Environmental Problems of the 21st Century: The Engineer as Villain and Hero

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Major Environmental Issues

- **Air Pollution**
  - *SO_2, NO_x, PM, etc*
  - *Air toxics*
  - *Acid deposition*
- **Ozone Depletion**
- ***Global Warming***
- **Water Pollution**
  - *Drinking water*
  - *Surface waters*
  - *Groundwater*
- Solid Wastes
- **Hazardous Wastes**
- ***Radioactive Wastes***
- **Depletion of Natural Resources**
- **Land Use Impacts**
  - *Loss of habitat*
- **Ecological Impacts**
  - *Biodiversity*
  - *Marine life*

A Pop Quiz

Engineers as Villains

Question:

Which of the following environmental problems is a direct result of engineering design?

(a) Industrial air pollution

(b) Automobile waste disposal

(c) Toxic metal water pollution

(d) Radioactive wastes

(e) Urban smog

(f) Global warming

Pop Quiz

(g) All of the above

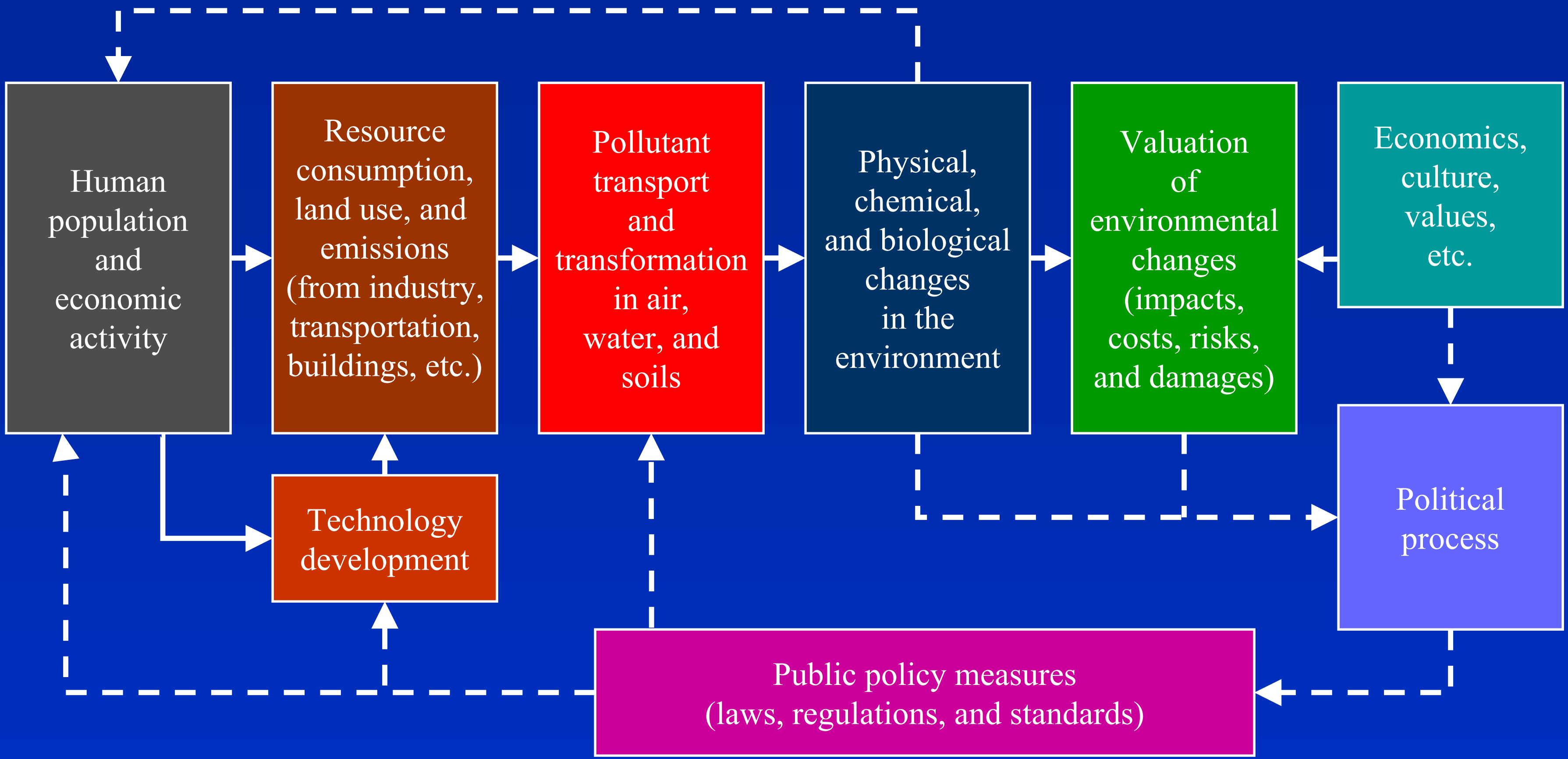
(h) None of the above

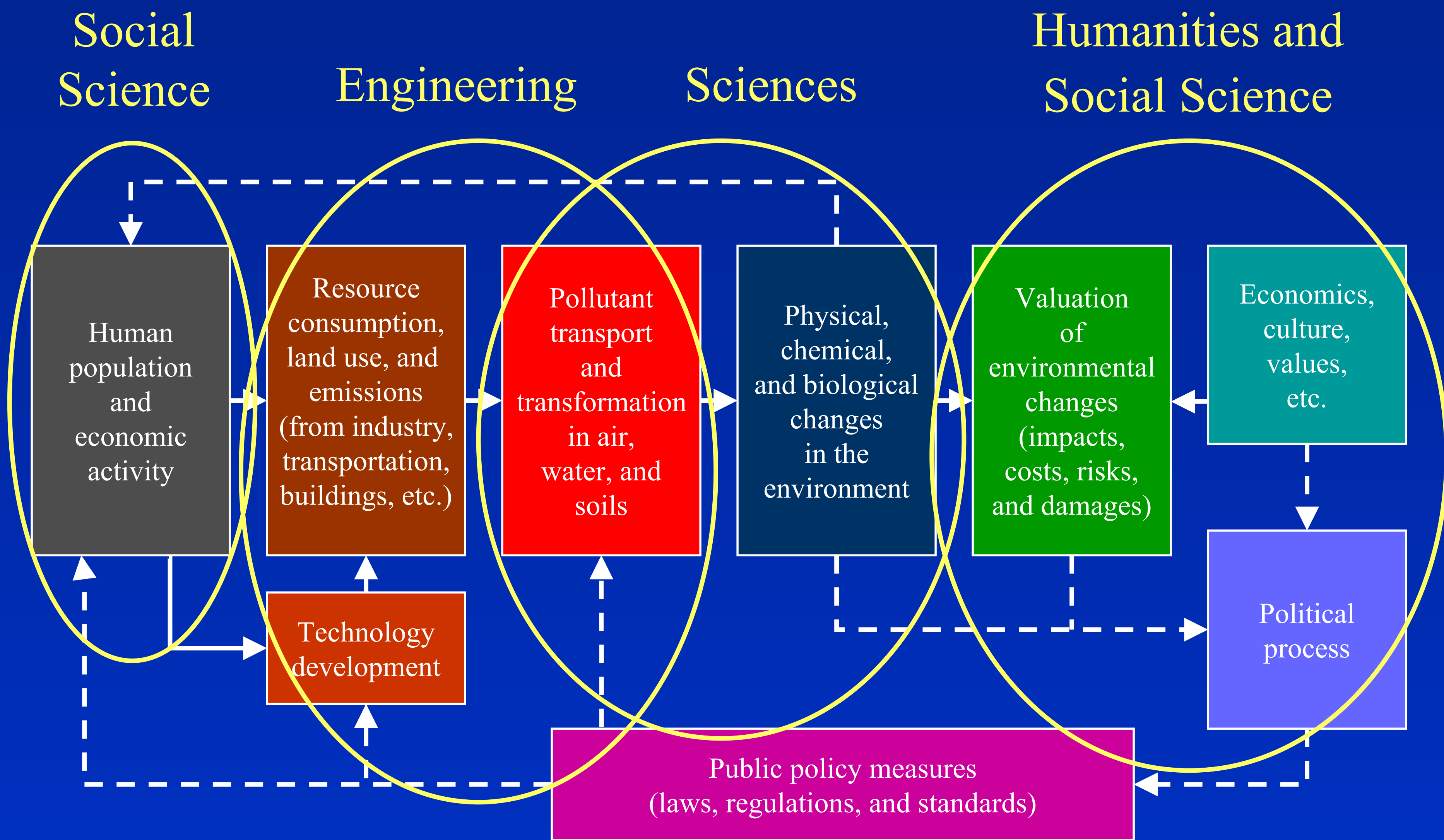
Answer:

(g) All of the above

Are engineers really the bad guys responsible for all these problems?

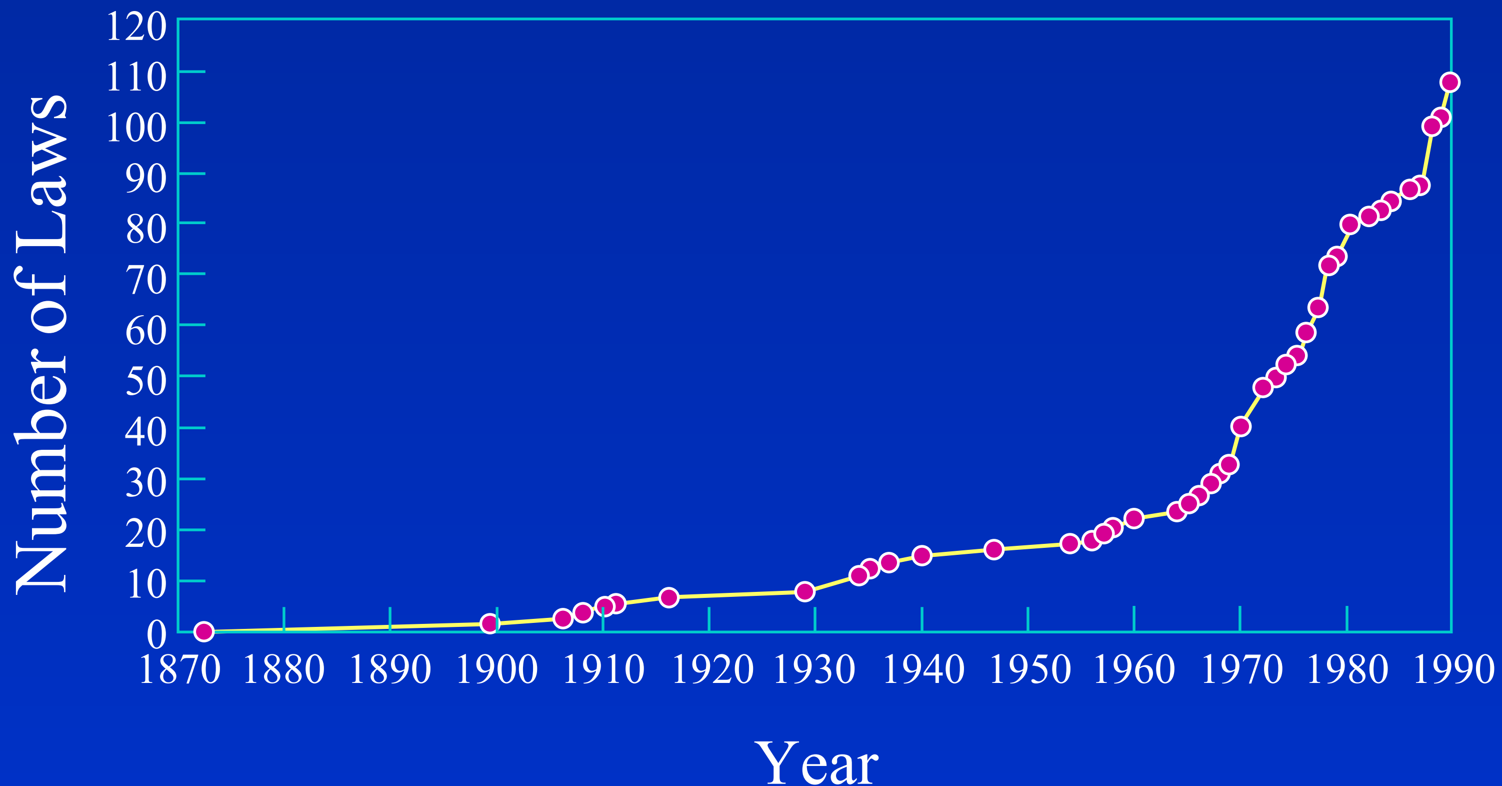
Sources of Environmental Impacts and Solutions





Mapping of environmental topics into undergraduate disciplines

Number of Federal U.S. Environmental Laws, 1870-1990



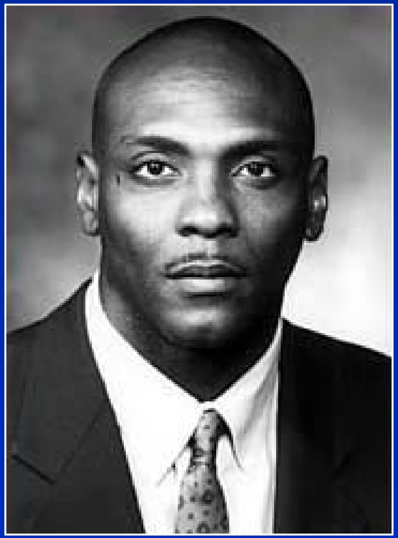
Source: EPRI

Engineers as Heroes

Question:

Which of the following engineers is working to solve environmental problems?

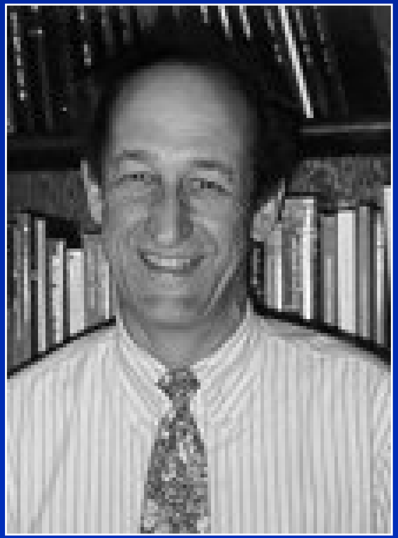
Who is the environmental hero?



Professor A?

Professor B?

Professor C?



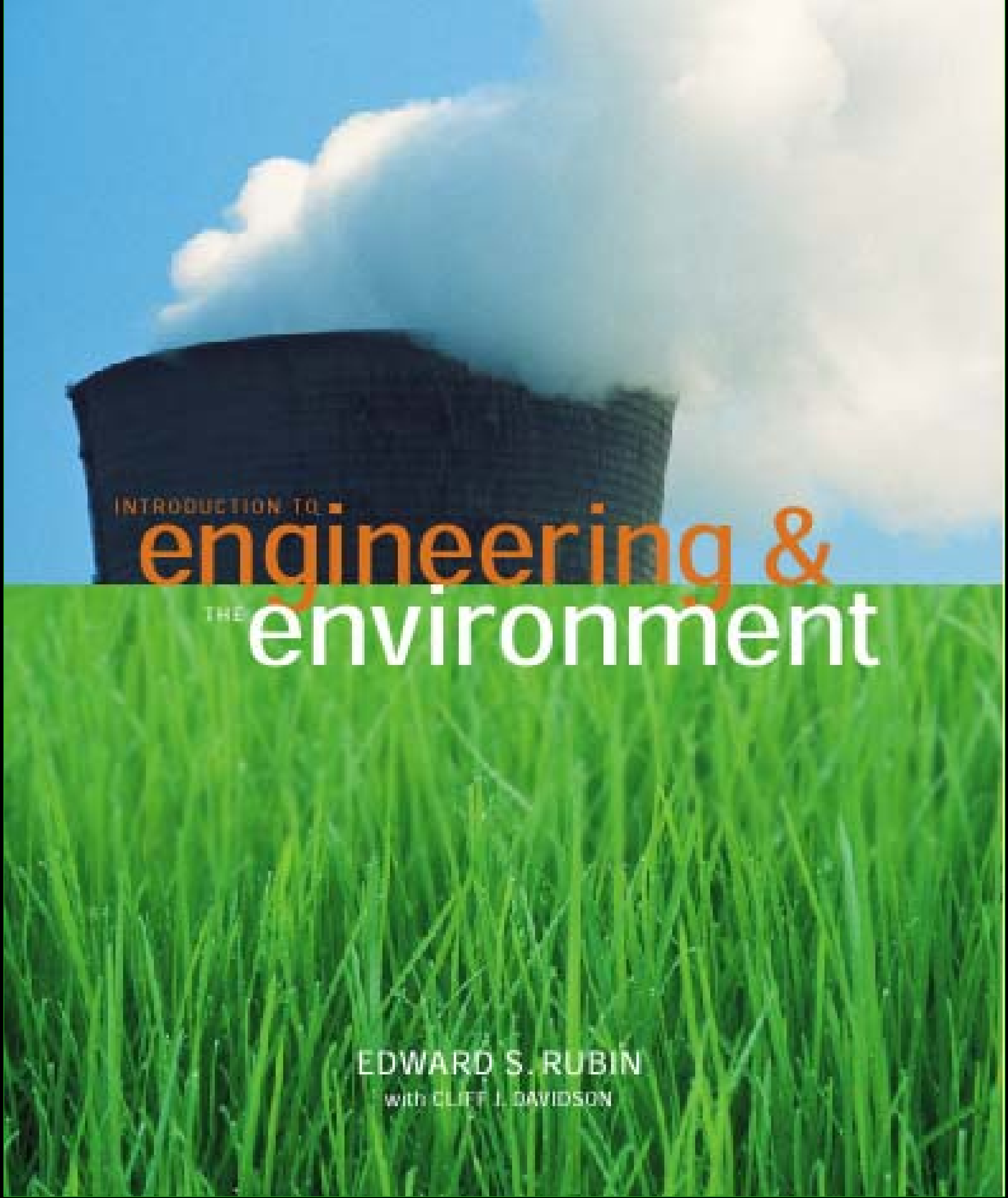
Professor D?

(e) All of the above?

(f) None of the above?

Answer:

(d) All of the above


INTRODUCTION TO
engineering &
THE
environment
EDWARD S. RUBIN
with CLIFF I. DAVIDSON

Sources of Environmental Impact that Engineers Can Influence

- *Design* of technology
- *Deployment* of technology
- *Operation/Use* of technology

leading to . . .

- Land use impacts
- Discharges to the environment (gases, liquids, solids)
  - Routine
  - Accidental
  - Direct
  - Indirect

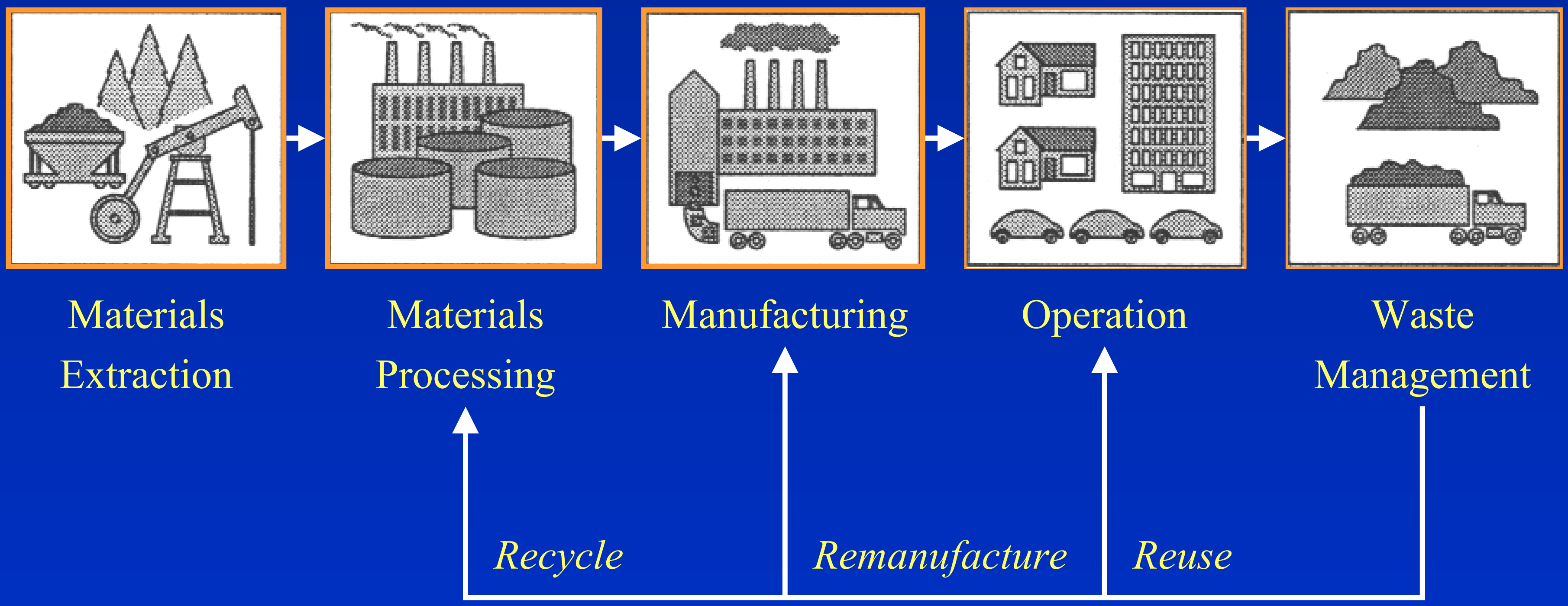
How to Become a Hero

- *Apply Principles of :*
  - Green Design
  - Pollution Prevention
  - Industrial Ecology
  - Sustainable Development

Reducing Environmental Impacts

- Produce desired goods and services in ways that:
  - Use less material
  - Produce less waste
  - Use less energy
- Use alternative materials, technologies and energy sources that offer environmental benefits

A Life Cycle Framework for Environmental Assessments



21st Century Challenges

- **Air Pollution**
  - *SO_2, NO_x, PM, etc*
  - *Air toxics*
  - *Acid deposition*
- **Ozone Depletion**
- ***Global Warming***
- **Water Pollution**
  - *Drinking water*
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  - *Biodiversity*
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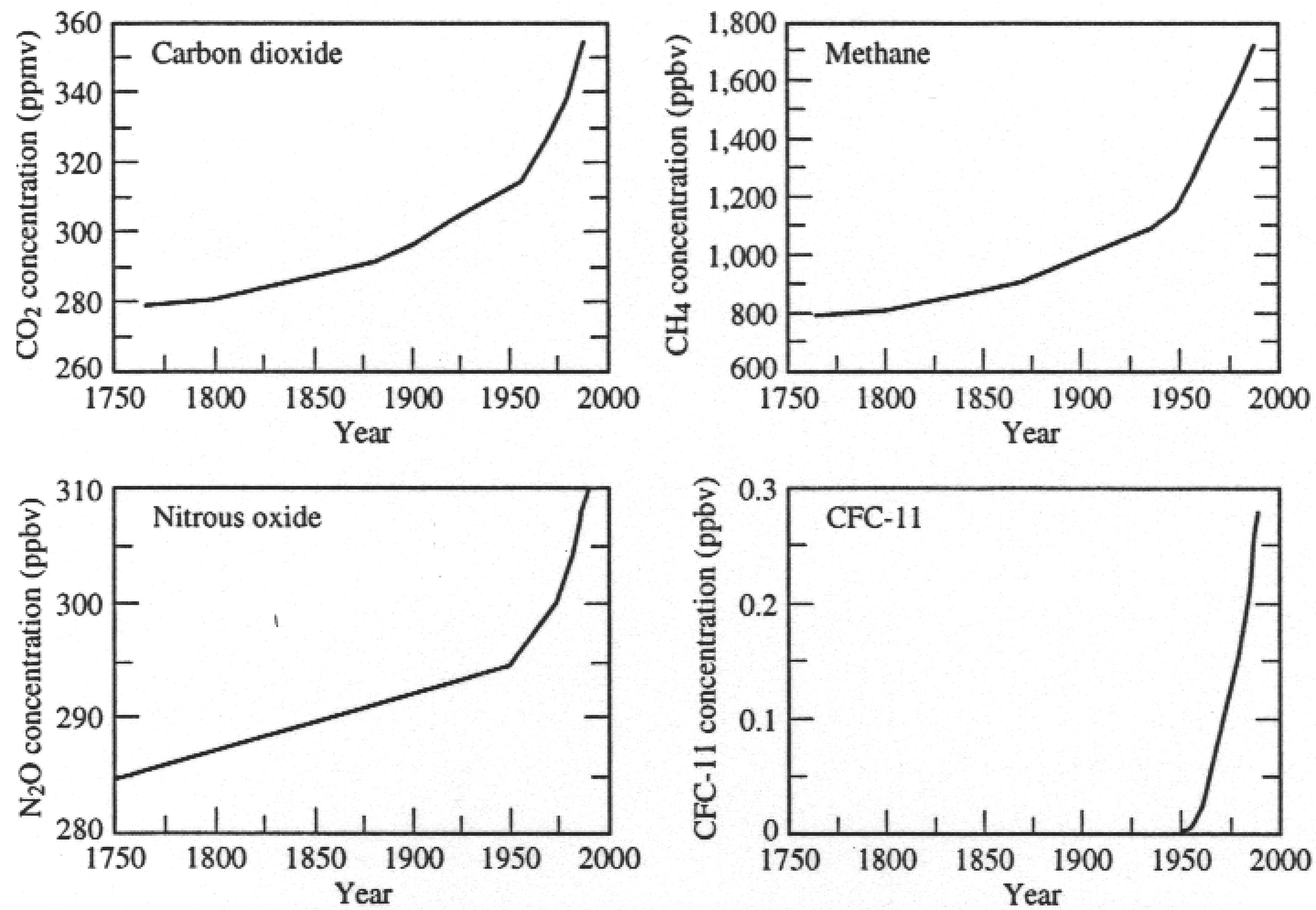
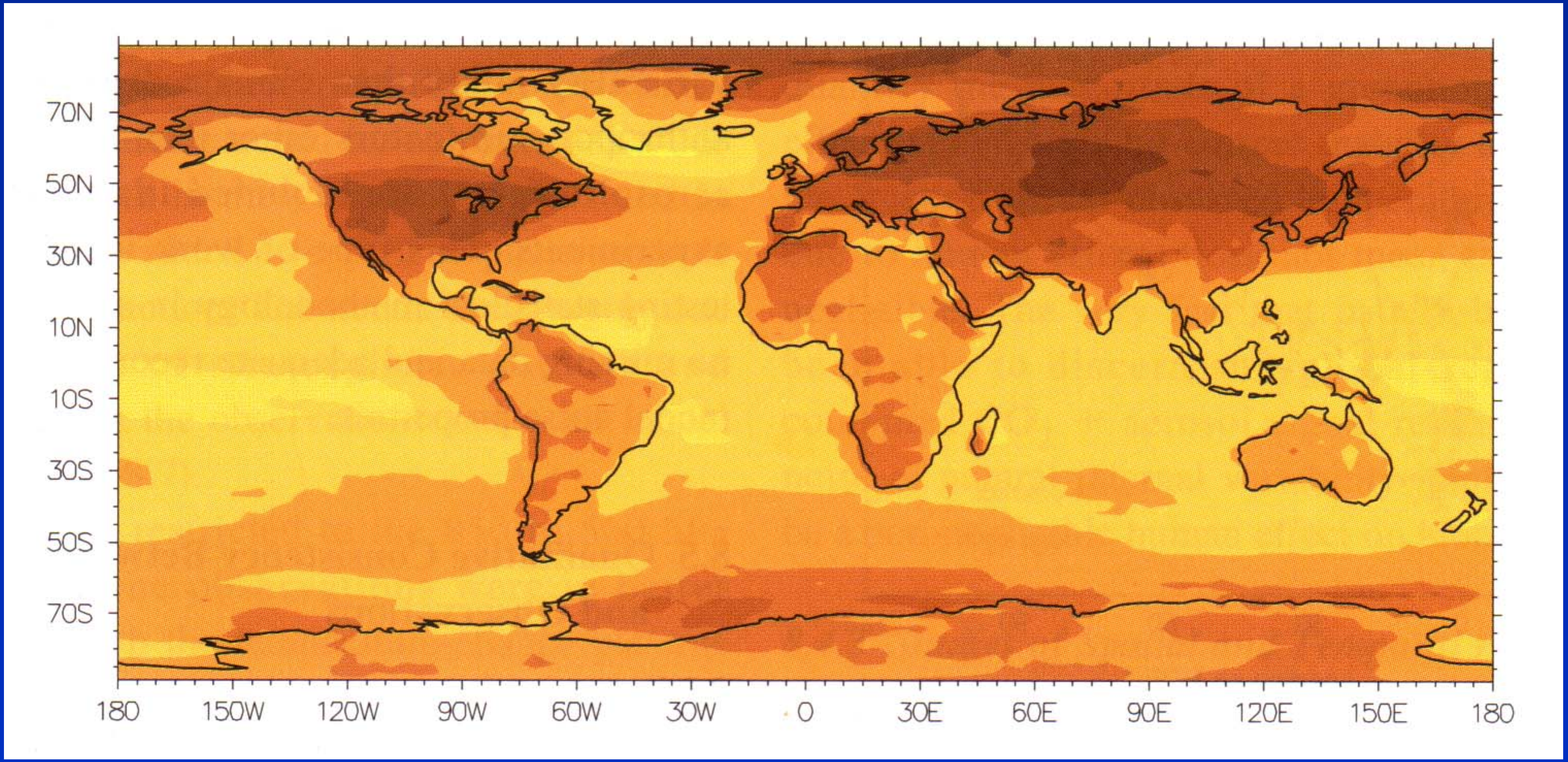
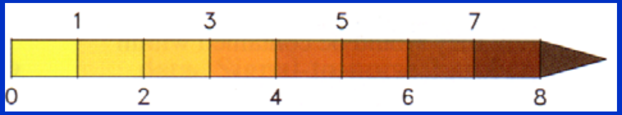
Growth in Atmospheric Greenhouse Gas Concentrations



Predicted Temperature Changes for a Doubling of Atmospheric CO_2 Concentration





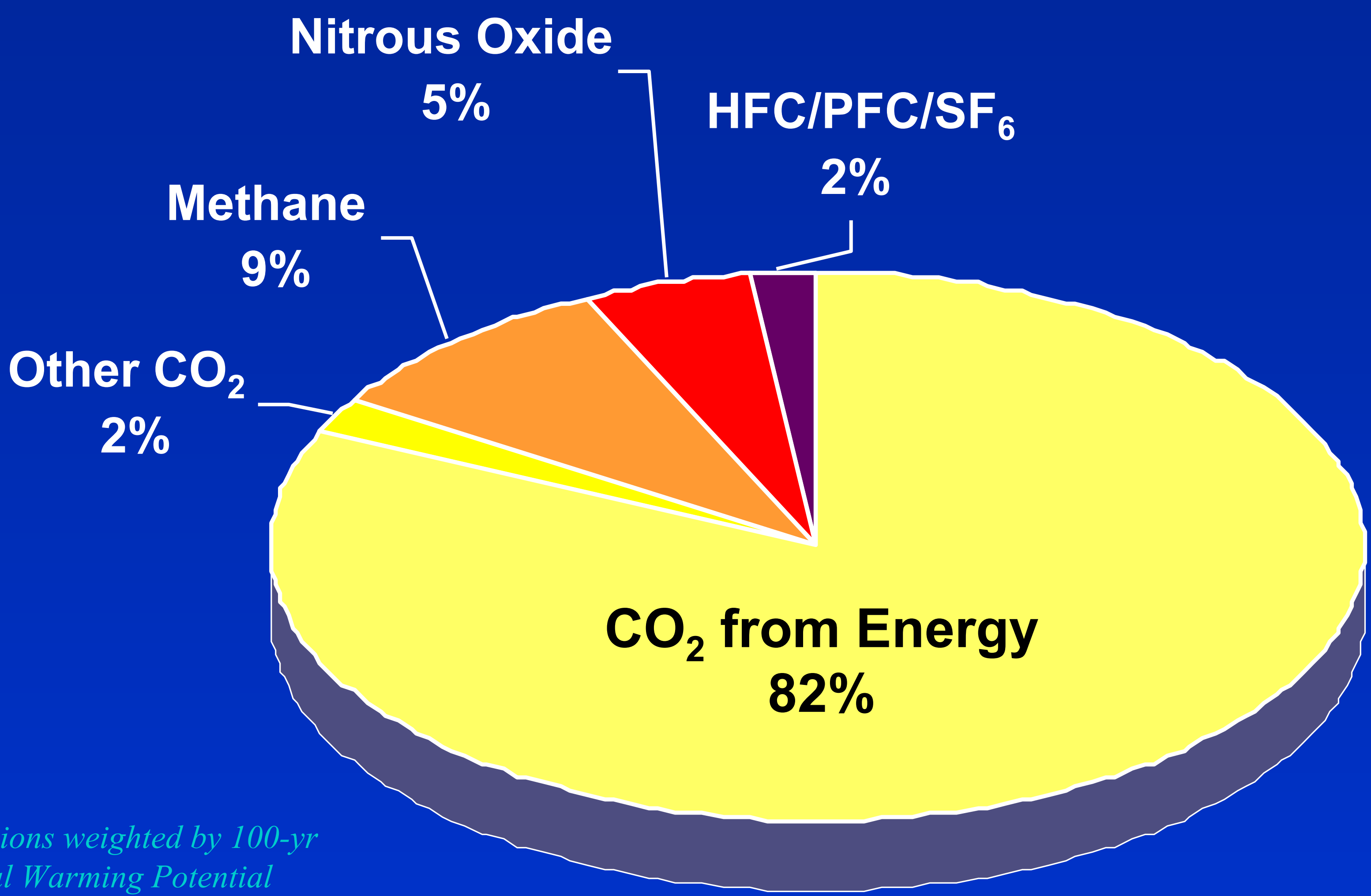
Temperature Increase (C)

Framework Convention on Climate Change (1992)

..... achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system..

Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

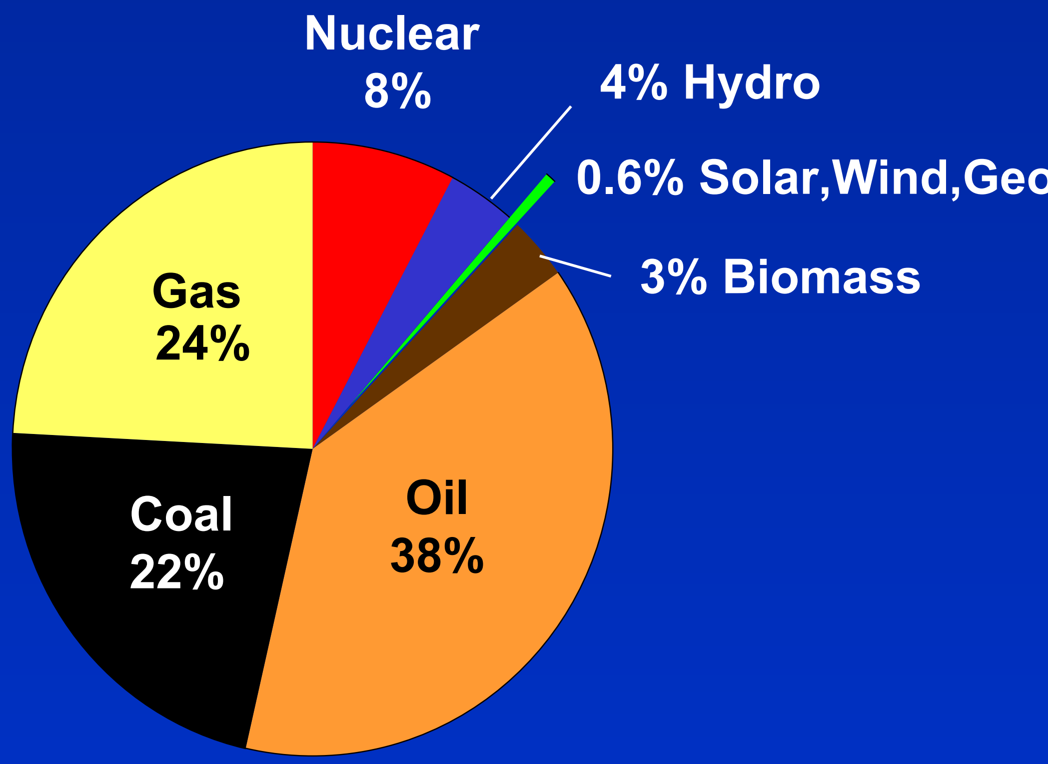
CO_2 From Energy Use is the Dominant Greenhouse Gas



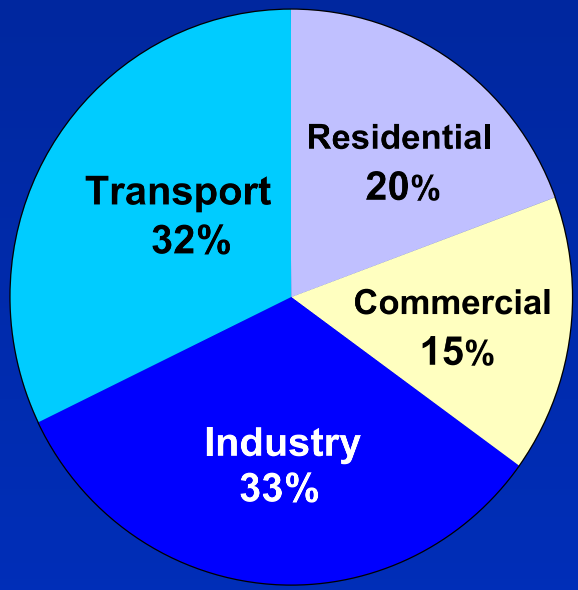
Emissions weighted by 100-yr Global Warming Potential

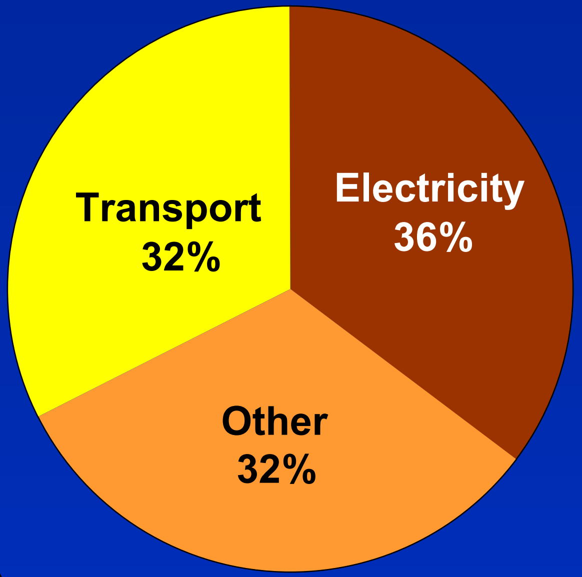
U.S.Energy Consumption by Fuel Type

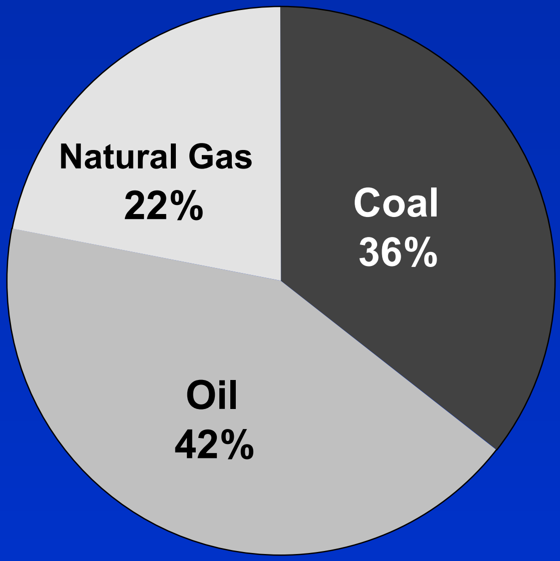
85% Fossil Fuels



Sources of U.S. CO_2 Emissions





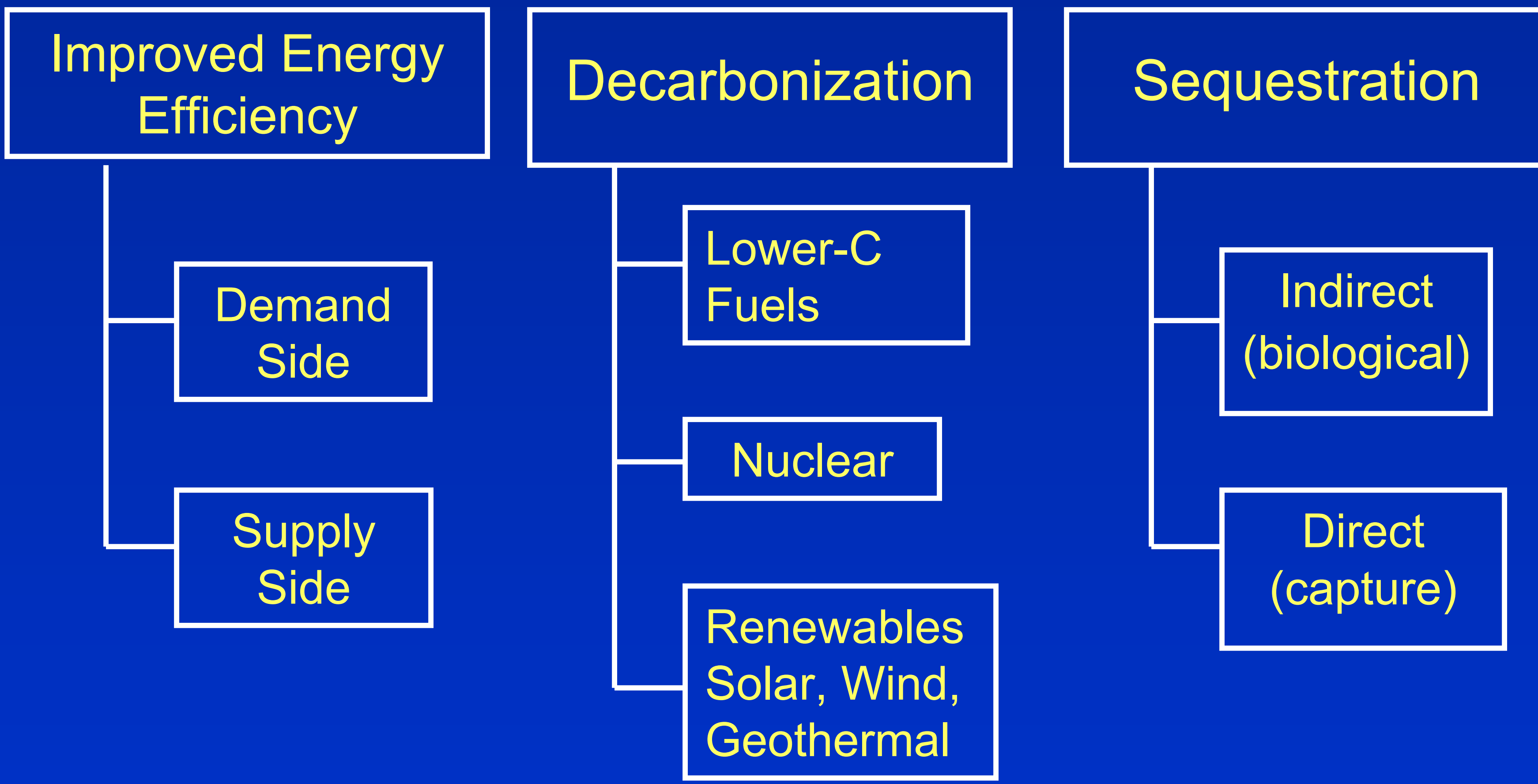


Controlling CO_2 Emissions Growth

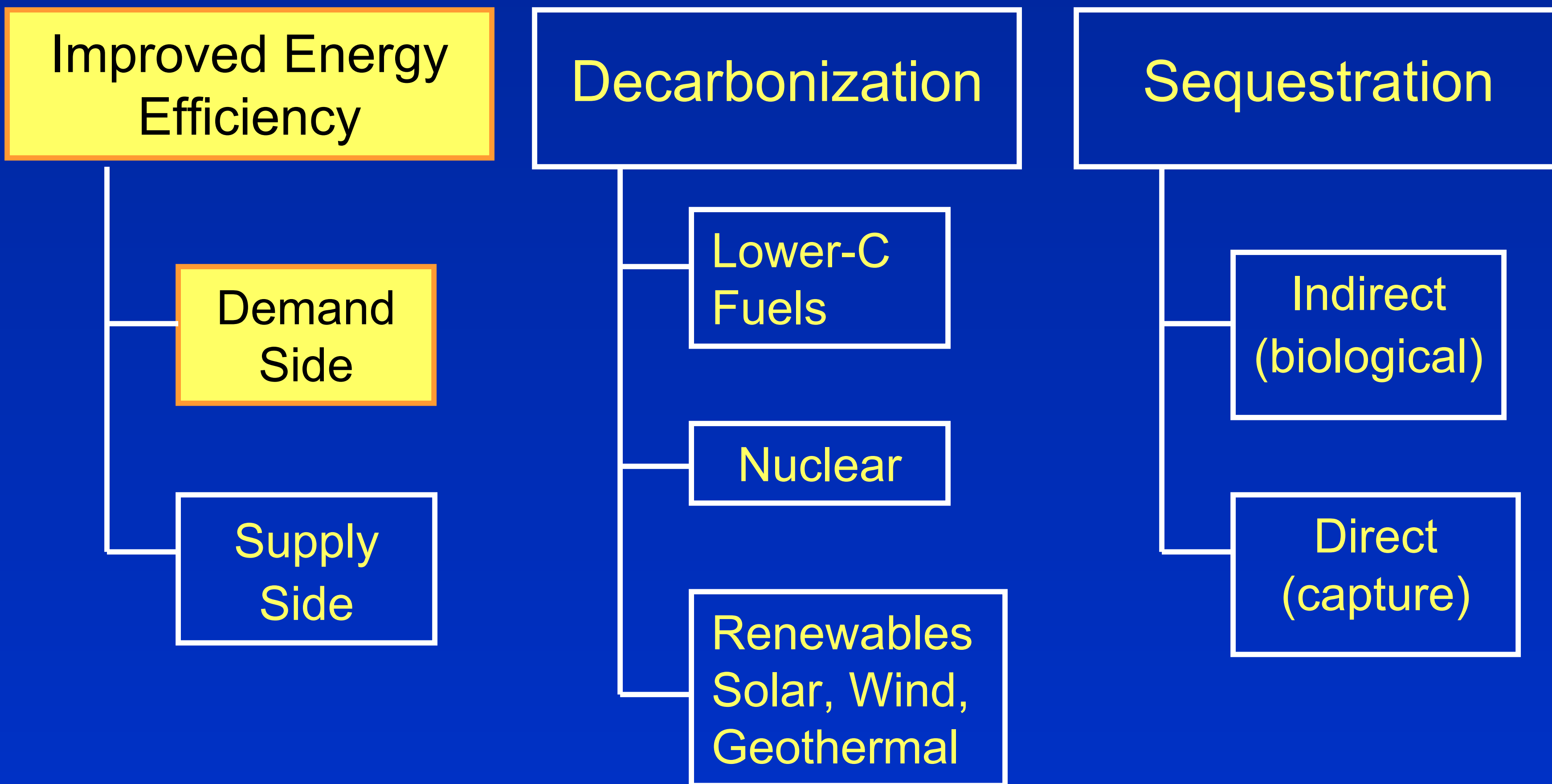
$$\frac{CO_2\text{ emissions}}{\text{per year}} = \left(\frac{\text{Population}}{\text{per year}}\right) \times \left(\frac{\text{GDP}}{\text{per capita}}\right) \times \left(\frac{\text{Energy use}}{\text{per GDP}}\right) \times \left(\frac{CO_2\text{ emissions}}{\text{per unit energy}}\right) \quad (12.46)$$

What role can engineers play ?

CO_2 Mitigation Options

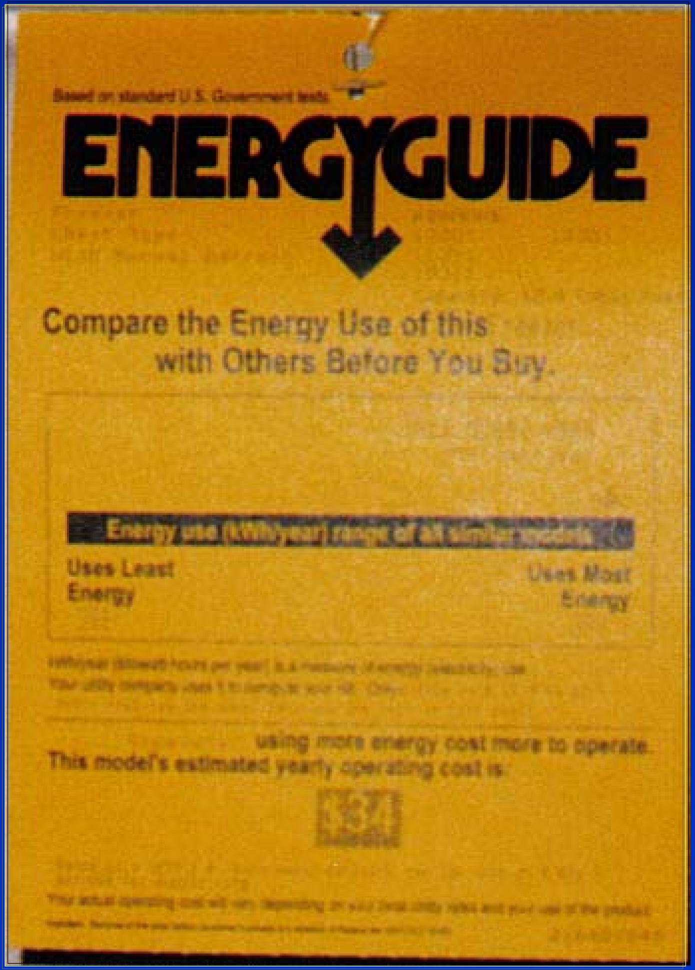


CO_2 Mitigation Options



A Success Story

Appliance Efficiency Standards



much more can be done

Information Technology is the Fastest-Growing Use of Electricity

Energy Sources for U.S. Electricity

- Fossil Fuels
  - Coal *52%*
  - Natural Gas *14%*
  - Petroleum *3%*
- Nuclear
  - Uranium *20%*
- Renewables
  - Hydro *8%*
  - Other *3%*

The Biggest Challenge

Improved Automotive Fuel Economy

CO_2 Mitigation Options

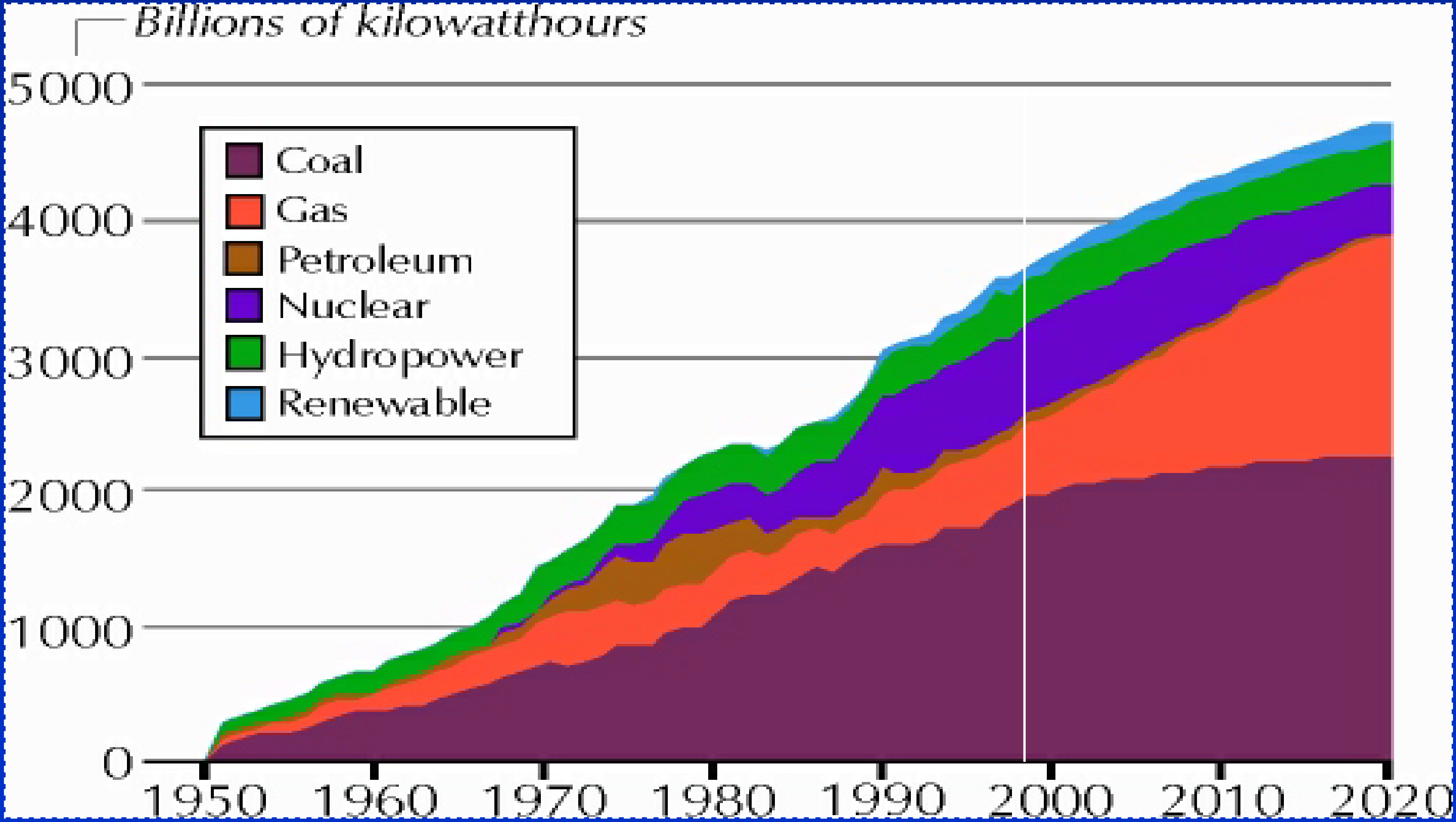
- Improved Energy Efficiency
  - Demand Side
  - Supply Side
- Decarbonization
  - Lower-C Fuels
  - Nuclear
  - Renewables Solar, Wind, Geothermal
- Sequestration
  - Indirect (biological)
  - Direct (capture)

The Biggest Challenge

Alternative Fuels for Transportation

U.S. Electricity Generation by Fuel

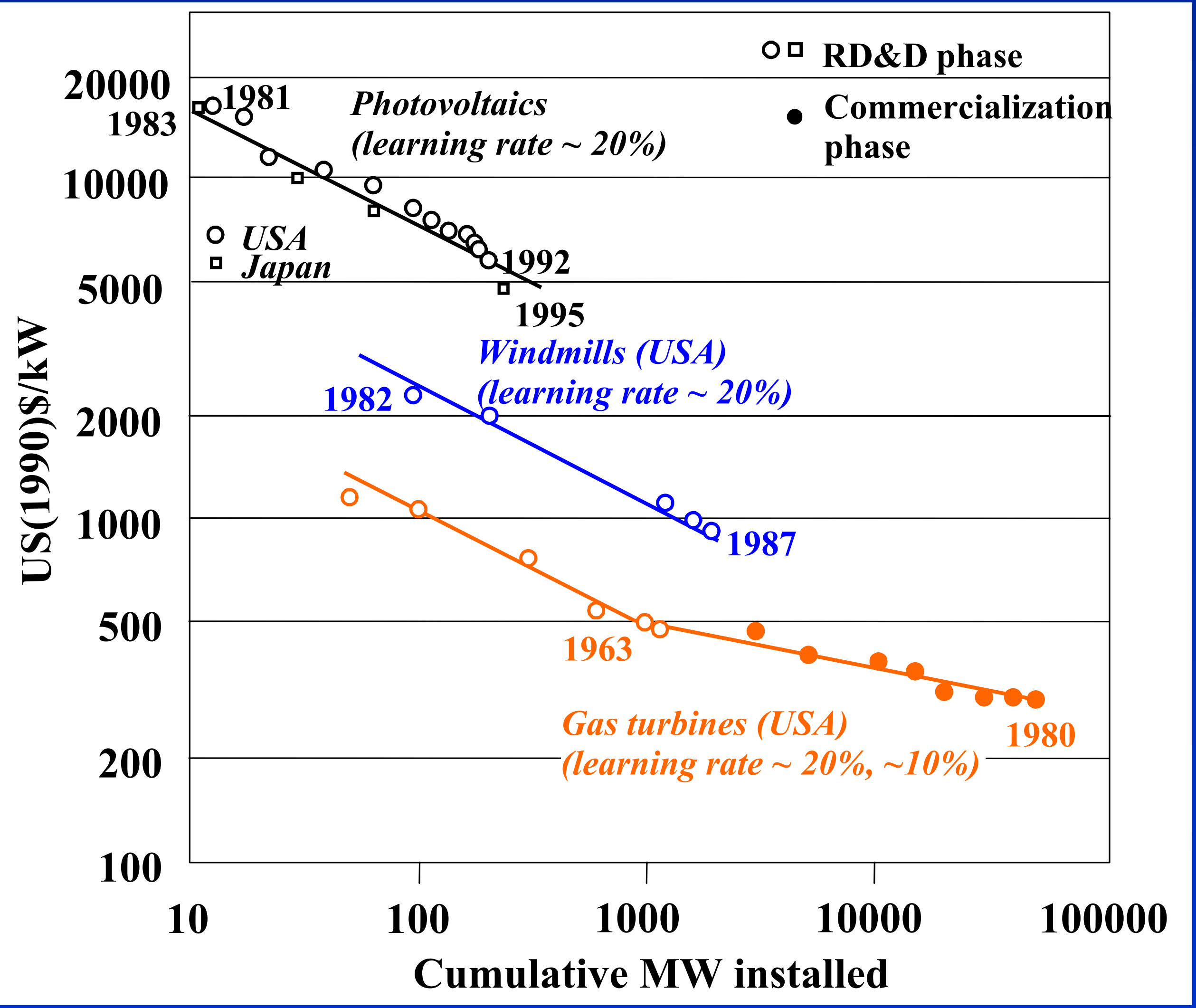
(DOE/EIA Reference Case)



A Modern U.S. Wind Farm

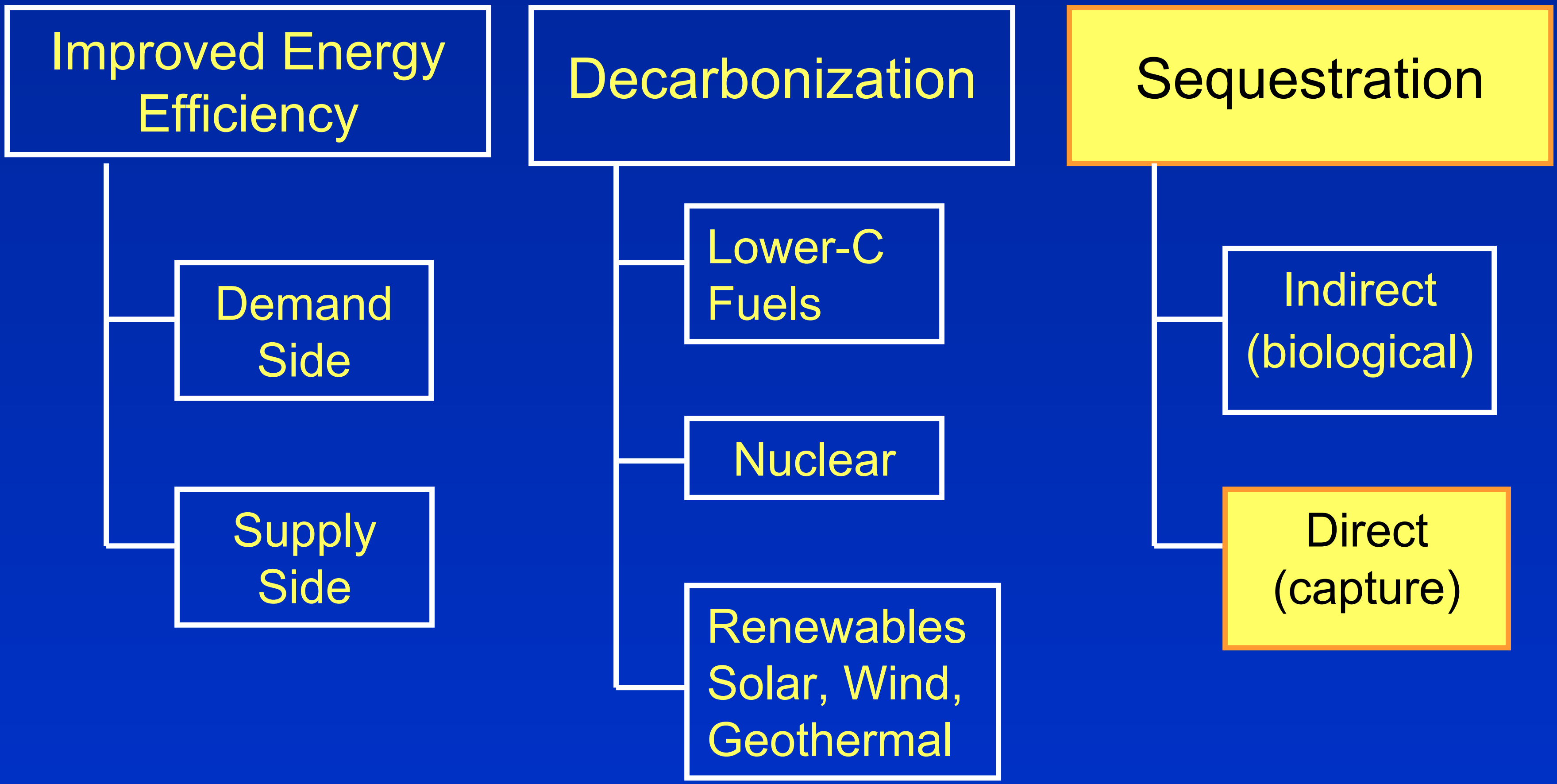
A Building-Integrated Photovoltaic System

Cost Trends for Renewable Energy Technologies



Source: IIASA

CO_2 Mitigation Options

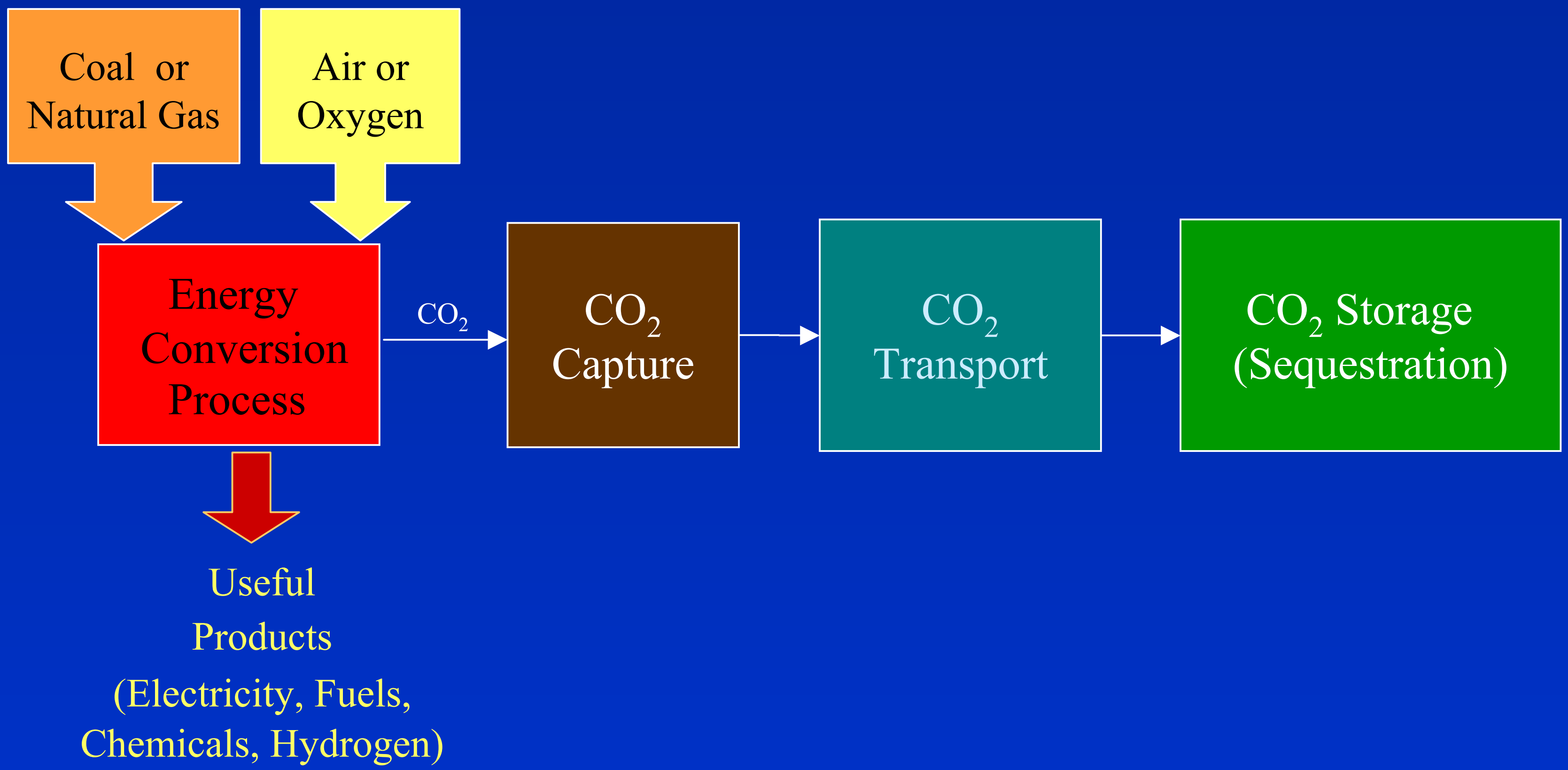


Why the Interest in Carbon Capture and Sequestration (CCS)

CCS technology may be a way to:

- Have your cake and eat it: use fossil fuels without CO_2 emissions
- Minimize the overall cost of reducing greenhouse gas emissions
- Provide a bridge to a more sustainable energy future

Schematic of CO_2 Capture and Storage System



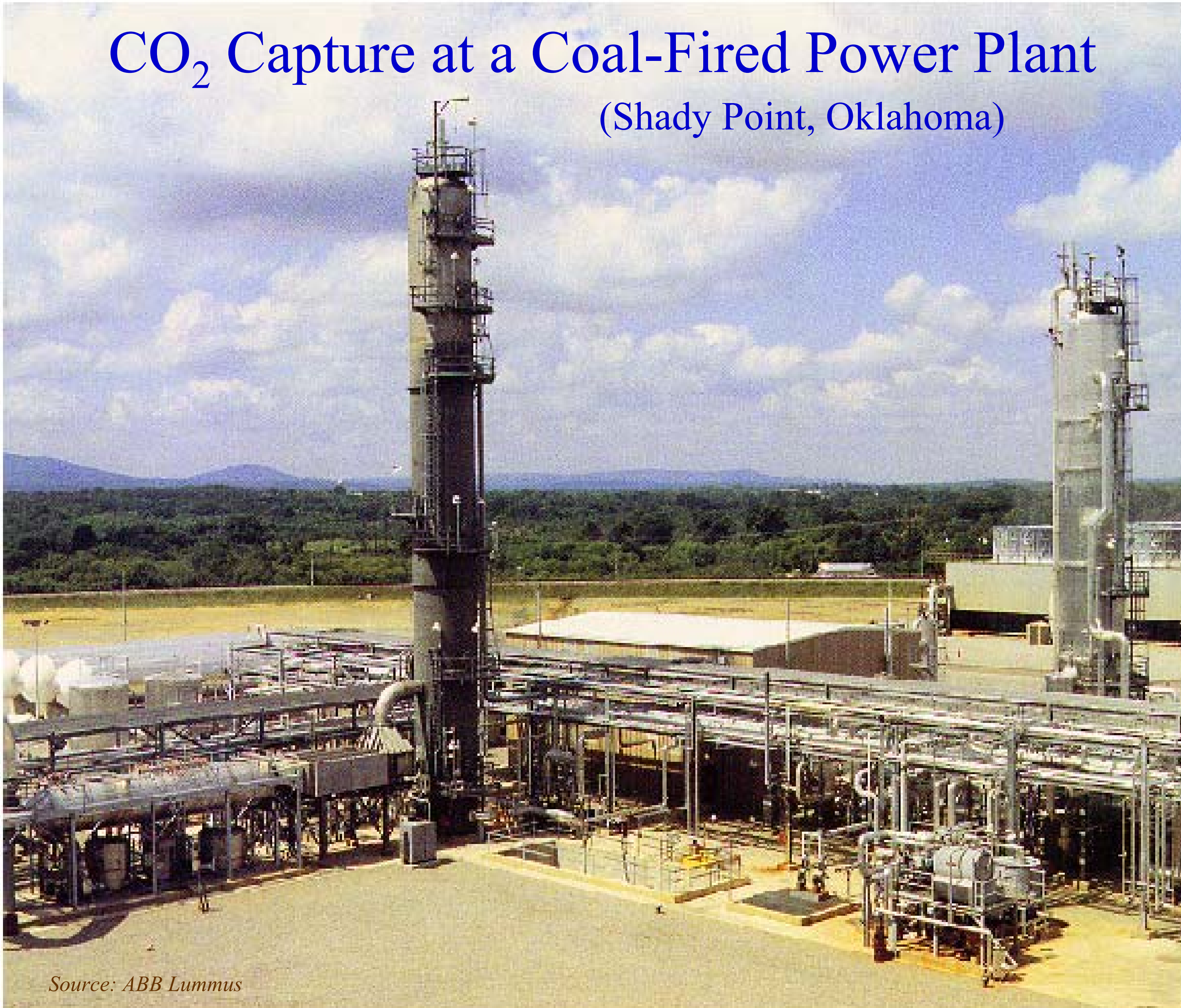
CO_2 Capture Technologies

CO2 Separation and Capture

- **Absorption**
  - Chemical
    - MEA
    - Caustic
    - Other
  - Physical
    - Selexol
    - Rectisol
    - Other
- **Adsorption**
  - Adsorber Beds
    - Alumina
    - Zeolite
    - Activated C
  - Regeneration Method
    - Pressure Swing
    - Temperature Swing
    - Washing
- **Cryogenics**
- **Membranes**
  - Gas Separation
    - Polyphenyleneoxide
    - Polydimethylsiloxane
  - Gas Absorption
    - Polypropelene
  - Ceramic Based Systems
- **Microbial/Algal Systems**

CO_2 Capture at a Coal-Fired Power Plant

(Shady Point, Oklahoma)



Source: ABB Lummus

Coal Gasification Combined Cycle Plant

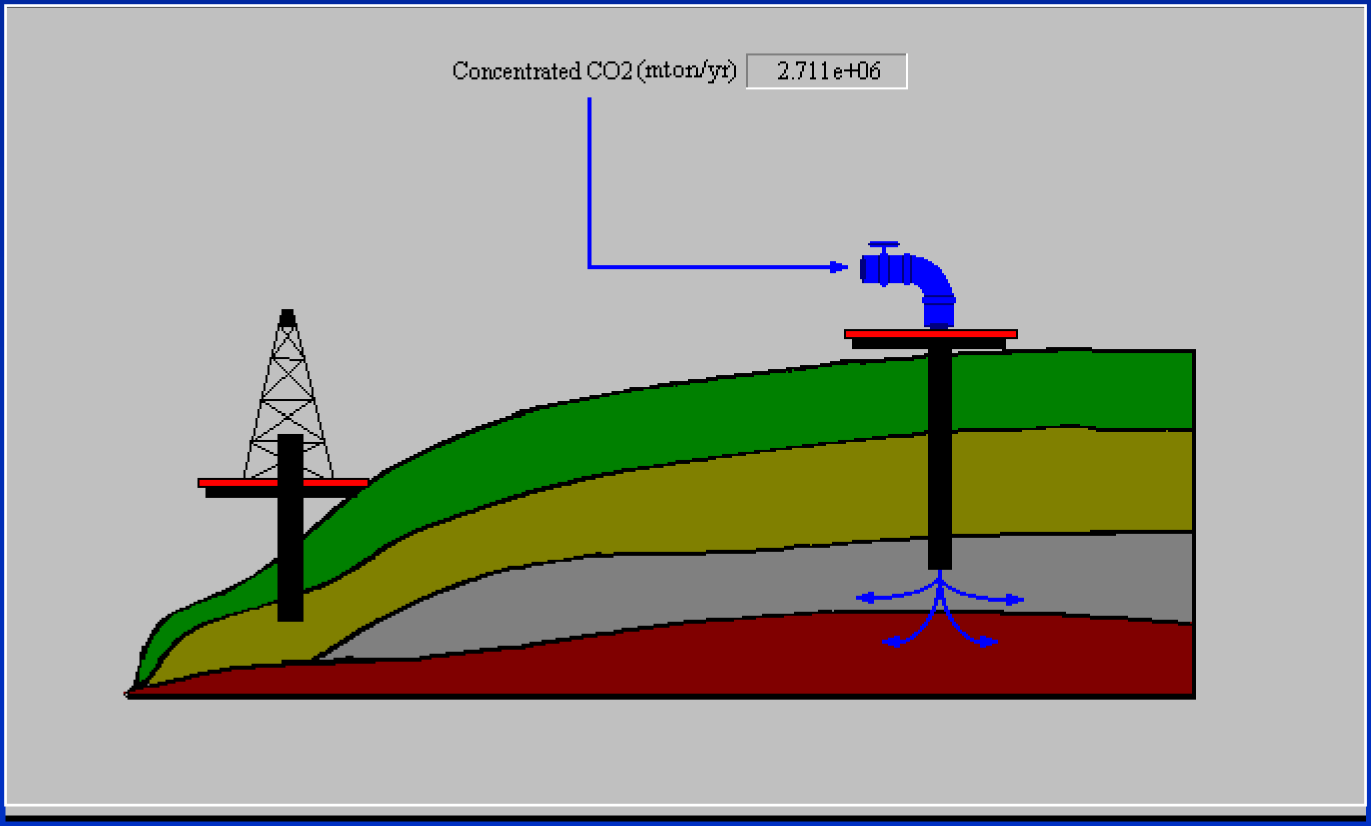
CO_2 Sequestration Options

- Geologic Sequestration
  - Deep saline reservoirs
  - Depleted oil and gas wells
  - Unmineable coal seams
- Ocean Sequestration

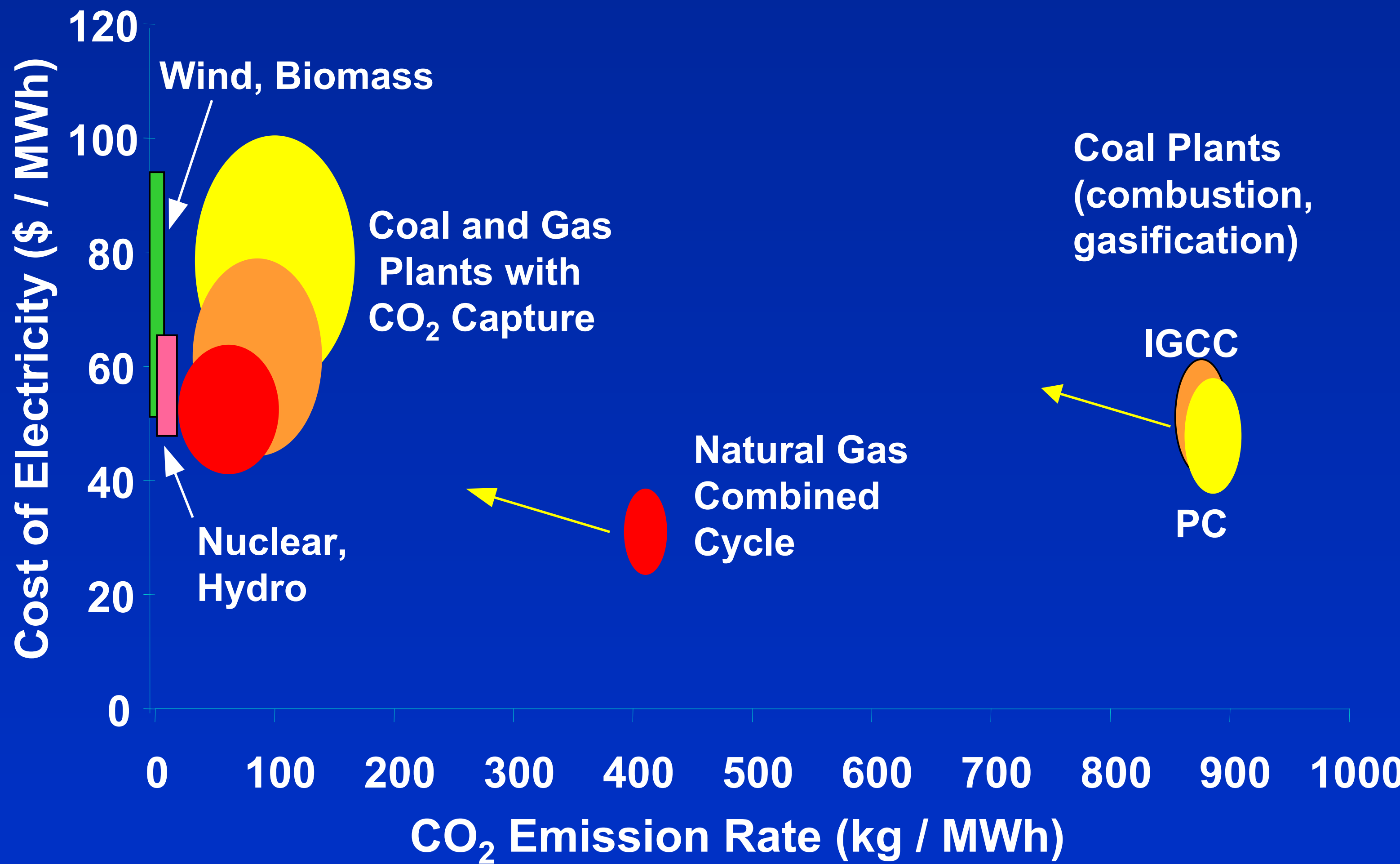
Geologic Sequestration of CO_2

(Sleipner Gasfield, North Sea, Norway)

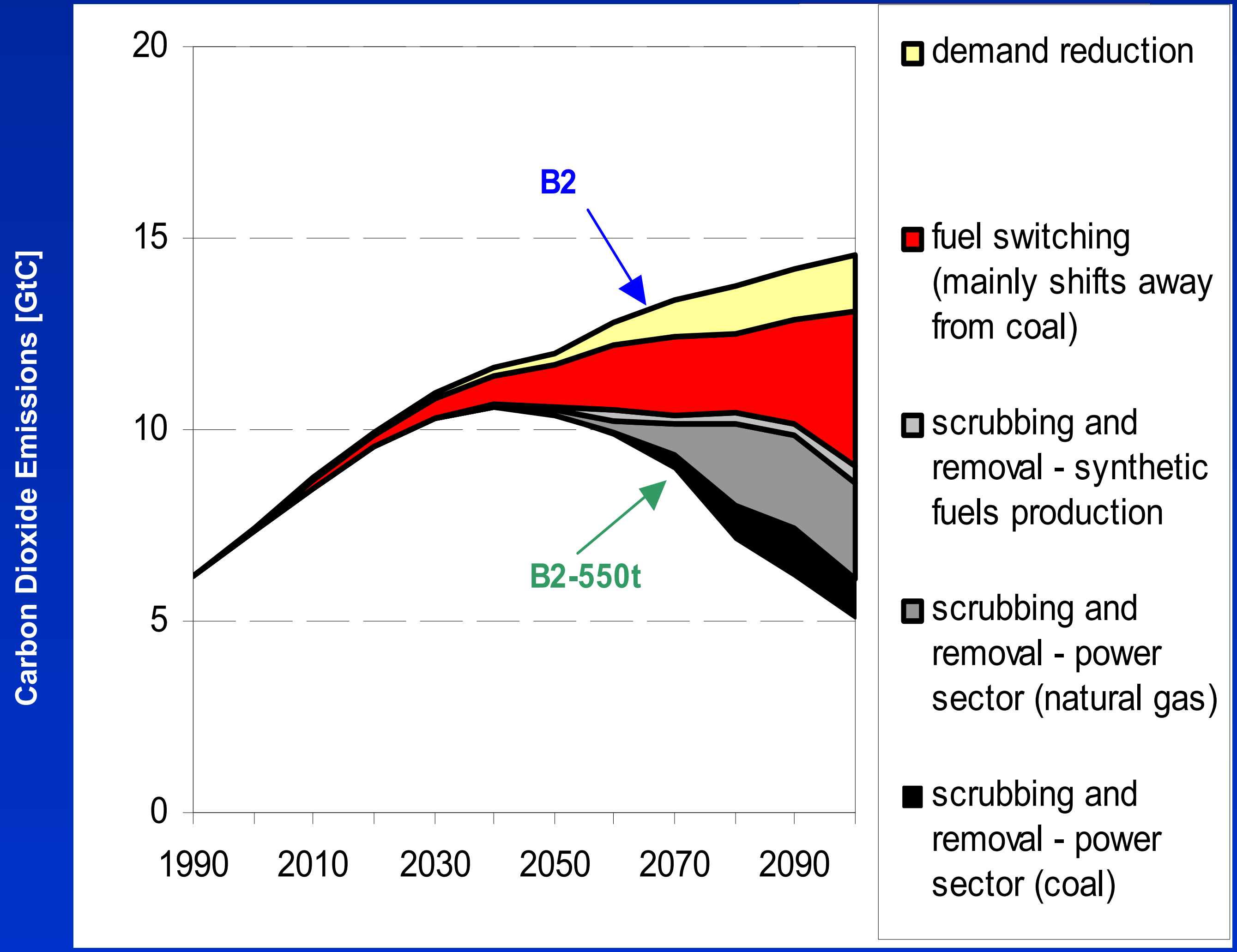
Geologic Sequestration with Enhanced Oil Recovery (EOR)



Cost of Alternative Options



Use of Carbon Capture Technologies in Climate Change Mitigation



Final Exam

(take home)

For Faculty

- Identify ways to incorporate environmental considerations into your courses
- Challenge your students to propose ways of reducing environmental impacts without sacrificing other key needs (functionality, reliability, etc.)

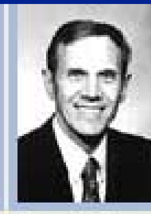
For Students

- Think about how your research and courses could have environmental consequences
- Challenge your professors to discuss and propose ways of reducing environmental impacts without sacrificing other key needs (functionality, reliability, etc.)

Who will be the new environmental hero ?

Ellen J. Bass
Assistant Professor

Peter A. Beling
Associate Professor

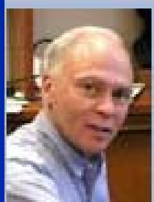


Donald E. Brown
Professor and Chair

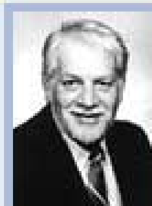
Alfredo Garcia
Assistant Professor

Stephanie Guerlain
Assistant Professor

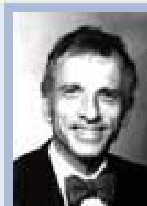
Yacov Y. Haimes
Lawrence R. Quarles Professor



Barry Horowitz
Professor



Thomas E. Hutchinson
Calcott Professor

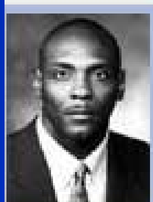


Roman Krzysztofowicz
Professor

James H. Lambert
Research Assistant Professor

James W. Lark III
Assistant Professor

Gerard P. Learmonth
Associate Professor



Garrick E. Louis
Assistant Professor

Christina M. Mastrangelo
Associate Professor

Stephen D Patek
Assistant Professor

William T. Scherer
Associate Professor

K Preston White Jr
Professor

All of the above

None of the above

Answer:

All of the above !