Technological Options to Address Global Climate Change

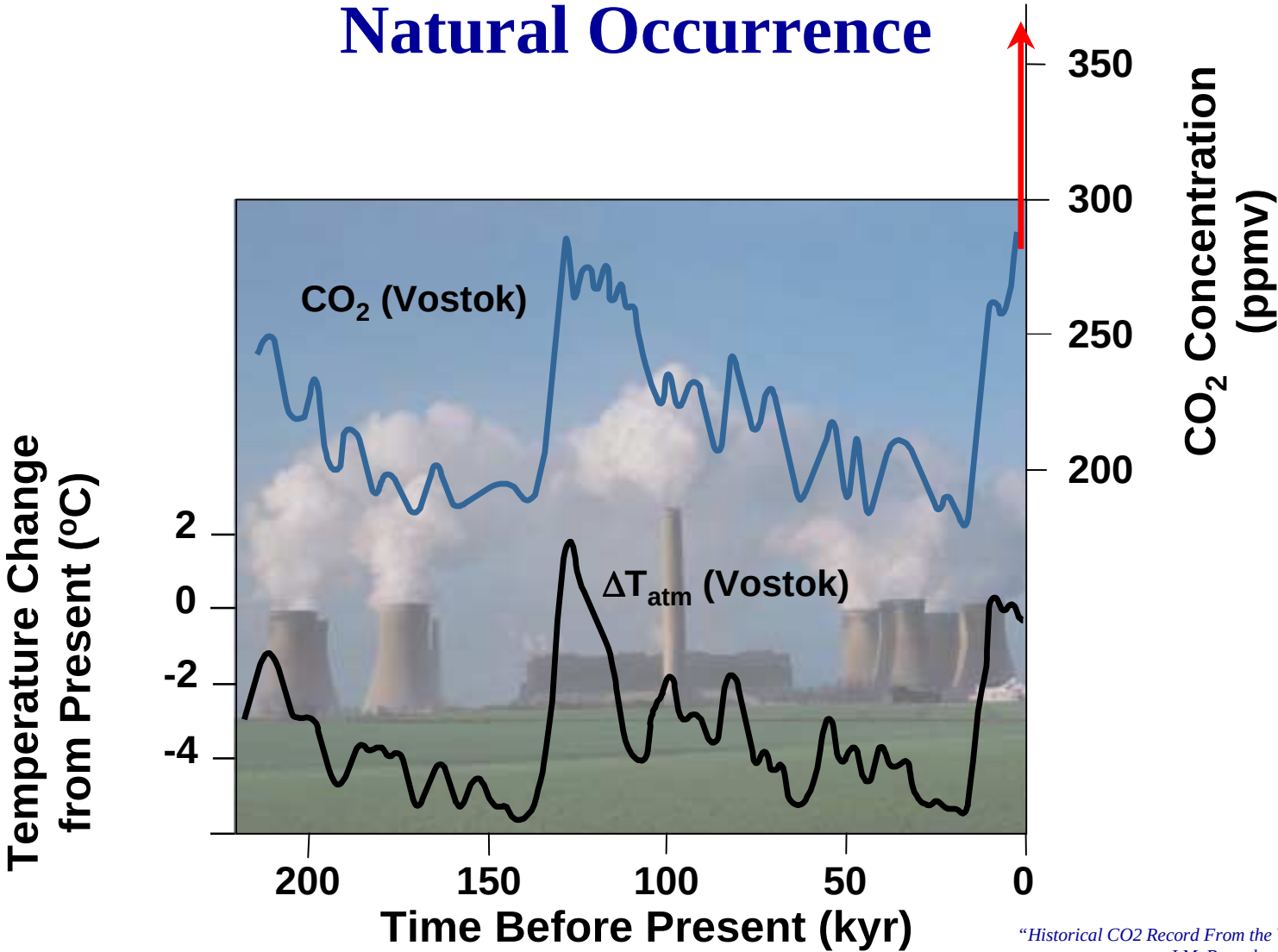
First National Conference on Carbon Sequestration

May 14-17, 2001

Rita A. Bajura, Director
National Energy Technology Laboratory

The Climate Change Debate

CO_2 Concentrations Beyond Range of Natural Occurrence

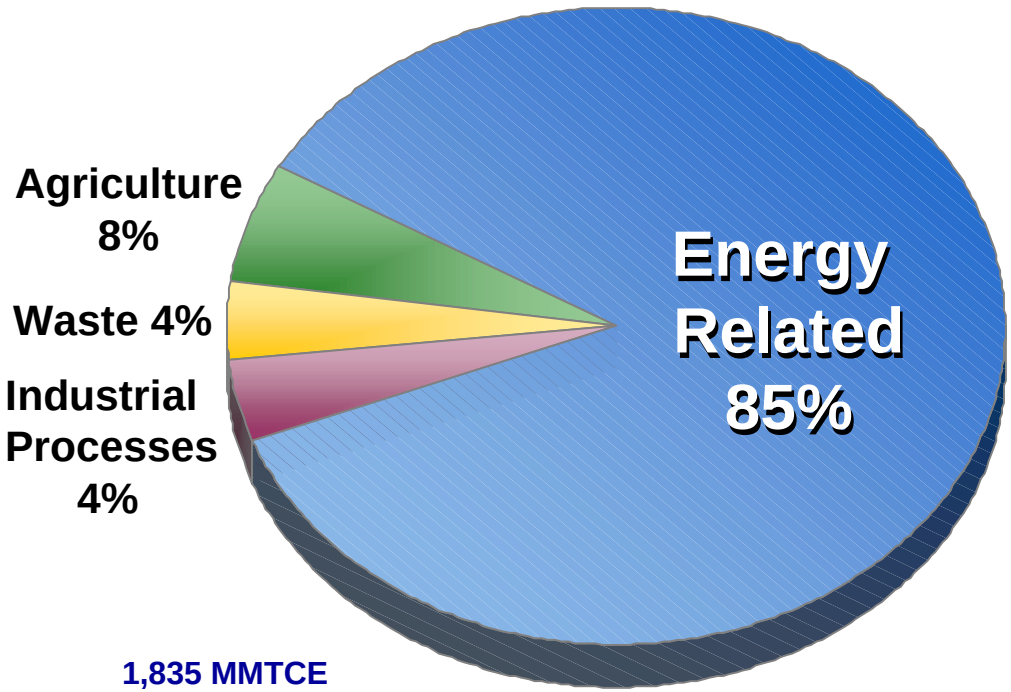


"Historical CO2 Record From the Vostok Ice Core"
J.M. Barnolo et al, August 1999
www.cdiac.esd.ornl.gov/ftp/trends/co2/vostok.icecore.co2

Energy Is Major Contributor

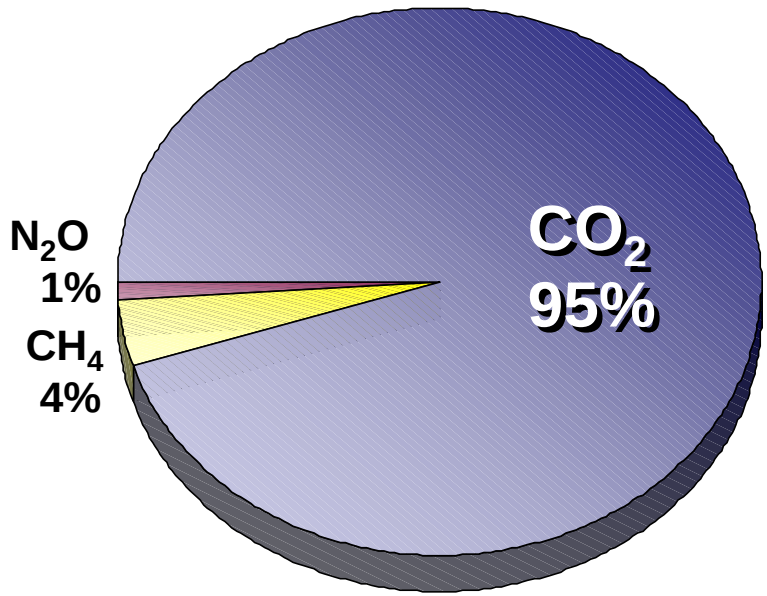
U.S. Anthropogenic Greenhouse Gas Emissions

85% of Emissions Energy Related



1,835 MMTCE

CO_2 Dominates Energy-Related Emissions



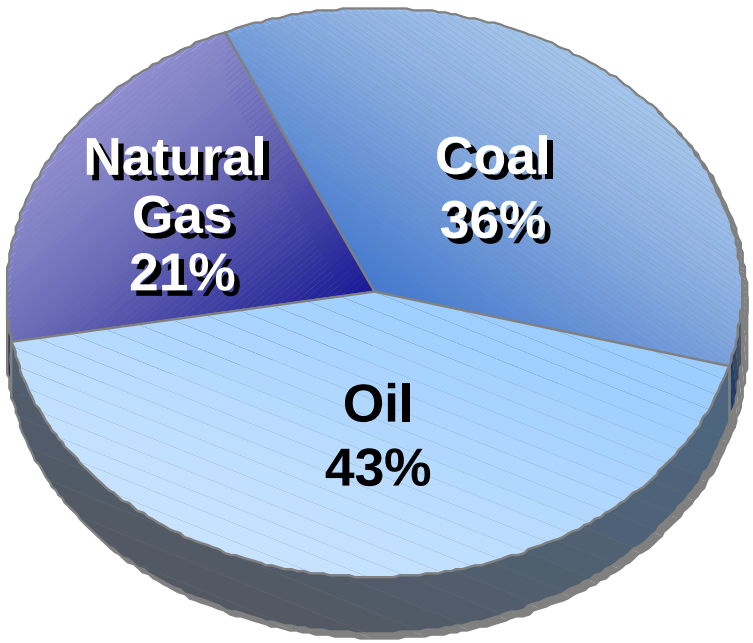
1,555 MMTCE

"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998," U.S. EPA, April 2000

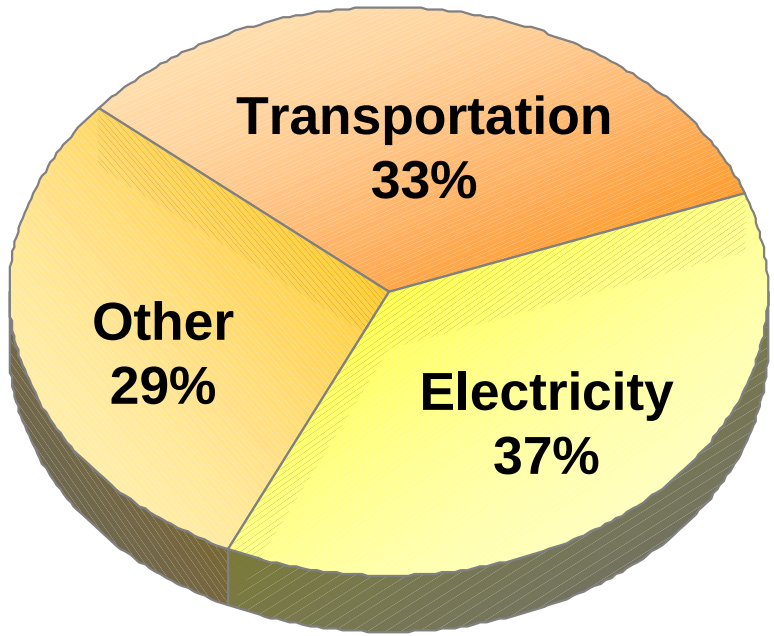
All Fossil-Based Sources and Uses Contribute

1999 U.S. CO_2 Emissions From Energy

Fuel Sources

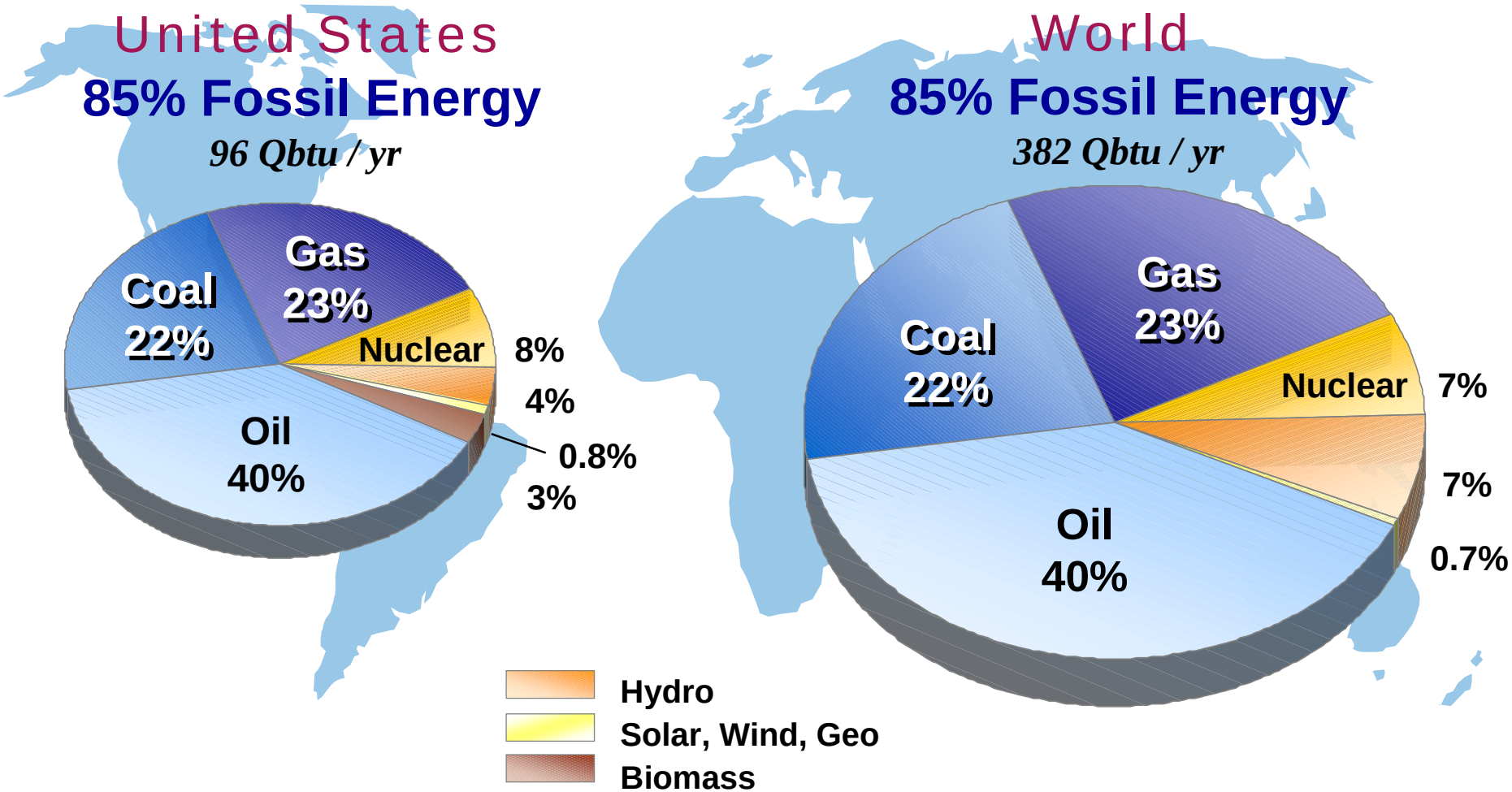


End Uses



AEO 2001, Table A19

U.S. and World Economies Based on Fossil Fuels



World data from International Energy Annual 1999 (February 2001)
U.S. data from Renewable Energy Annual 2000 (March 2001)
World data does not include non-grid-connected biomass

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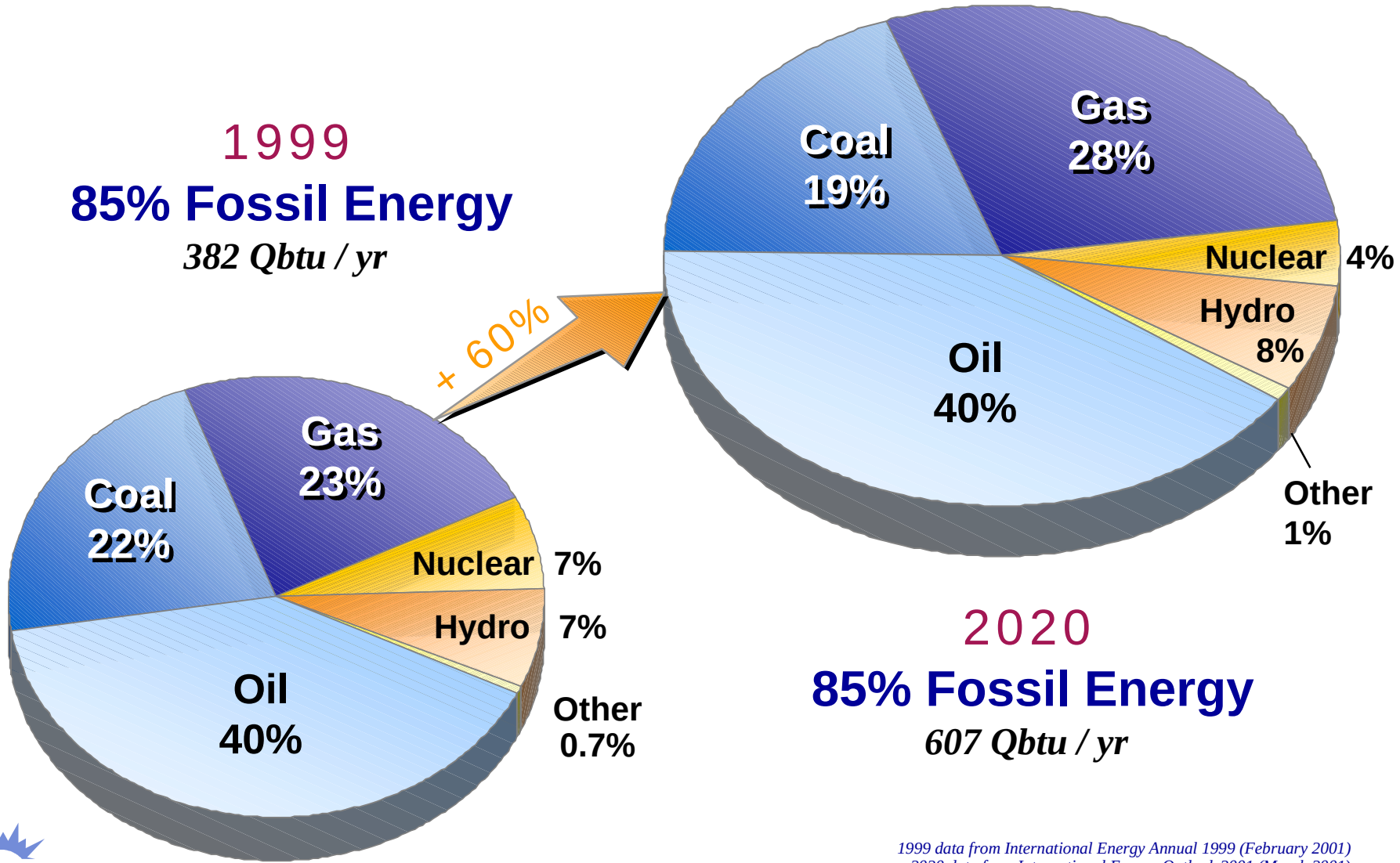
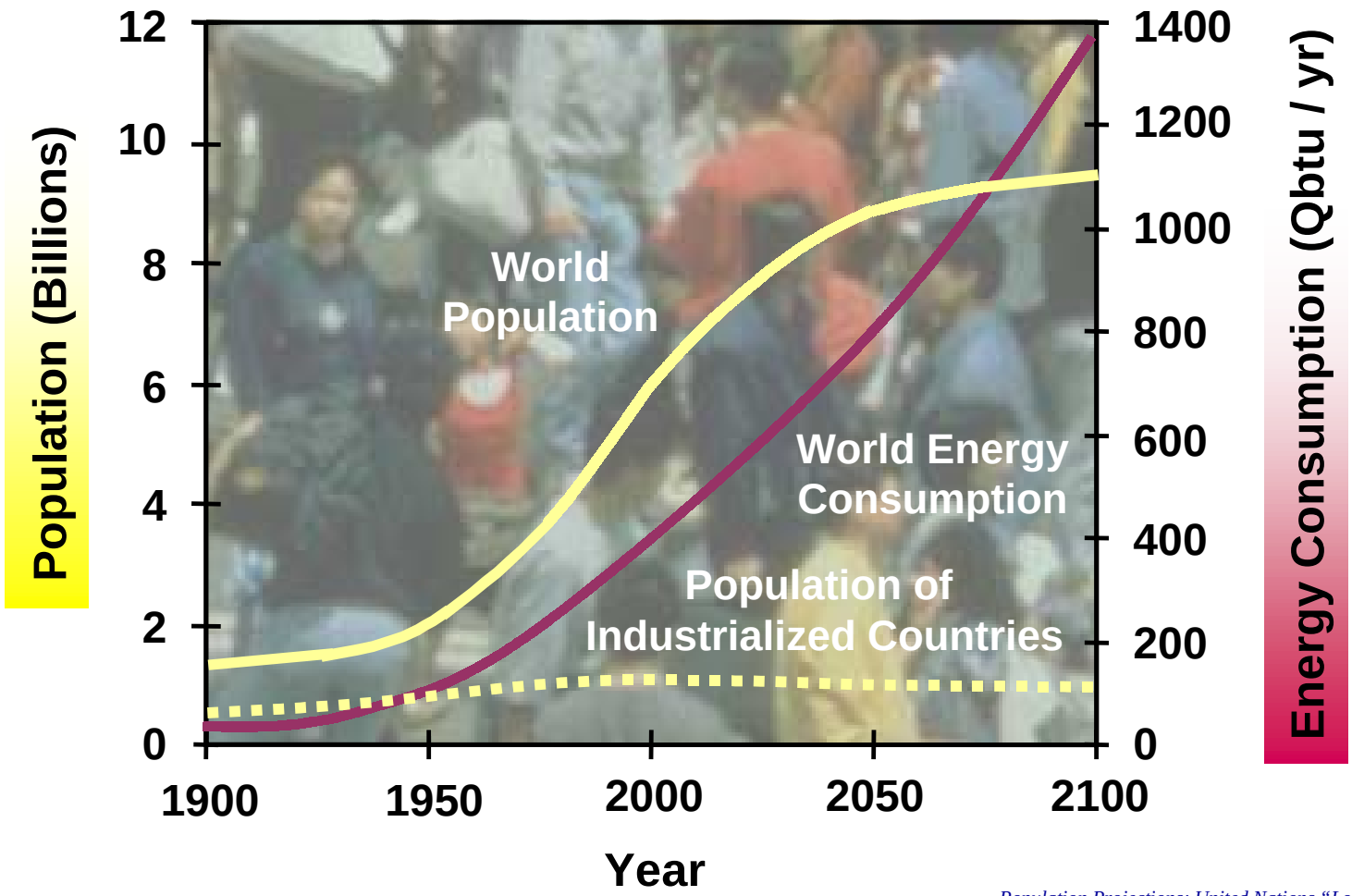
Fossil Fuels Will Continue as Key to World Economy



1999 data from International Energy Annual 1999 (February 2001)
2020 data from International Energy Outlook 2001 (March 2001)

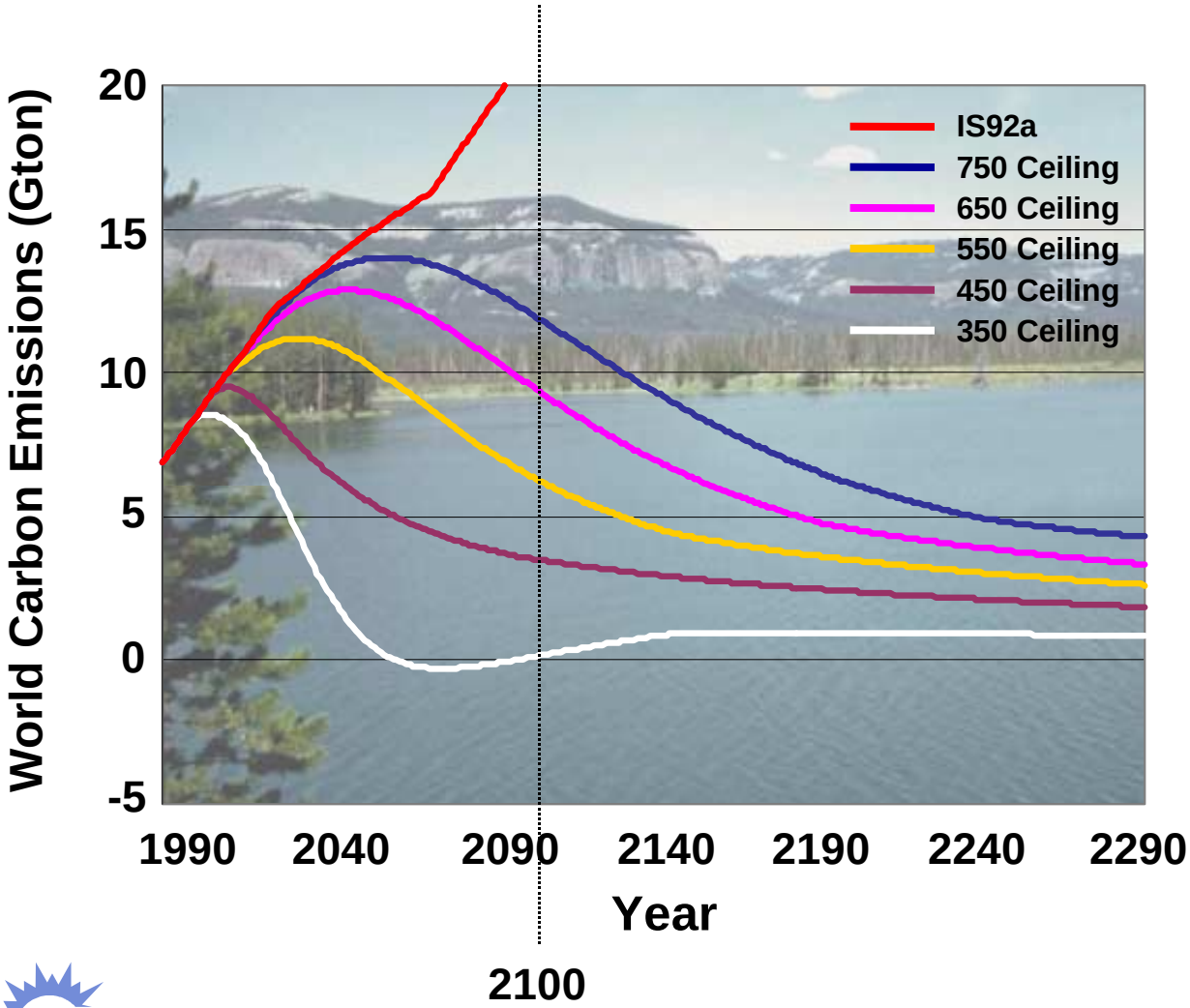
World Energy Demand Growing Dramatically



Population Projections: United Nations "Long-Range World Population Projections: Based on the 1998 Revision"

Energy Projections: "Global Energy Perspectives" ITASA / WEC

Scenarios to Stabilize CO_2 Concentrations



550 ppmv pathway requires 60% reduction from 1990 levels by 2100

Wigley, T.M.L., Richels, R., and Edmonds, J.A. ***Nature 379****, 240-243 (1996)*

Technological Carbon Management Options

Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency

- Demand Side
- Supply Side

Sequester Carbon

- Capture & Storage
- Enhance Natural Processes

All options needed to:

- Supply energy demand
- Address environmental objectives

Approaches to Sequester Carbon

Capture and Storage

Enhance Natural Processes

Unmineable Coal Seams

Deep Ocean Injection

Depleted Oil / Gas Wells, Saline Reservoirs

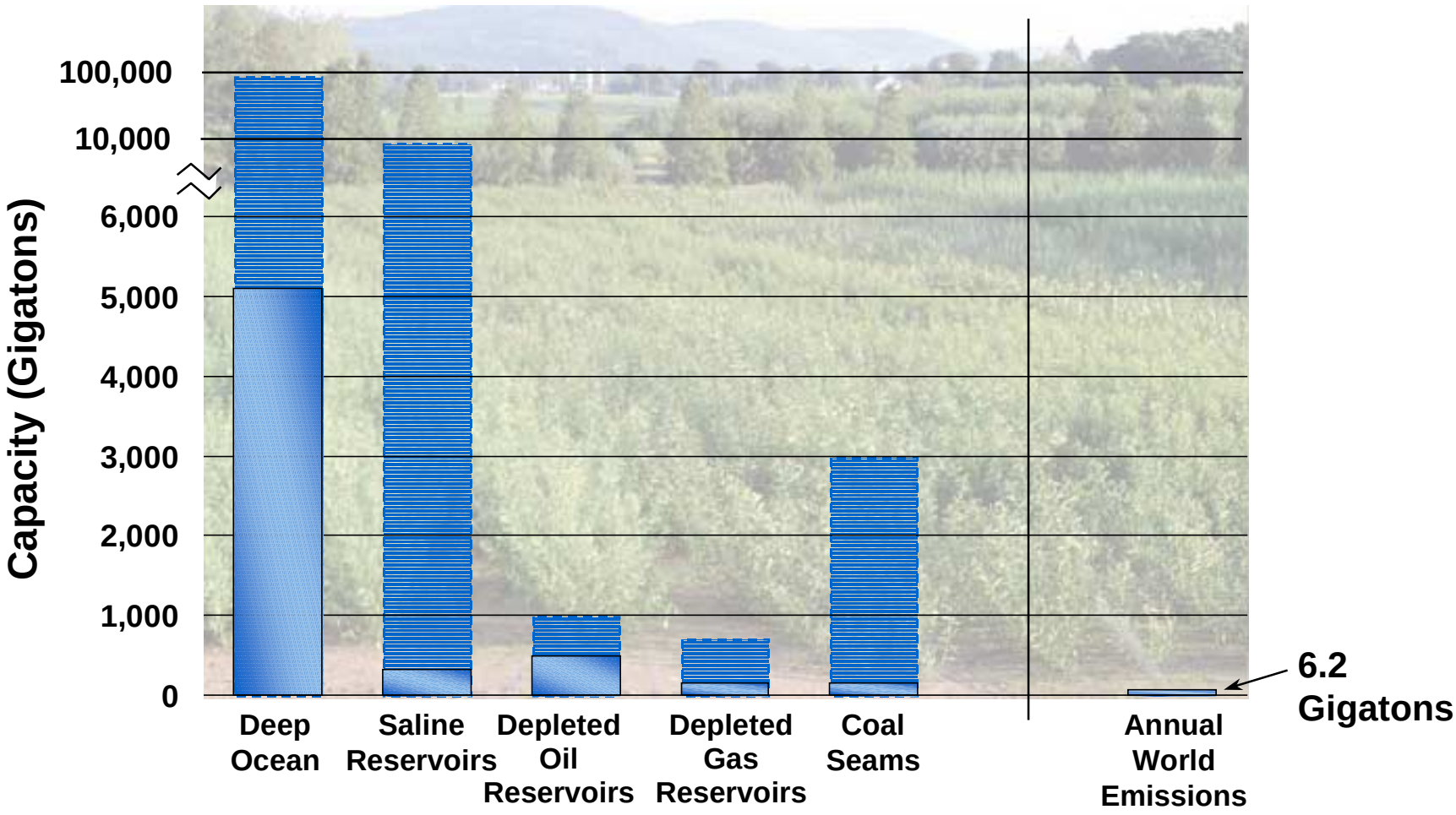
Mineral Carbonation

Iron or Nitrogen Fertilization of Ocean

Forestation

Enhanced Photosynthesis

Large Potential Worldwide Storage Capacity



Storage Options: IEA Greenhouse Gas R&D Program;
Advanced Resources International estimates for coal seams
World Emissions: International Energy Outlook 2000, Table A10

Requirements for Sequestration

- **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**

DOE's Sequestration Program

Office of Fossil Energy

- Separation and capture
- Terrestrial ecosystems
- Geologic sequestration
- Ocean sequestration
- Conversion and reuse
- Modeling and assessments

Research coordination

Office of Science

- Geologic sequestration
- Enhanced carbon sequestration in terrestrial ecosystems (CSiTE)
- Ocean carbon sequestration (DOCS)
- Sequencing genomes of microorganisms
- Advanced chemical and biological processes

Applied R&D ← → *Basic Science*

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Agencies Conducting Sequestration-Related Research

USGS
Geologic sequestration research

NASA
Space-based studies of earth as integrated system

EPA
Inventory of greenhouse gases

OSM
Carbon sequestration on abandoned mine sites

USAID
Tropical reforestation in developing countries

NOAA
Atmospheric and oceanic global observations

NSF
Science of CO_2 and N_2 cycles in oceans

USDA
Terrestrial sequestration, soil carbon database, sequestration models

Forest Service
Management practices to increase carbon sequestration

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Office of Fossil Energy's Sequestration Program

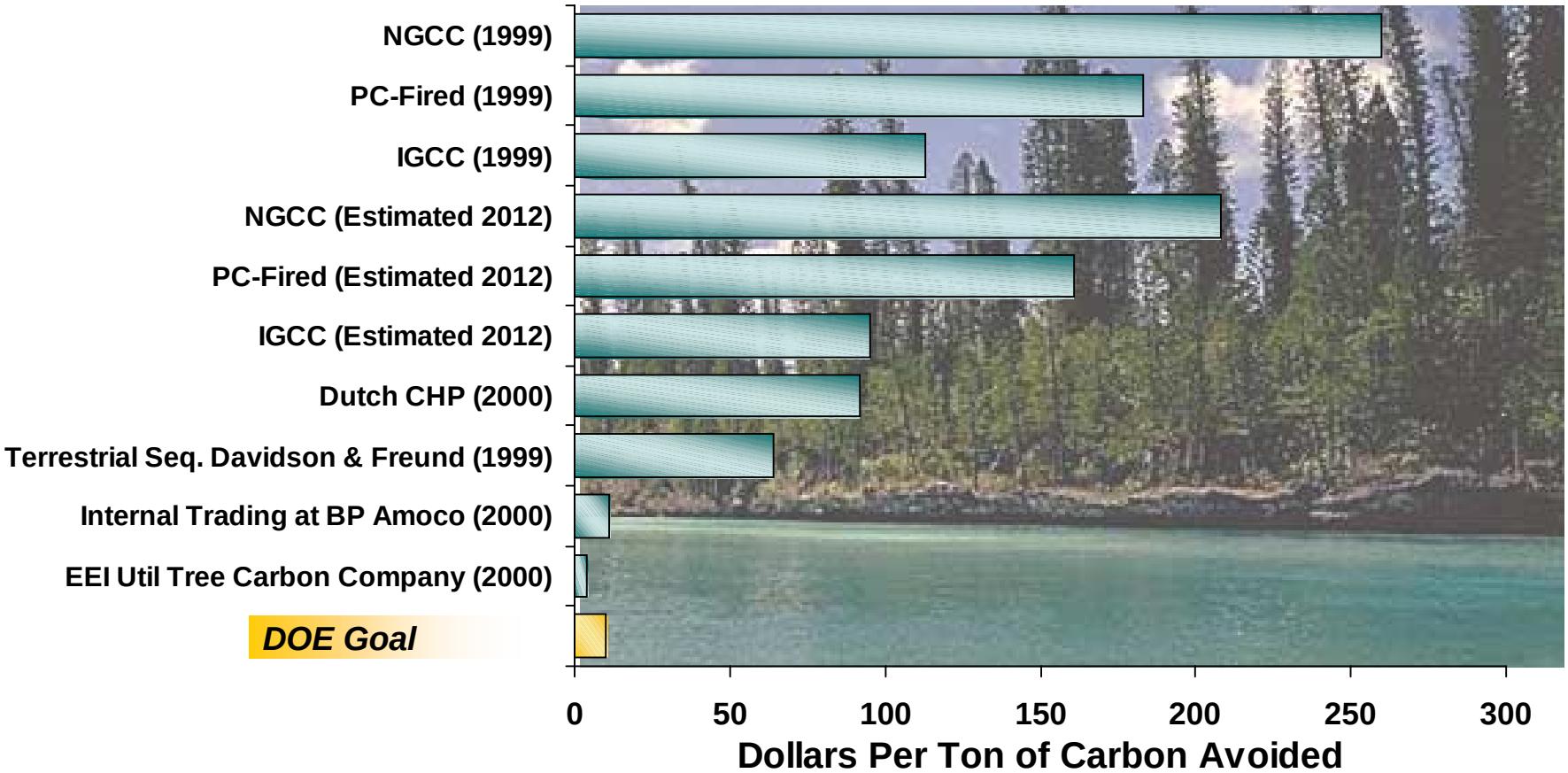
Number of Projects by Research Area

15	Separation and capture
3	Terrestrial ecosystems
17	Geological sequestration
7	Ocean sequestration
9	Conversion and reuse
7	Modeling and assessments

1995 — *Exploratory Assessments* — *Laboratory-Scale R&D* — *Technology Validation* — 2010

DOE Cost Goal for Sequestration

Net Costs



Long Term Cost Goal Is $10 Per Ton of Carbon Avoided

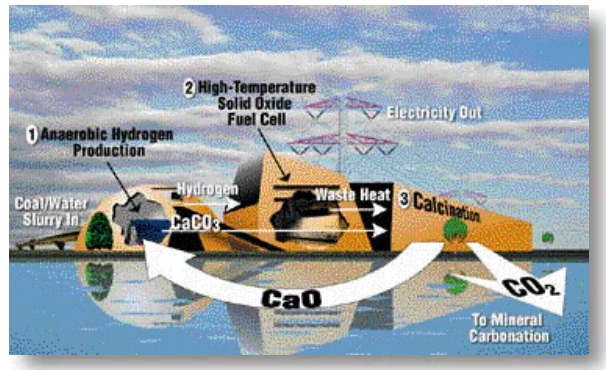
Dollar figures are for year cited & are not adjusted to a constant year dollar

Designs for Carbon Sequestration

Advanced Energy Plants

Coal Gasification With Water Gas Shift to H_2 and CO_2

Pressurized Combustion Using Pure O_2

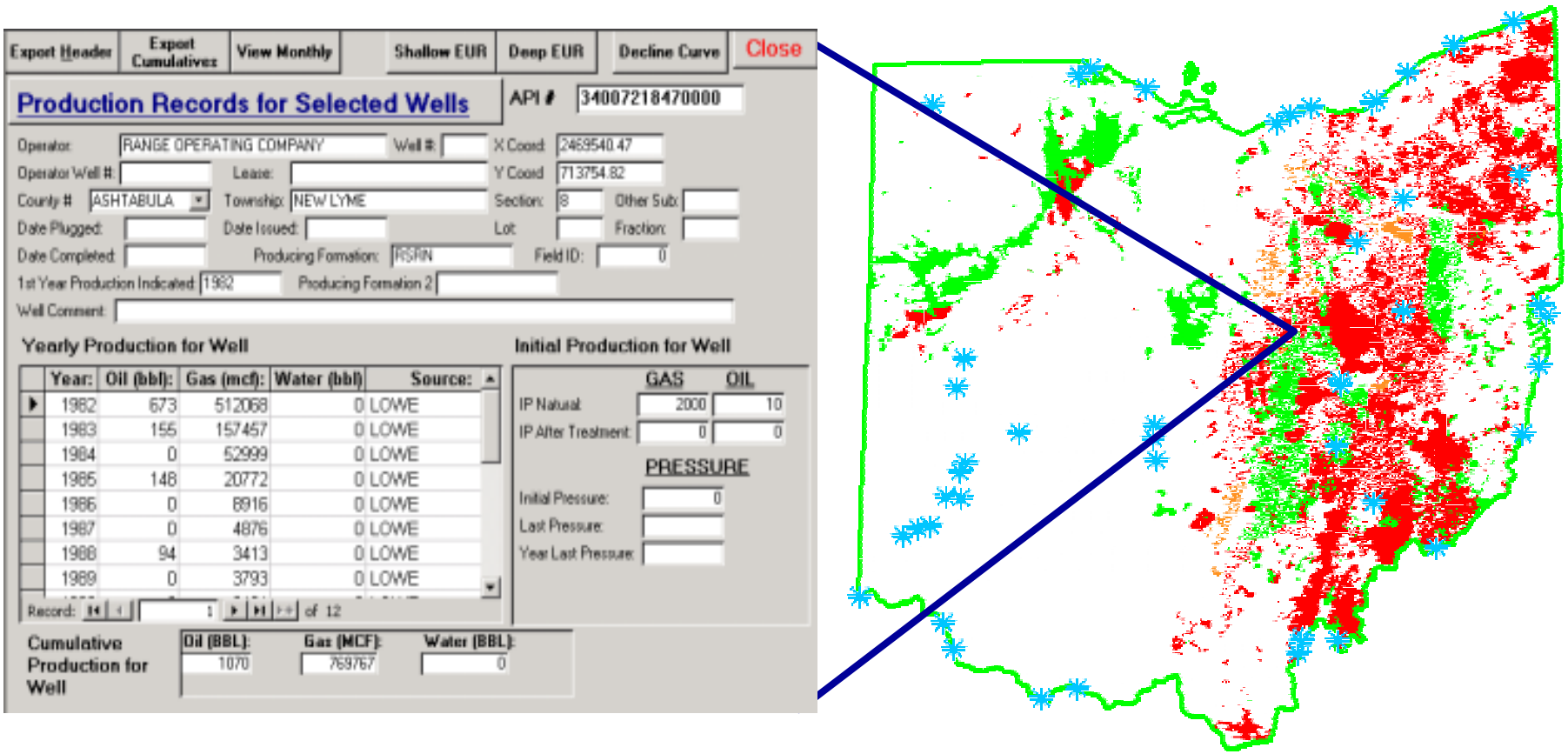


Coal Gasification With $CaCO_3$ Intermediate to Produce H_2 and CO_2

Producing a Concentrated Stream of CO_2 at High Pressure

- ***Improves Sequestration Economics***
- ***Reduces Energy Penalty***

Energy Production → Geological Sinks



Midcontinent **I**nteractive **D**igital **C**arbon **A**tlas and **R**elational Data**B**ase

www.midcarb.org

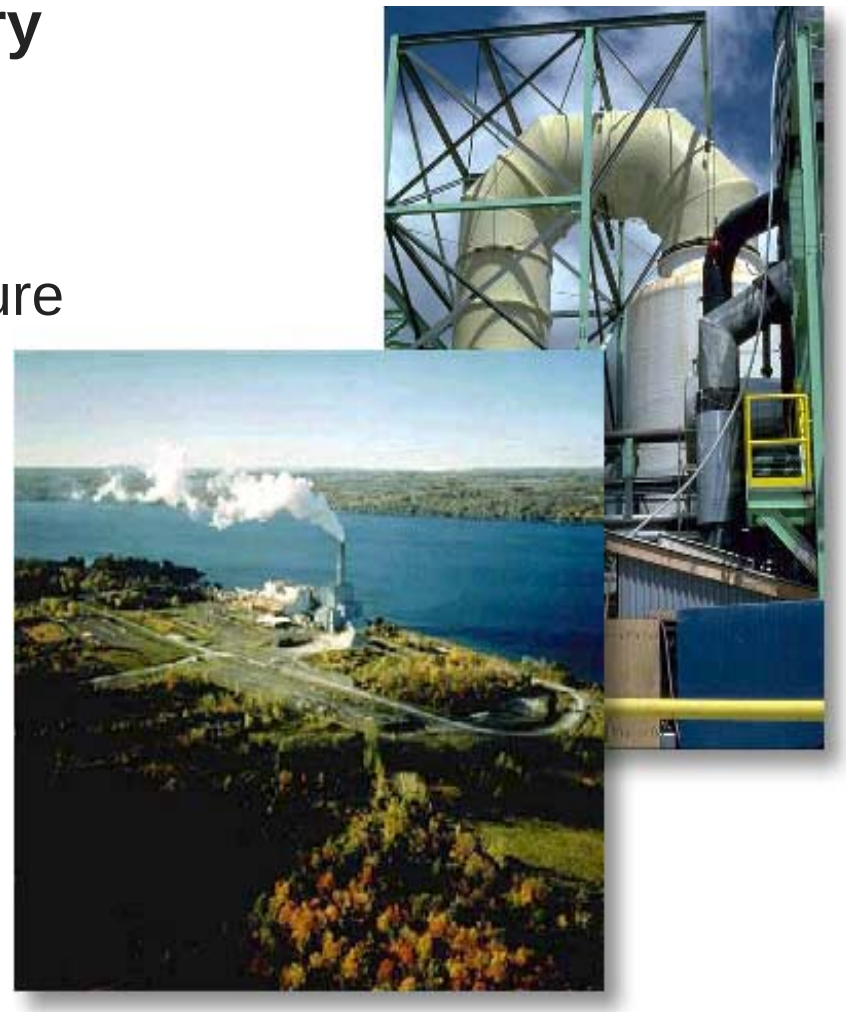
Geologic Sequestration in a Depleted Oil Reservoir

First U.S. Depleted Reservoir Storage Project

- **Inject CO_2 and monitor its movement**
- **Location**
  - Oil reservoir near Roswell, New Mexico
- **Partners**
  - Pecos Petroleum
  - Strata Production
  - New Mexico Tech U.
  - Sandia
  - LANL
  - NETL

CO_2 Separation from Flue Gas

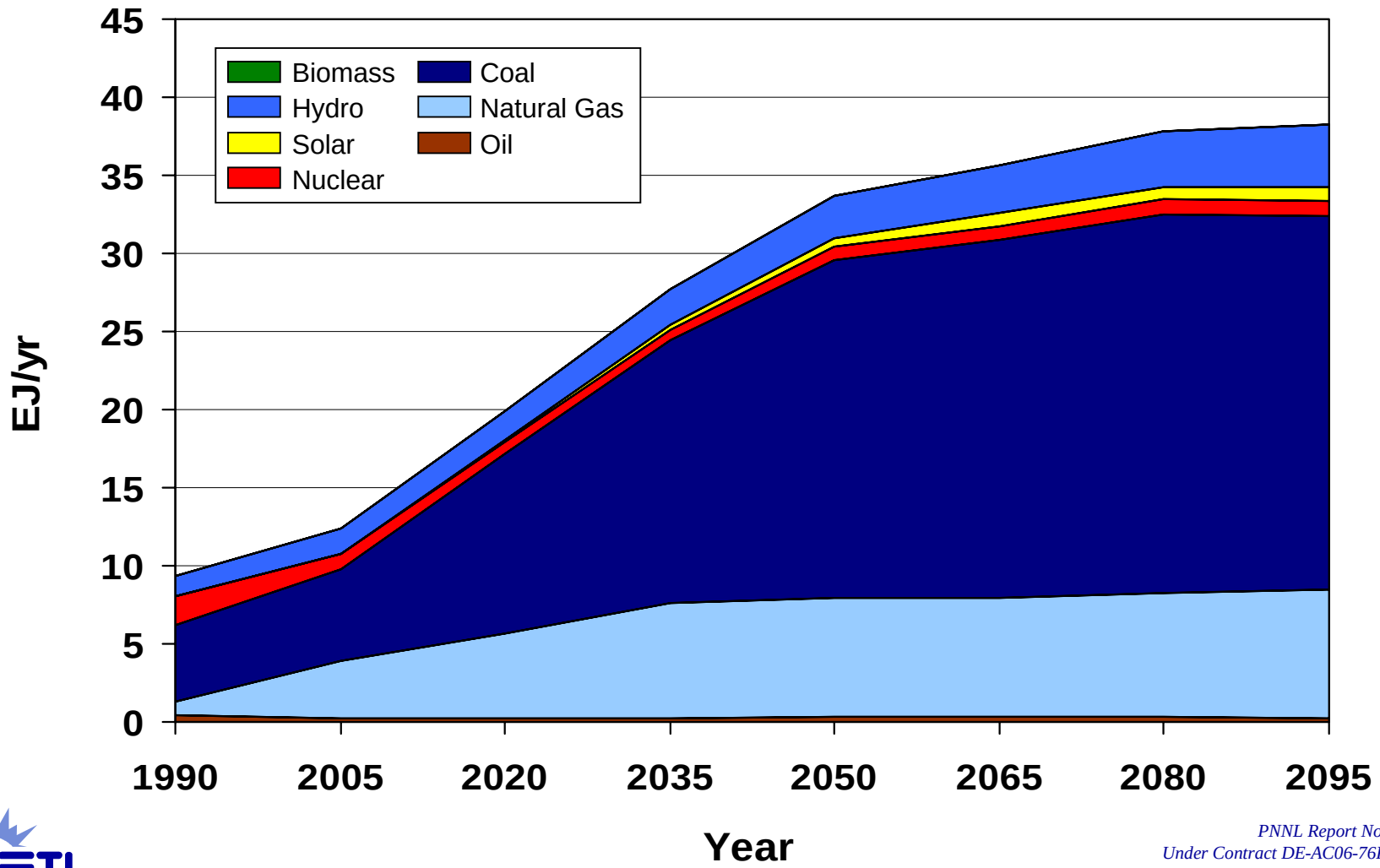
- **Use sodium carbonate, a dry regenerable sorbent**
- **Benefits**
  - Capable of 100% CO_2 capture
  - $15/ton carbon at 25-50% capture
- **Team members**
  - Research Triangle Institute
  - Church and Dwight, Inc.



Terrestrial Sequestration at a Power Plant

- **Amend coal mine spoil land near Paradise Power Plant in KY using FGD solids**
- **Multiple benefits**
  - Sequester carbon
  - Improve soil quality
  - Integrated assessment
- **Partners**
  - TVA
  - EPRI
  - NETL

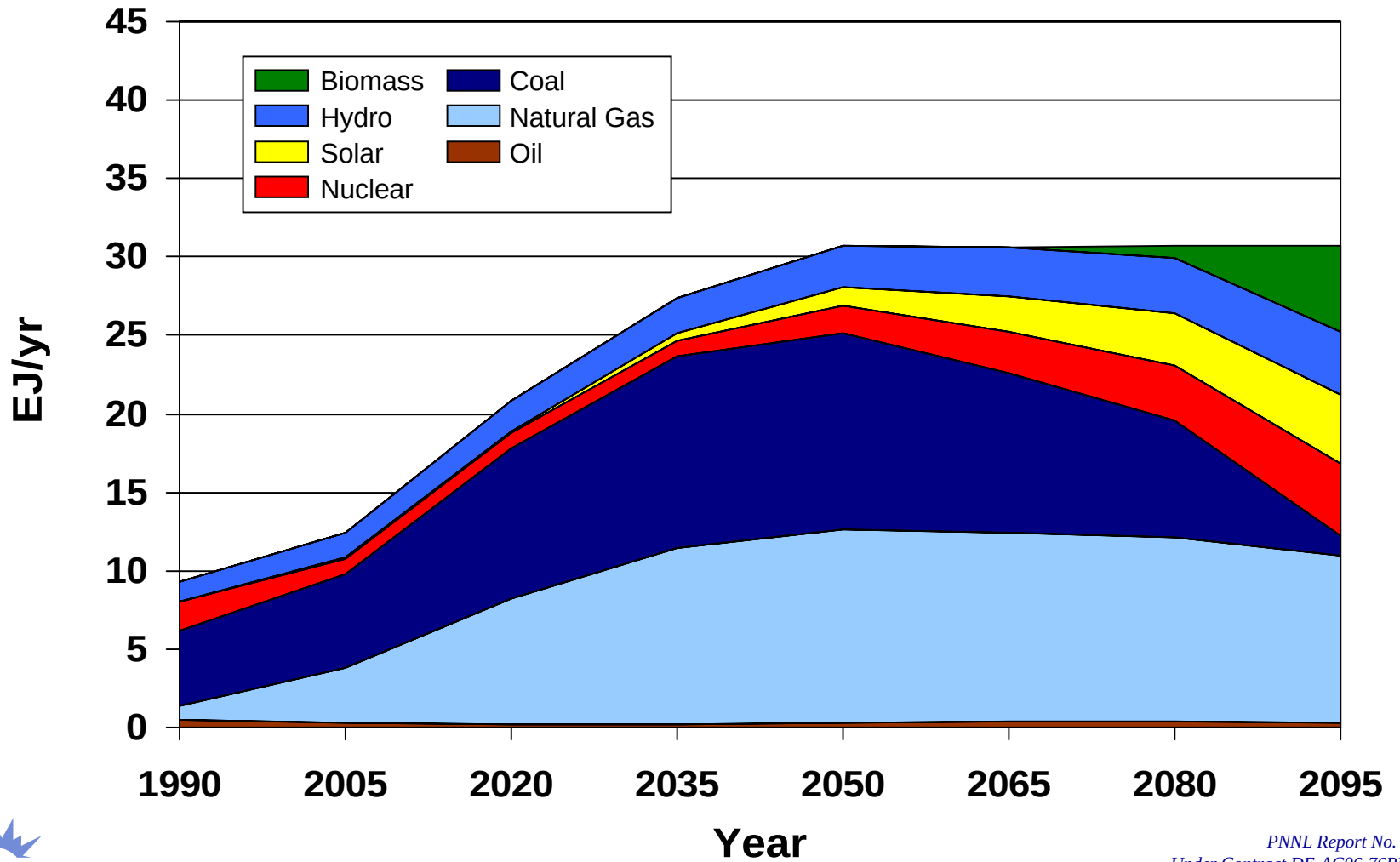
A Reference Case Scenario
U.S. Electricity Generation



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

Case Without Carbon Sequestration

U.S. Electricity Generation- 550 ppmv



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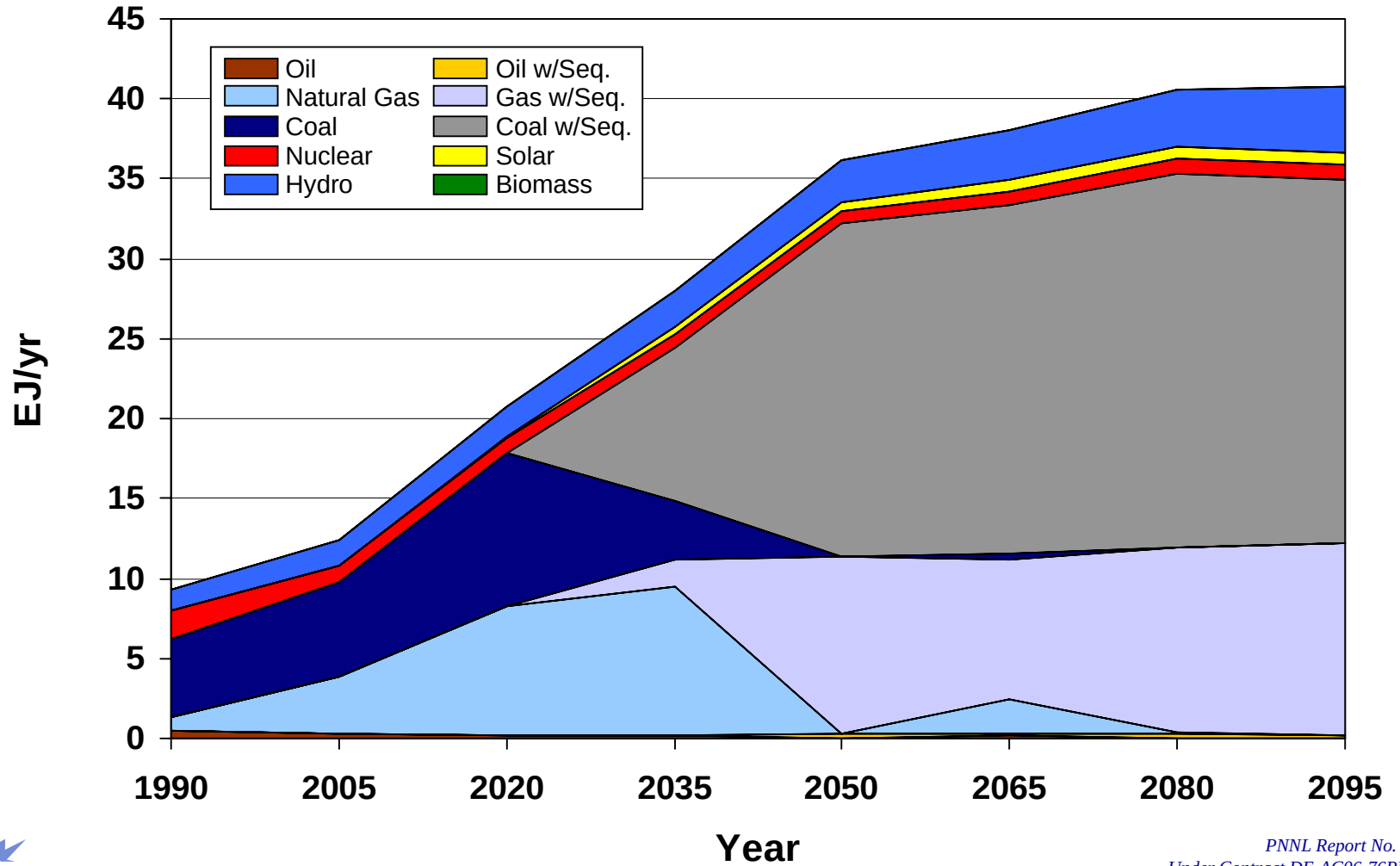
Sequestration / High-Efficiency Generation

U.S. Electricity Generation - 550 ppmv



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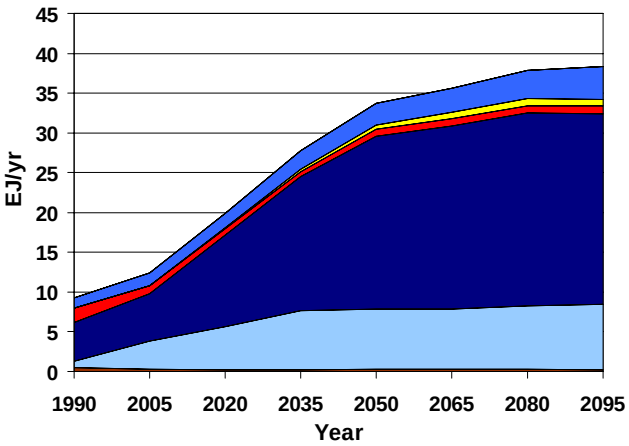
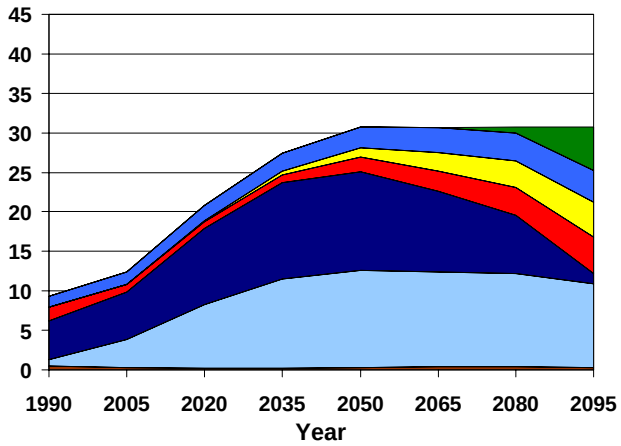
The Benefit of Sequestration

Reference Case



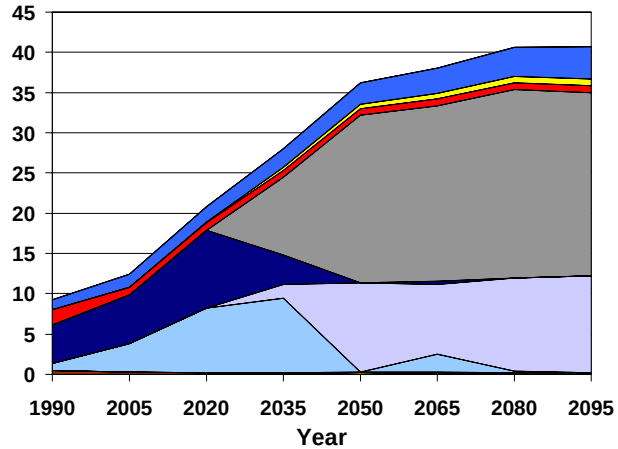
- **Miss environmental target**

No Sequestration



- **Meet 550 ppmv target**

Sequestration Option



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

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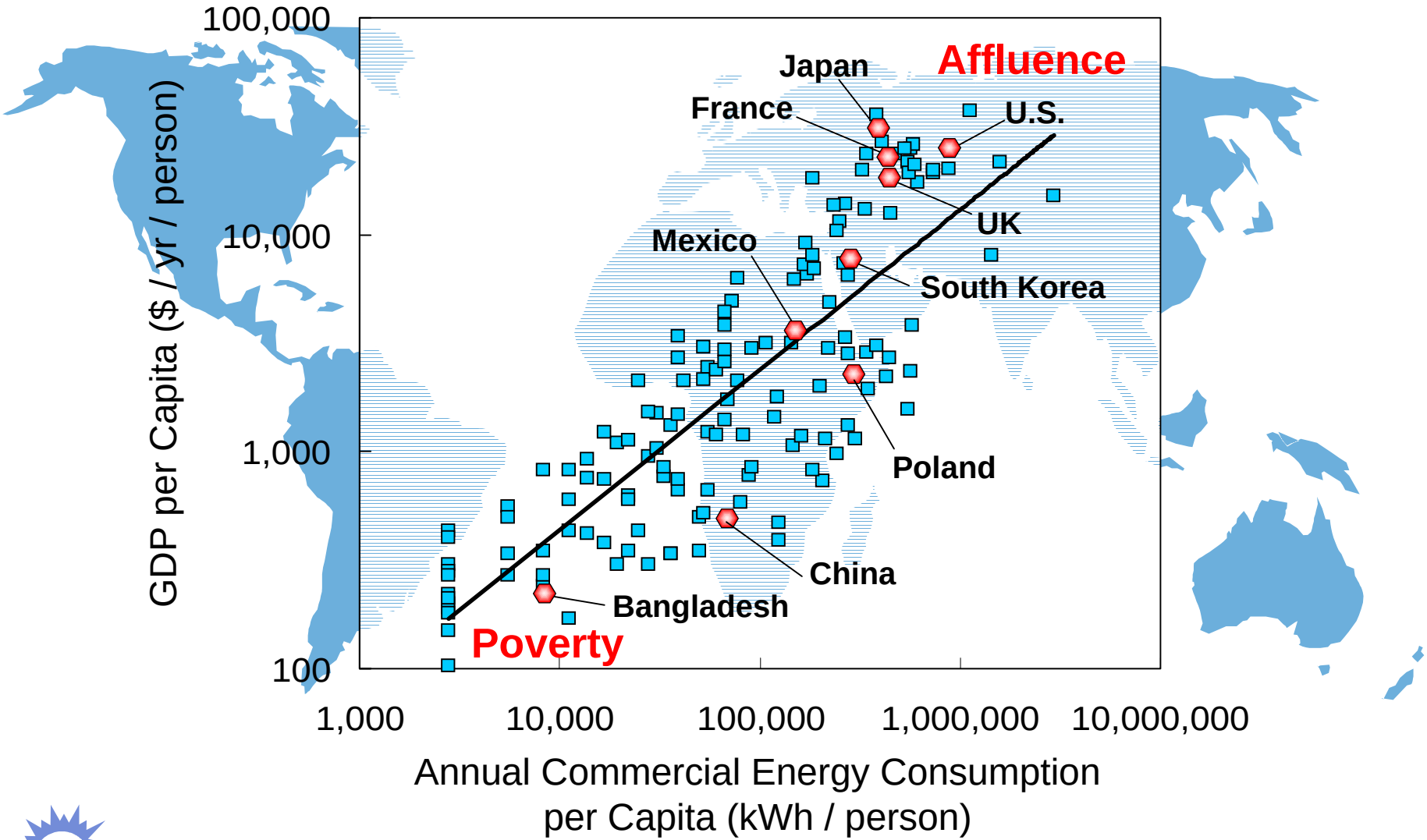
The World Needs Affordable Energy



World Resources Institute Database 1996-1997

Focus on All Technological Options to Address Climate Change

Reduce Carbon Intensity

Improve Efficiency

Sequester Carbon

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