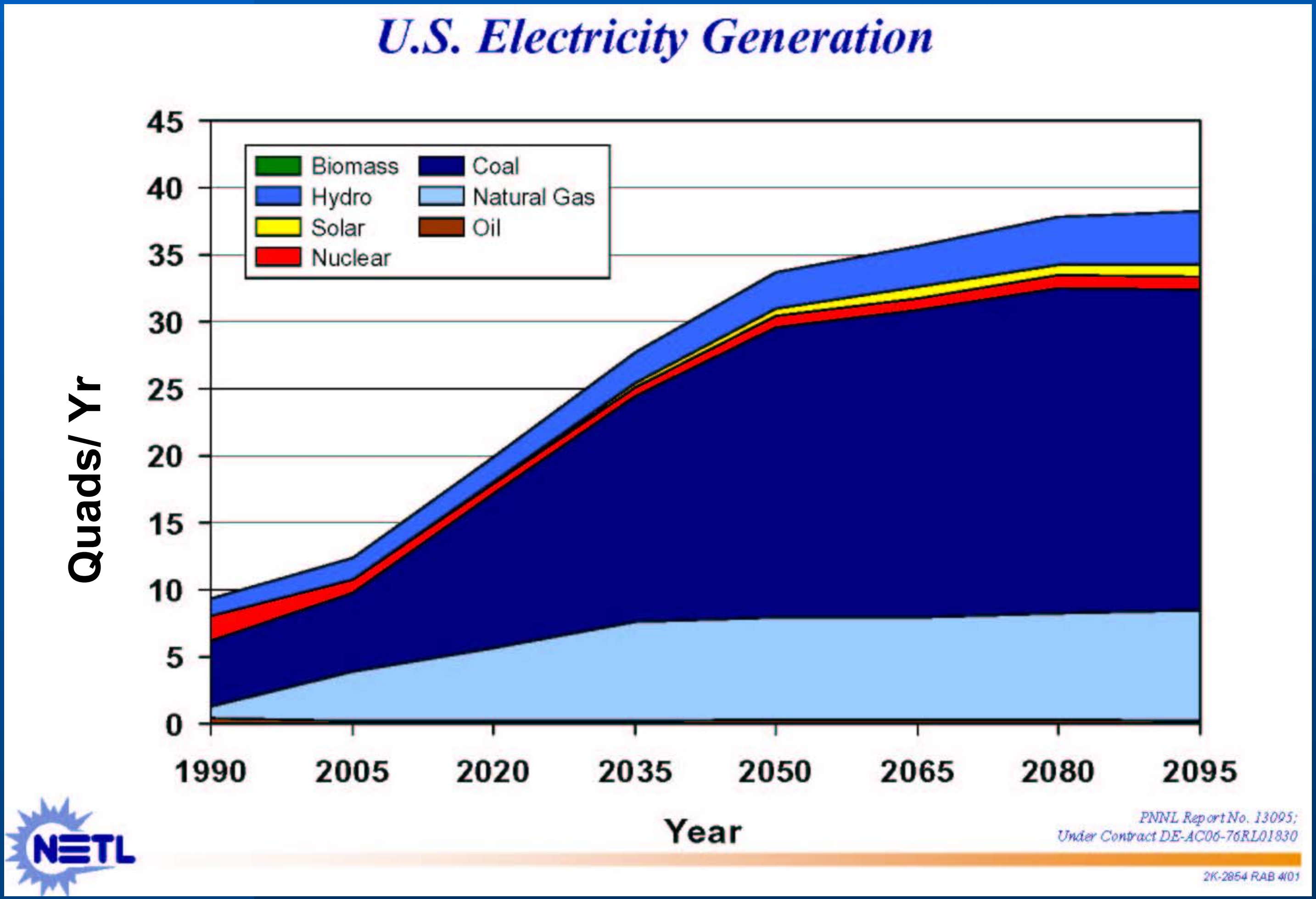
- **Environmentally acceptable**
  - No legacy for future generations
  - Respect existing ecosystems
- **Safe**
  - No sudden large-scale CO_2 discharges
- **Verifiable**
  - Ability to verify amount of CO_2 sequestered
- **Economically viable**

-$10 / ton of carbon avoided

NETL

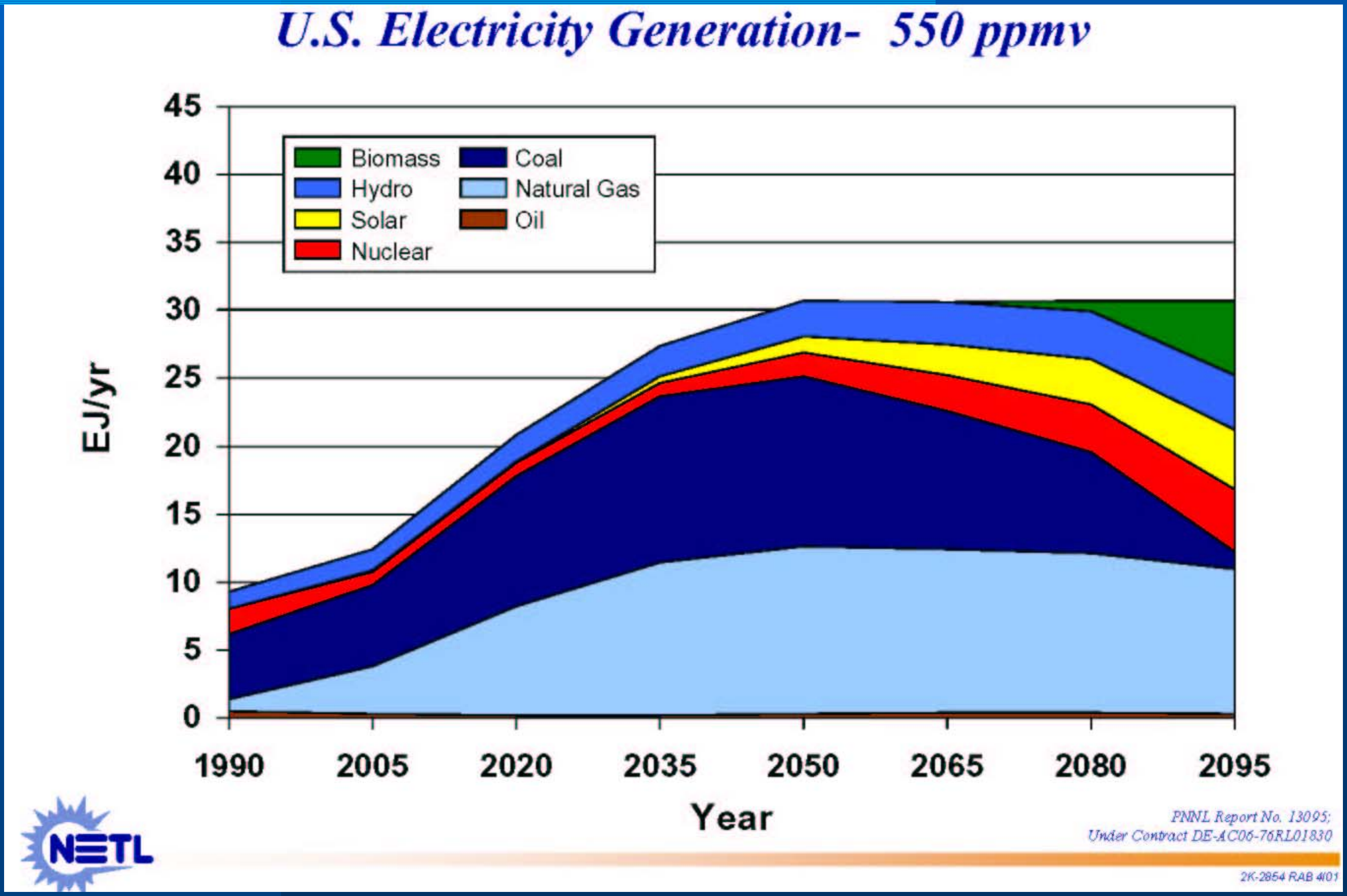
2K-2854 RAB 4/01

Future Scenarios : Supplying Demand, without Addressing Environment



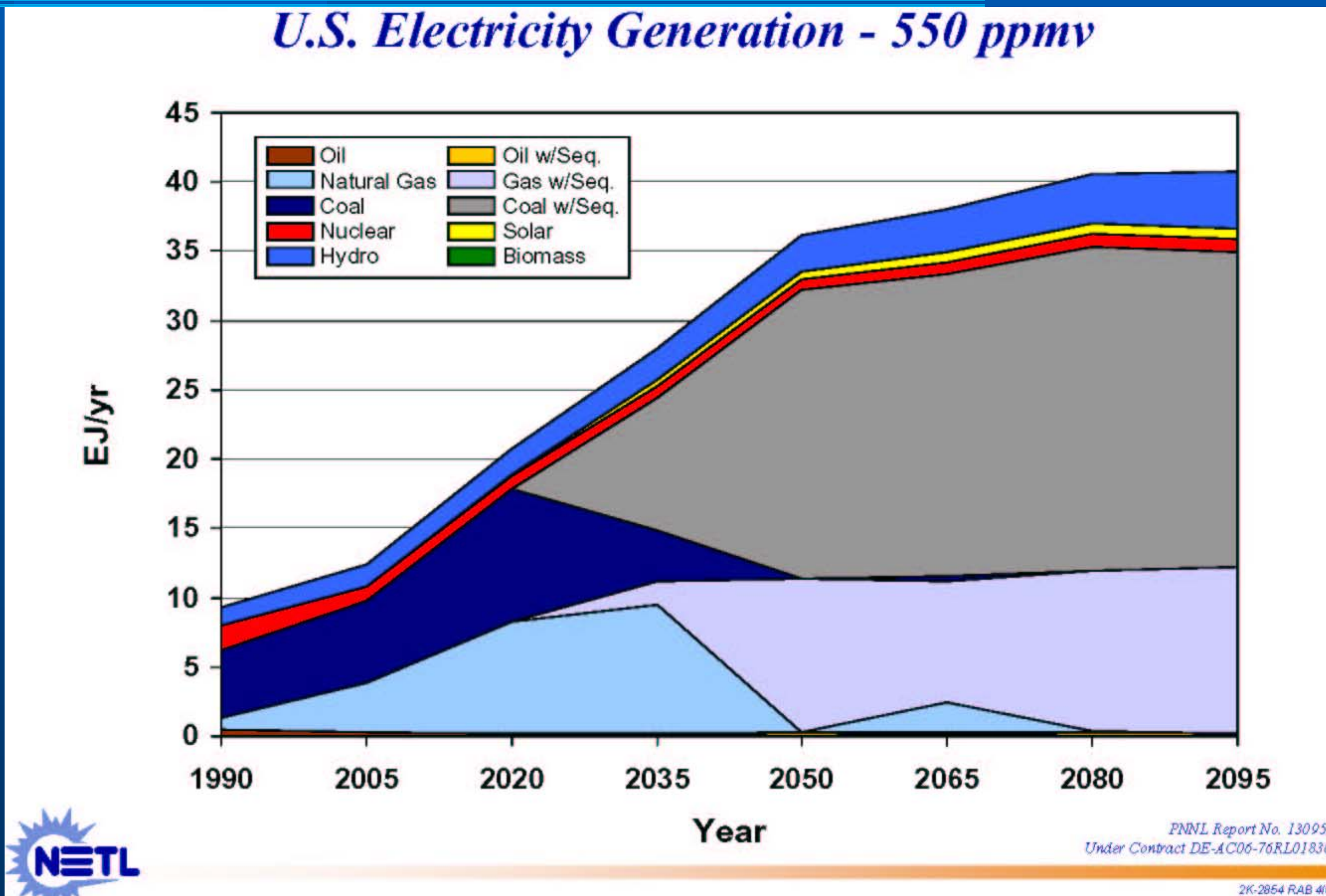
- Assumes a 4x increase in electricity demand
- Reliable, affordable energy
- "Hydrogen Economy" ~2050?
  - Non-carbon sources

Future Scenarios: Setting an Environmental Target, but Limiting Supply



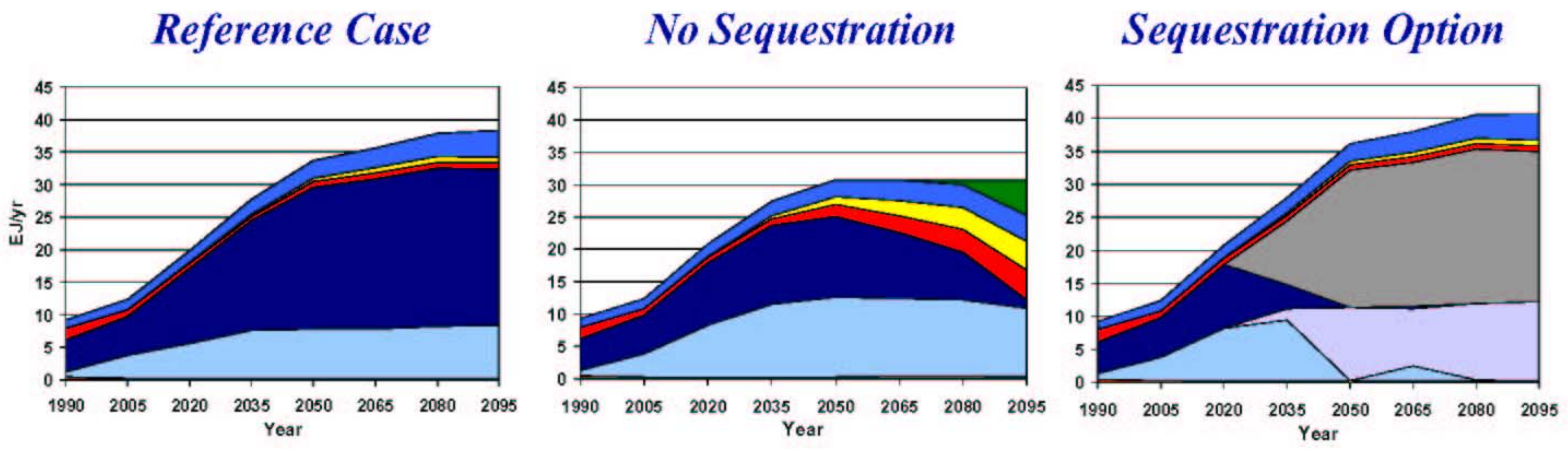
- Limits emissions by conservation and increasing carbon-free energy sources
- Electricity prices rise and less is used
- E-generation decreases 20%
- Negative economic effect

Having Our Cake and Eating it too ?: High-Efficiency Generation and Sequestration



- Sequestration begins after 2020
- Coal and natural gas fuels 86% of total power generation by 2100
- Save U.S. $215 B; world savings $1T

The Benefit of Sequestration



- Miss environmental target

- Meet 550 ppmv target

- Meet 550 ppmv target
- Save U.S. $215 billion
- World Wide Saving ⇛ $1 Trillion

NETL

PNNL Report No. 13095;
Under Contract DE-AC06-76RL01830

2K-2854 RAB 4/01

FutureGen Relies on Sequestration

- $1billion; industry/DOE
- Coal gasification; coal-to-hydrogen
- H used as fuel & product
- CO_2 sequestered
- Byproducts from NO_x and SO_x
- Goal: Electricity with zero pollution

Sequestration Options: Geologic Among the Best

- Relatively high capacity
- Safe
- Long-term
- Kentucky's geologic options
  - Depleted oil and gas fields (enhanced oil and gas recovery)
  - Unmineable coal beds (enhanced gas recovery)
  - Deep saline aquifers (storage only)
  - Unconventional reservoirs
    - Deep, poorly known reservoirs (ECRB)
    - Devonian black shale (enhanced recovery)

MIDCARB

Midcontinent

Interactive

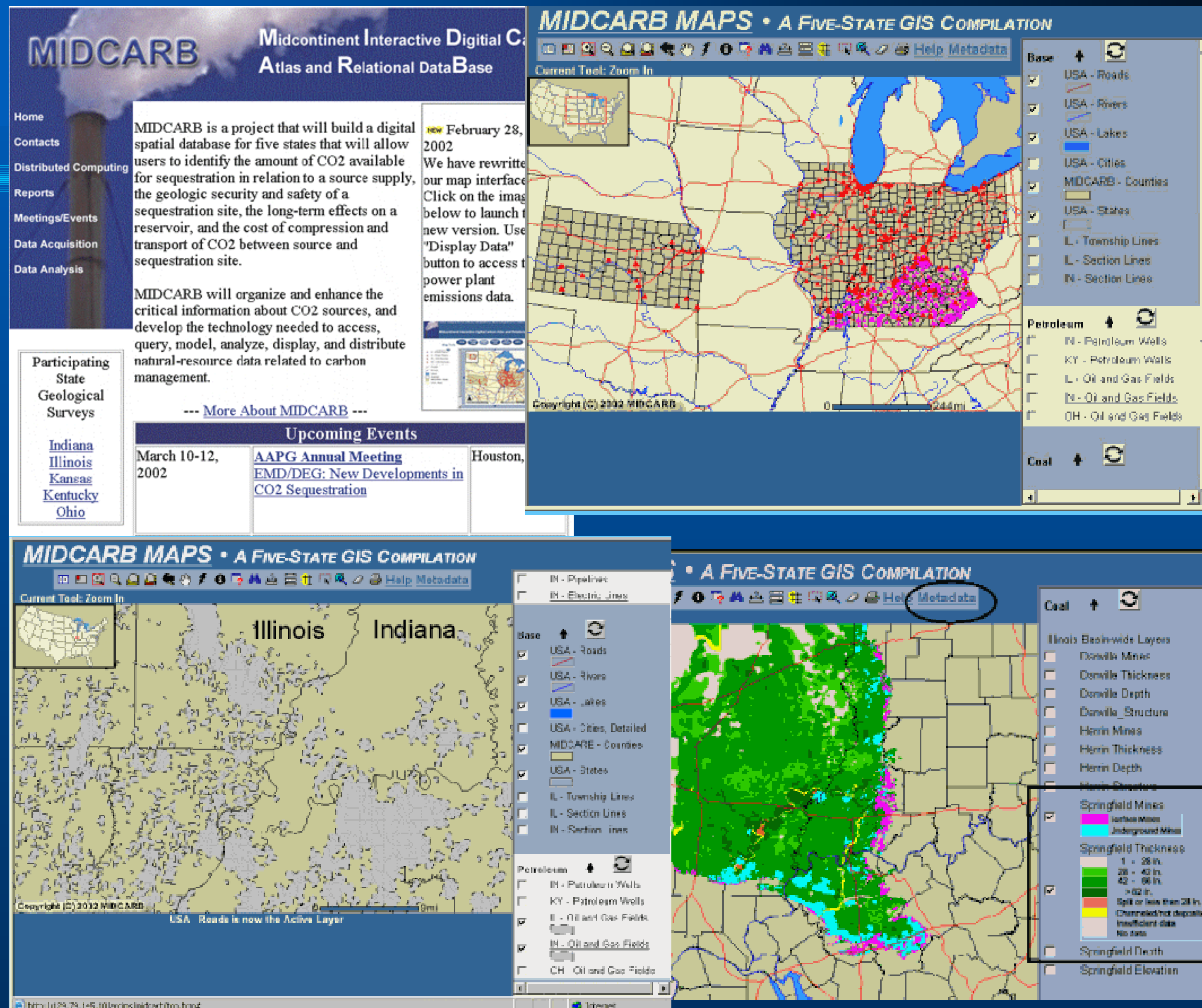
Digital

Carbon

Atlas and

Relational

Data**B**ase



MIDCARB: Summary

- Quality, Size and Geologic Integrity of Sequestration Sites (Safety and Longevity)
- Location of Sequestration Sites Relative to CO_2 Sources (Cost)
- Relation of Quantity and Quality of CO_2 Source to Sequestration Options
- Economic Impact and Value of CO_2 Recovery and Sequestration
- Make Results Easily Available via Internet

CO_2 Source and Characterization

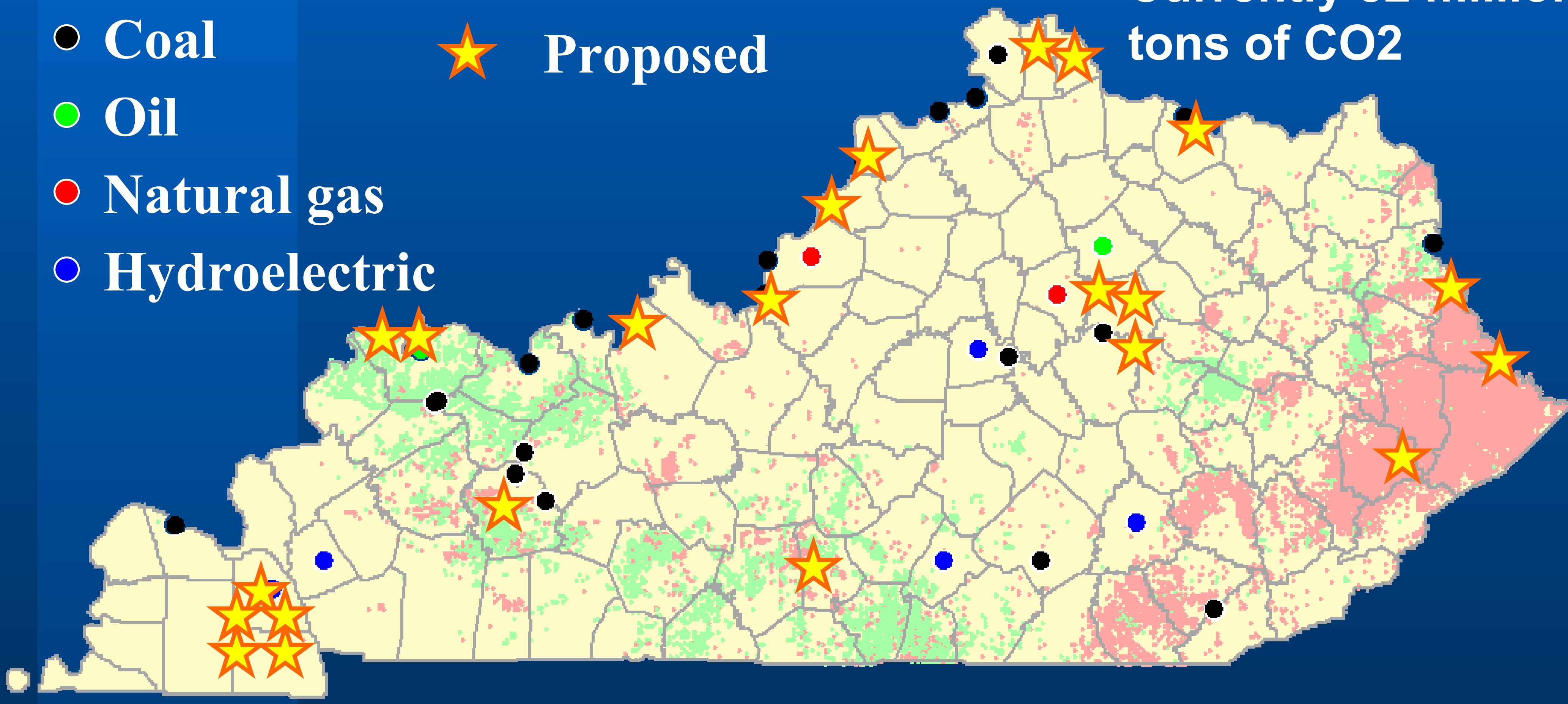
- Anthropogenic Sources
  - Power Plants
  - Other Large Stationary Sources
- Flue Gas
  - Pressure, Temperature
  - Concentrations, Output Patterns
- Location in relation to:
  - Sequestration Sites/Sinks
  - Transportation Infrastructure

Kentucky Power Plants and Oil & Gas Fields

- Coal
- Oil
- Natural gas
- Hydroelectric

★ Proposed

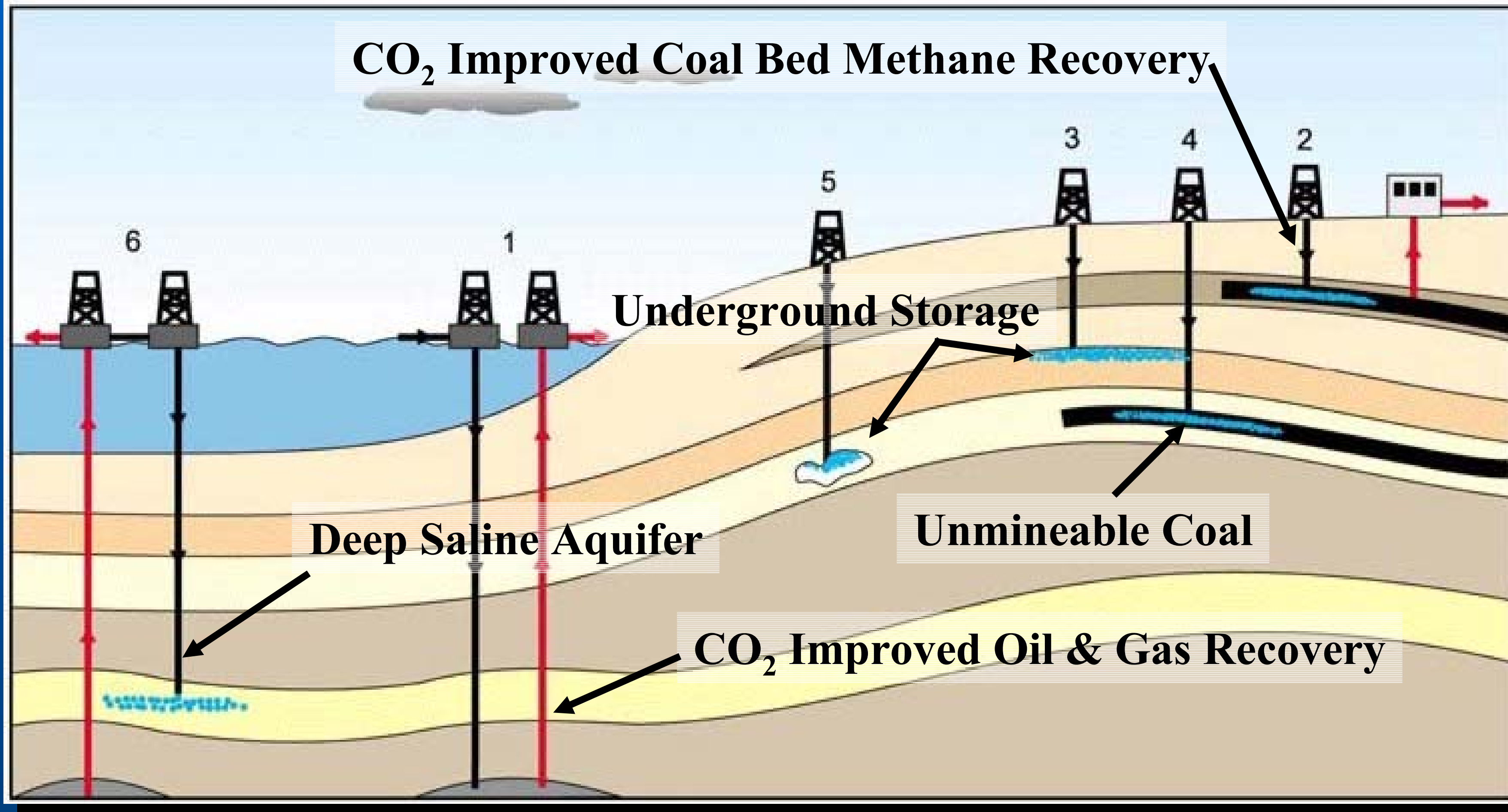
Currently 82 million tons of CO_2



MIDCARB CO_2 Sequestration

- Active and Depleted Oil and Gas Reservoirs
- Unmineable Coal Beds
- Deep Saline Aquifers
- Unconventional Gas Reservoirs
  - Deep, Poorly Known Reservoirs
  - Devonian Black Shale

CO_2 Geologic Sequestration Options



Modified from: http://www.spacedaily.com/news/greenhouse-00j.html

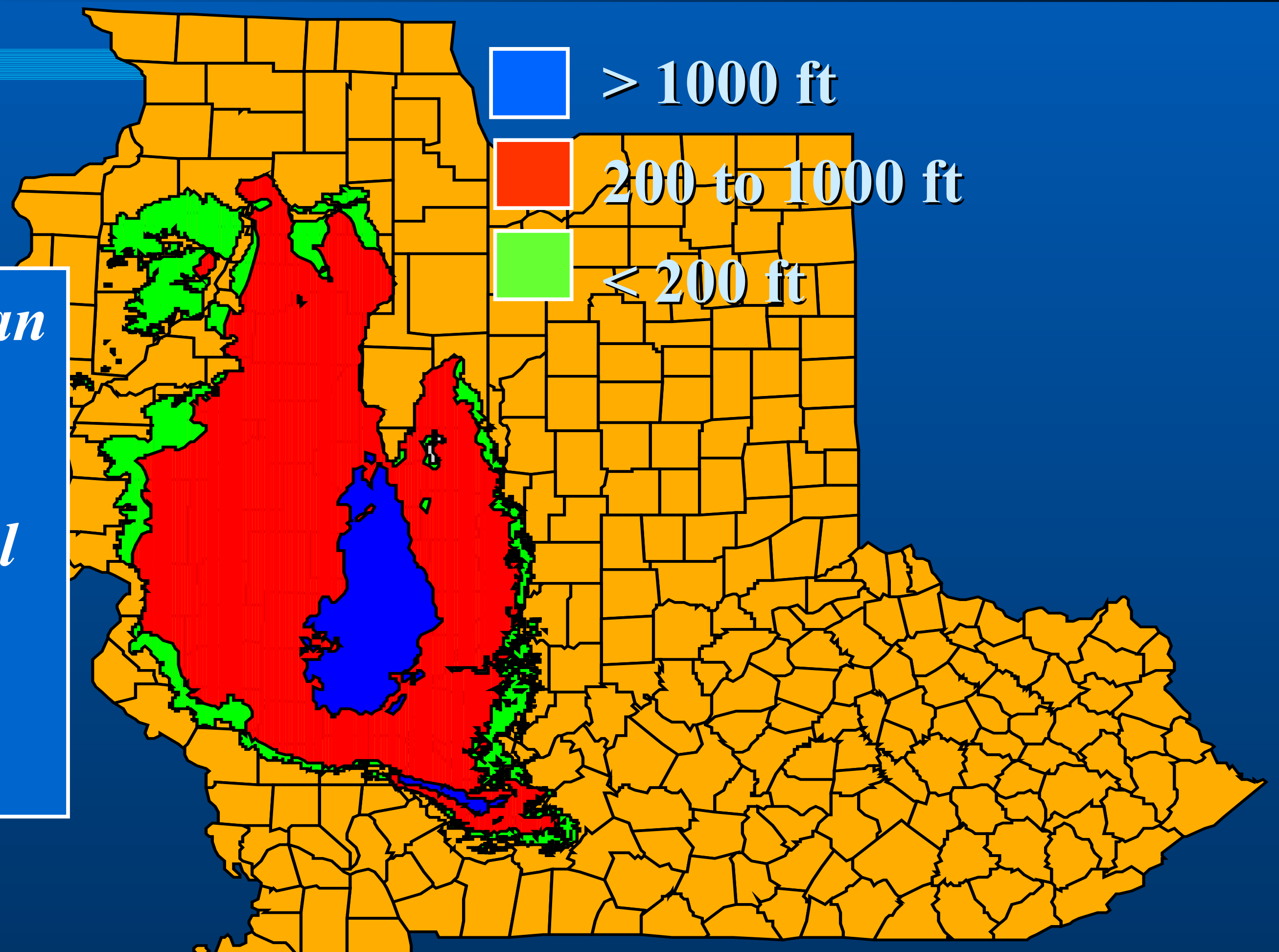
CO_2 Sequestration - Active Oil and Gas Reservoirs

- CO_2 Flooding (EOR Activities)
  - Miscible and Immiscible in Oil Reservoirs
  - Possible Pressure Maintenance in Gas Reservoirs
- Benefits
  - Increase Oil and Gas Production
  - Sequester CO_2: Lower Net Cost for Sequestration
- Extensive Industry CO_2 EOR Experience and Data
- MIDCARB Data
  - Reservoir Fluid and Rock Properties
  - Geologic and Engineering Data

CO_2 Sequestration - Coalbed Methane

- Trapping
  - Adsorption of CO_2 by Coal
  - Displacement of CH_4 by CO_2 (2 CO_2 : 1 CH_4)
- Double Benefit
  - Sequestration of CO_2
  - Enhanced CBM Production
  - Lowers Sequestration Net Costs
- Growing Industry Experience and Data
  - San Juan Basin
- MIDCARB Data

Sequestration Potential of the Springfield Coal



In coals at depths greater than 1000'
Estimated 488 MMT
CO_2 Sequestration Potential
Almost 2 years of CO_2 emissions from all Illinois Basin Power Plants

KGS

CO_2 Sequestration - Deep Saline Aquifers

- Trapping
  - Immiscible Displacement of Brine Phase
  - Dissolution (Minor) in the Brine
  - Mineral Trapping
- Benefits
  - Includes Vast Areas of U.S.
  - Large Reservoir Volumes
  - Storage over Geologic Time Periods
- Growing Industry Experience and Data
- MIDCARB Data

KGS Response: Geologic Sequestration

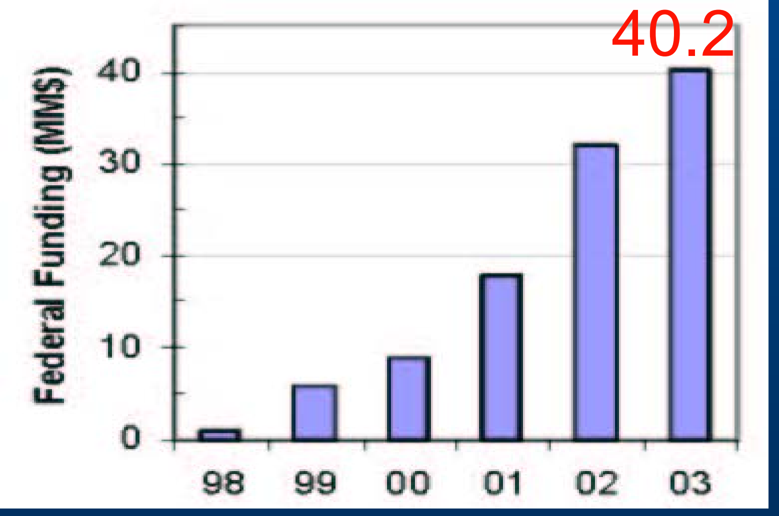
- MIDCARB (ongoing)
- CO_2 and Organic-rich, Devonian Black Shale (ongoing)
- Regional Sequestration Partnerships (pending)
- MIDCARB II? (possible)

New DOE Programs: Regional Partnerships in Carbon Sequestration

- Regional Partnerships
  - Midwest Geological Sequestration Consortium (IBC)
  - Appalachian Regional Carbon Sequestration Partnership (SSEB)
  - Midwest Regional Carbon Partnership (Battelle Memorial Institute)
  - Partnership for Appalachian Regional Carbon Sequestration (NRCCE)
- MIDCARB II
- KGS Interests: oil, gas, coal resources; subsurface

DOE Program: Regional Partnerships in Carbon Sequestration

- **Phase I**
  - evaluate options for storage and capture
  - CO_2 transport
  - Regulatory permitting
  - Communication/ Outreach
  - Public acceptance
  - Monitoring
  - Verification
  - Environmental efficacy
- **Phase II**
  - Field validation tests
  - Detailed regulatory and infrastructure planning
  - Up to $7MM / partnership



Deep Natural Gas

- **Trenton-Black River**
  - **Clark Co. Analog Study**
    - Field Investigations
    - Geochemistry
    - Geophysics
  - **Regional Study**
    - 5 States, 18 Companies, DOE
      - **Seismic/Structure (KGS)**
      - **Stratigraphy (OGS)**
      - **Petrology (PSG)**
      - **Geochemistry (PGS)**
      - **Production (WVGS/NYSM)**
      - **GIS (WVGS)**

Deep Natural Gas

- Seismic Interpretations and Future Natural Gas Potential
  - Armens and Associates
  - Bretagne
  - Columbia Natural Resources
  - Daugherty and Associates
  - Moore and Associates
  - North Star Energy
  - Pioneer Natural Resources
  - Thorpe and Associates