



# Global Climate and Energy Project

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Diesel Engine Emissions Reduction Conference  
August 23, 2003

*“This is the century that human beings will have to come to grips with whether they can continue to live on this planet...”*

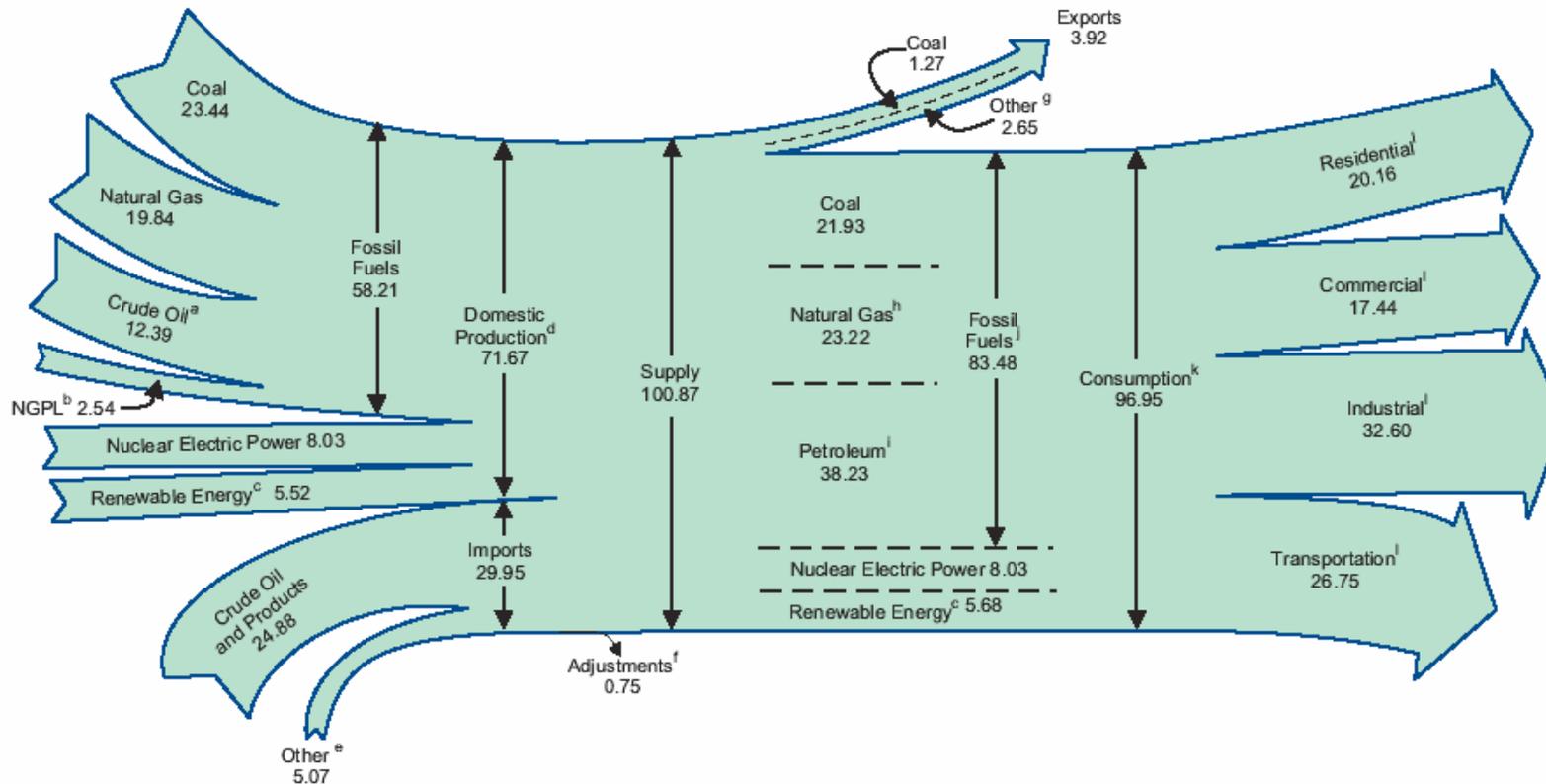
Franklin M. Orr

(former Dean of Earth Sciences,  
Director, Global Climate and Energy Project)

# Energy

- There is no Energy shortage. Energy can neither be created nor destroyed.
- Our problem is one of the Availability of energy.
- Energy is made available for our use only by interaction with the environment.

**Diagram 1. Energy Flow, 2001**  
(Quadrillion Btu)



<sup>a</sup> Includes lease condensate.

<sup>b</sup> Natural gas plant liquids.

<sup>c</sup> Conventional hydroelectric power, wood, waste, ethanol blended into motor gasoline, geothermal, solar, and wind.

<sup>d</sup> Includes -0.09 quadrillion Btu hydroelectric pumped storage.

<sup>e</sup> Natural gas, coal, coal coke, and electricity.

<sup>f</sup> Stock changes, losses, gains, miscellaneous blending components, and unaccounted-for supply.

<sup>g</sup> Crude oil, petroleum products, natural gas, electricity, and coal coke.

<sup>h</sup> Includes supplemental gaseous fuels.

<sup>i</sup> Petroleum products, including natural gas plant liquids.

<sup>j</sup> Includes, in quadrillion Btu, 0.04 coal coke net imports and 0.05 electricity net imports from fossil fuels.

<sup>k</sup> Includes, in quadrillion Btu, -0.09 hydroelectric pumped storage and -0.15 ethanol blended into motor gasoline, which is accounted for in both fossil fuels and renewable energy but counted only once in total consumption.

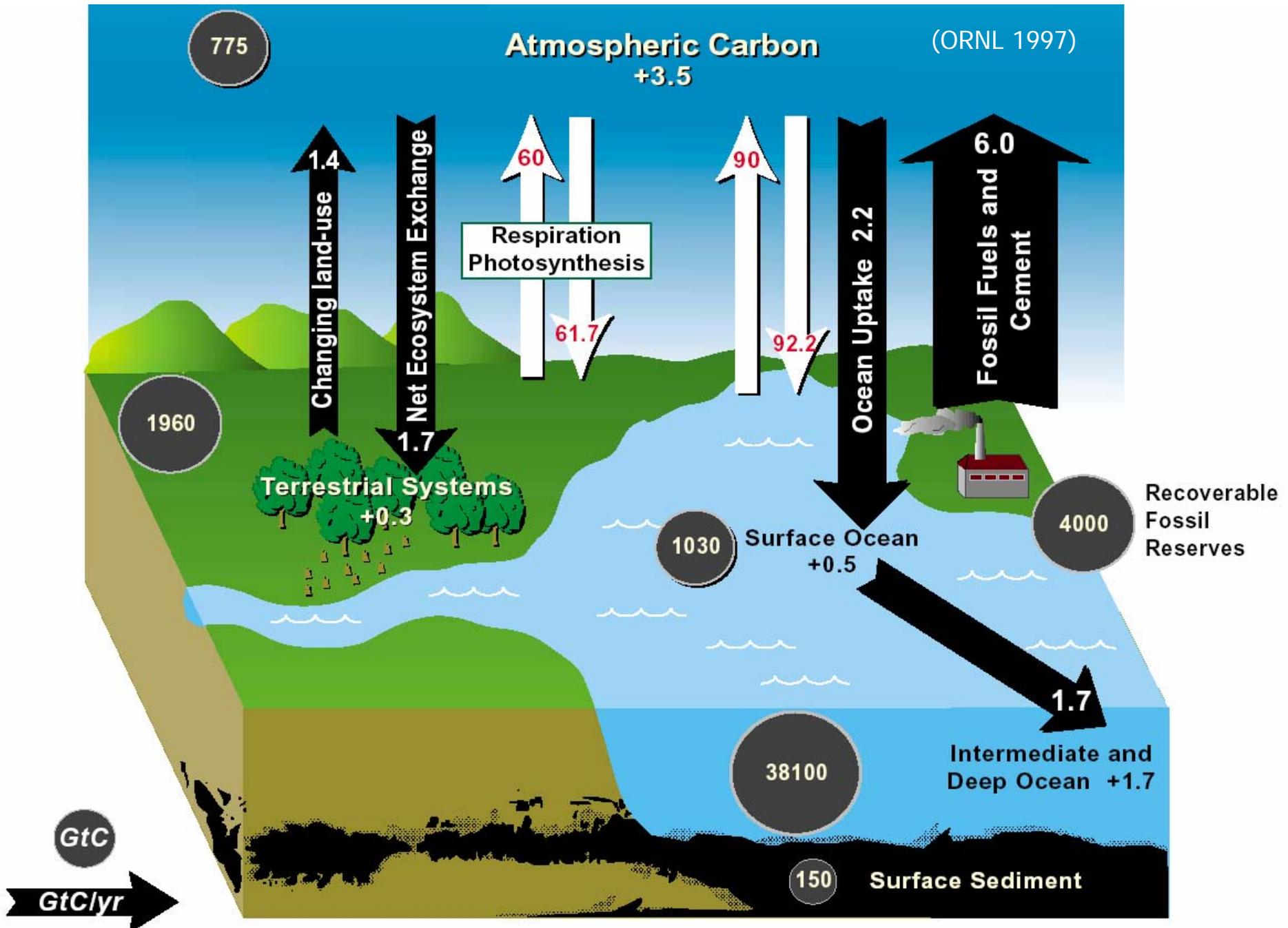
<sup>l</sup> Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note 1 at end of Electricity section.

Notes: • Data are preliminary. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 1.1, 1.2, 1.3, 1.4, and 2.1a.

# Environment

- The environment is not an infinite reservoir.
- The scale of human endeavors is now such that we must take responsibility for maintaining equilibrium with our environment.
- This requires that byproducts be returned to nature in such a way that they can equilibrate on nature's terms & time scale.



775

**Atmospheric Carbon +3.5**

(ORNL 1997)

1960

**Terrestrial Systems +0.3**

1.4

**Changing land-use**

1.7

**Net Ecosystem Exchange**

60

**Respiration**

61.7

**Photosynthesis**

90

92.2

**Ocean Uptake 2.2**

6.0

**Fossil Fuels and Cement**

1030

**Surface Ocean +0.5**

4000

**Recoverable Fossil Reserves**

1.7

**Intermediate and Deep Ocean +1.7**

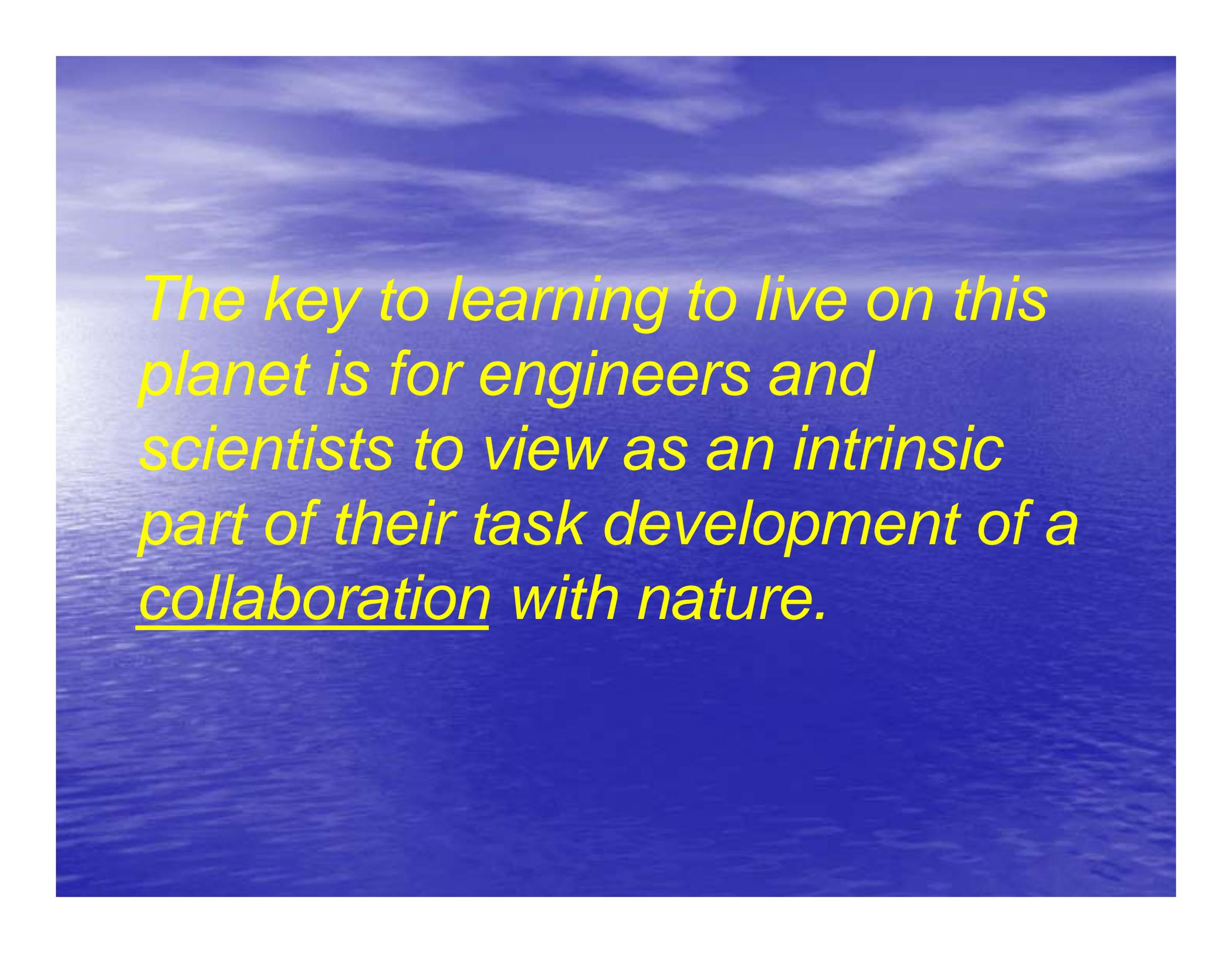
38100

150

**Surface Sediment**

**GtC**

**GtC/yr**



*The key to learning to live on this planet is for engineers and scientists to view as an intrinsic part of their task development of a collaboration with nature.*

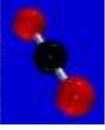
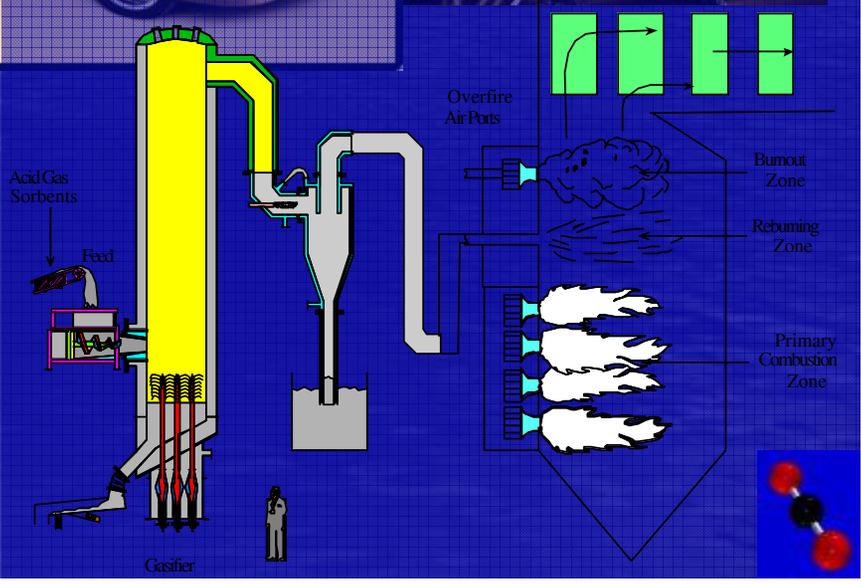
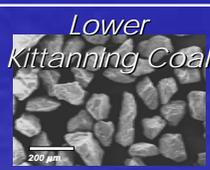
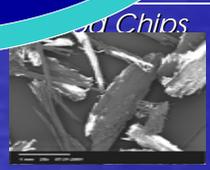
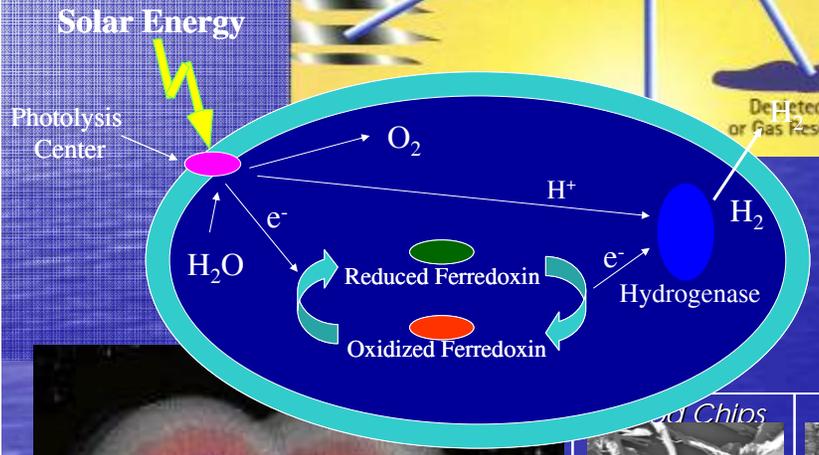
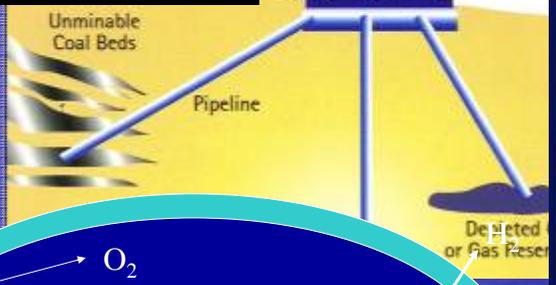
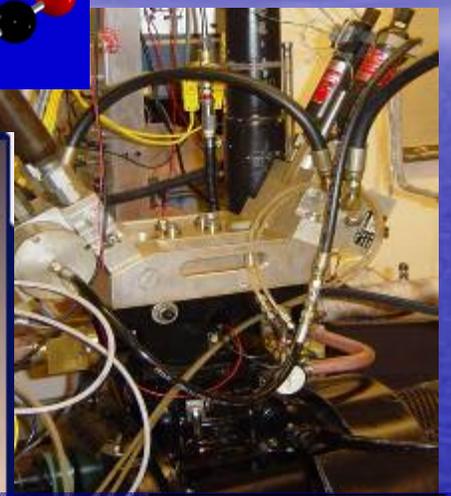
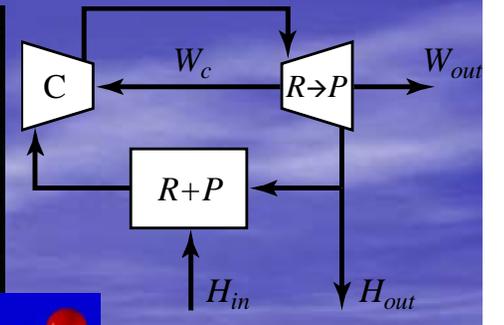
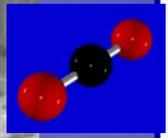
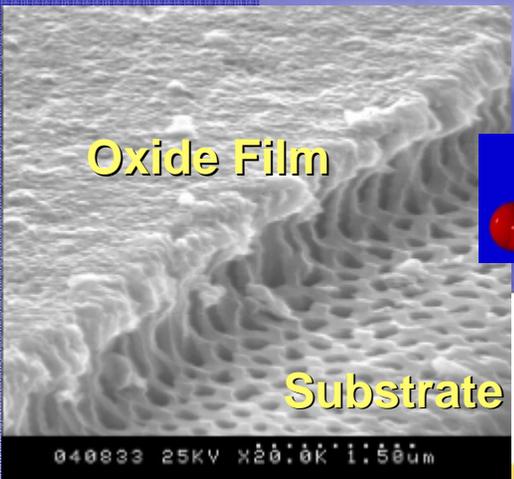
# Uncertainty

- Future fuel supplies, energy technologies, and the consequences of greenhouse gas emission are uncertain.
- Uncertainty can lead to inaction until it is too late. (Inverse Apollo effect.)
- Engineers are in a unique position to provide options that allow us to choose a better future despite uncertainty.

# The Global Climate and Energy Project



- Objective is to create new technologies for a low-greenhouse-gas energy future.
- Four industrial sponsors (ExxonMobil, General Electric, Toyota, Schlumberger) have committed \$225 million over 10 years.
- Perform research at Stanford and at leading research institutions worldwide.
- Create a sustained university/industry collaboration and flow of talented students.

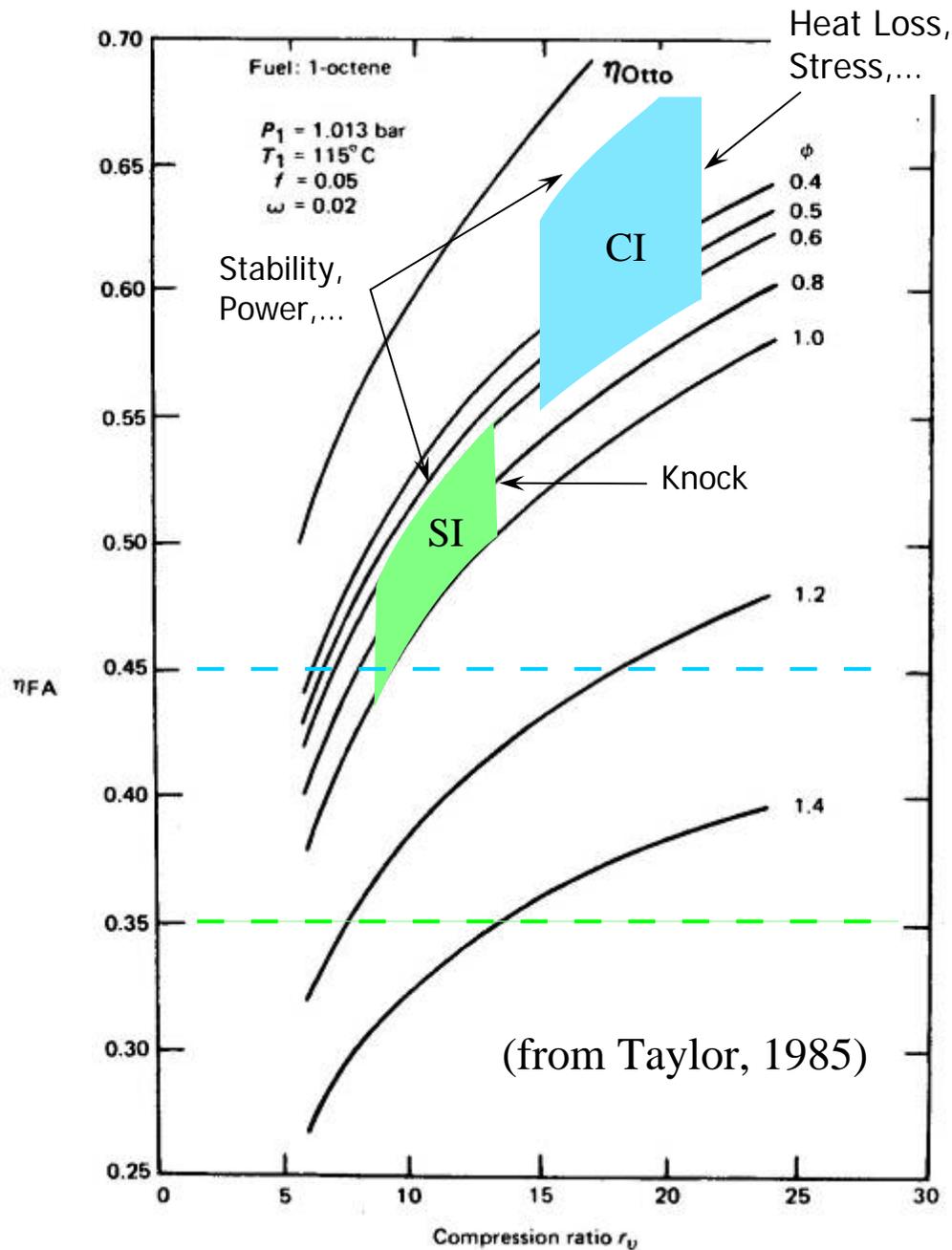


*Achieving a sustainable collaboration with nature will be required to provide a safe and secure energy future.*

*Engineers and scientists will play a leadership role in realizing that collaboration.*

# Diesel

- As a thermodynamic cycle...
- As a petroleum-derived fuel...
- As an engine...
- As an energy pioneer...



### Criteria Emissions

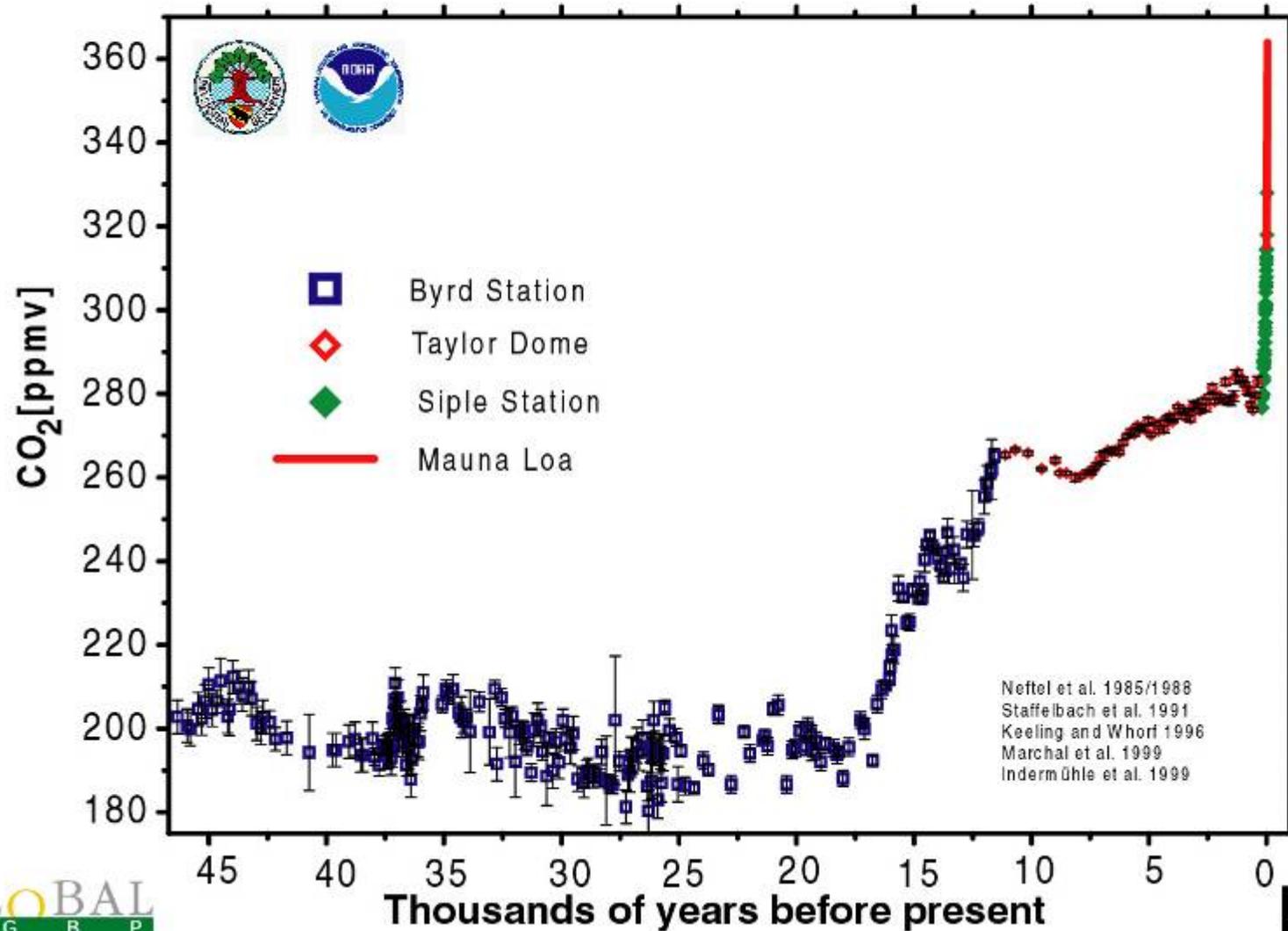
- EGR, Injection Control...
- HCCI...
- Aftertreatment...
- Other...

### Carbon Emissions

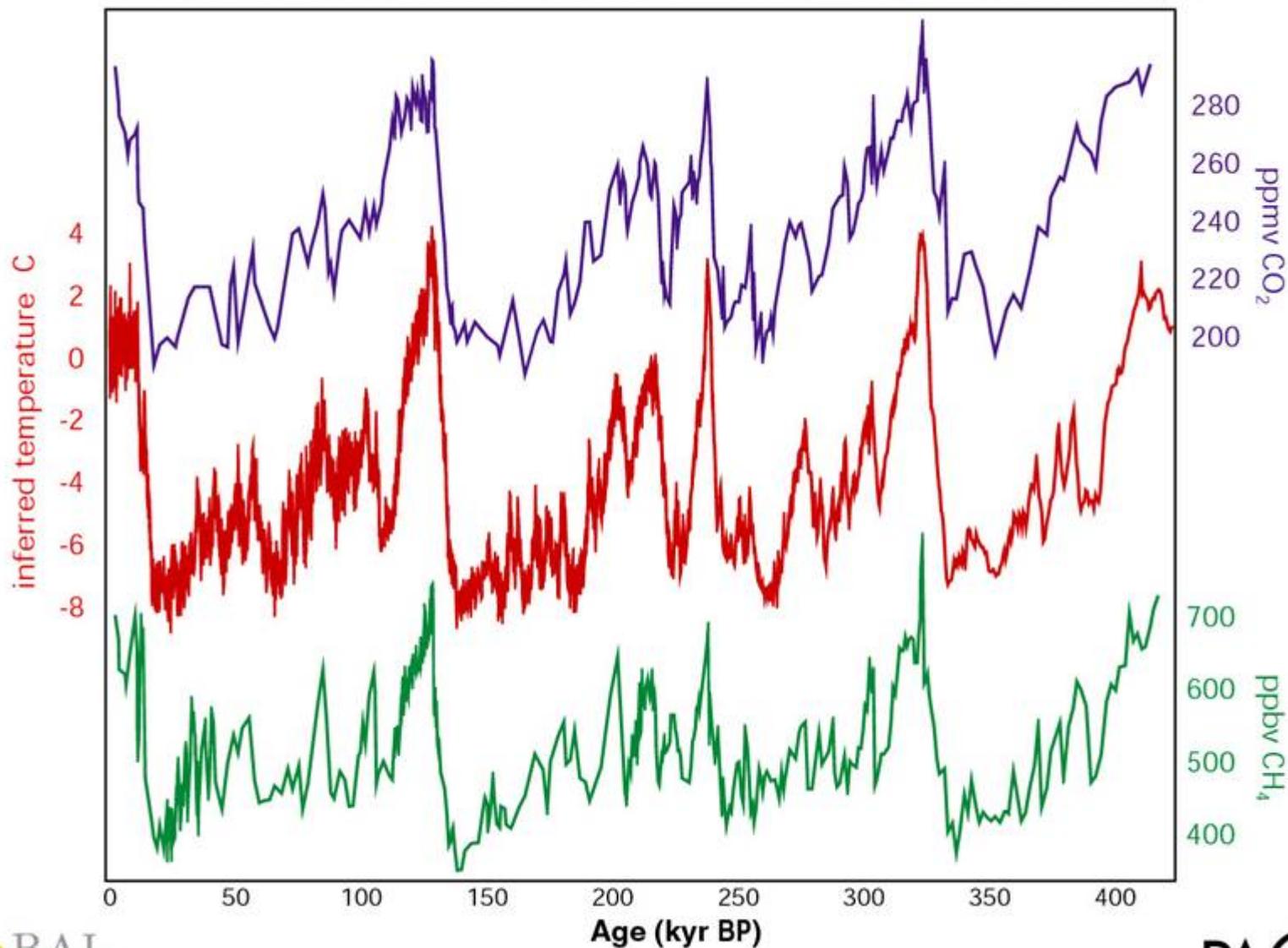
- Efficiency...
- Reduced-Carbon Fuel...
- Carbon-Neutral Fuel...
- On-Board Carbon Capture...
- Carbonless Fuel...
- Other...

# Atmospheric CO<sub>2</sub> Concentration

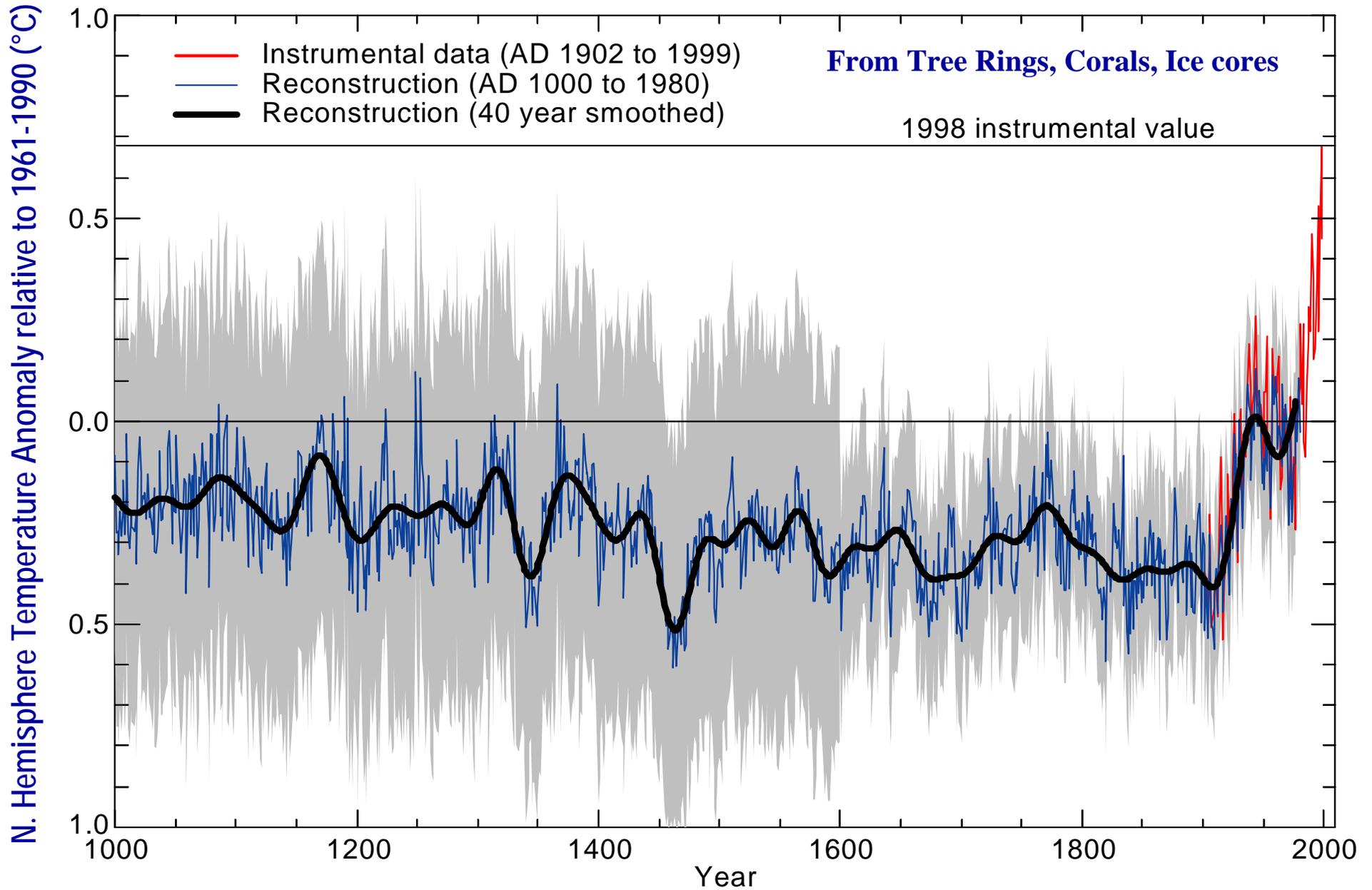
Last Glacial Maximum to present



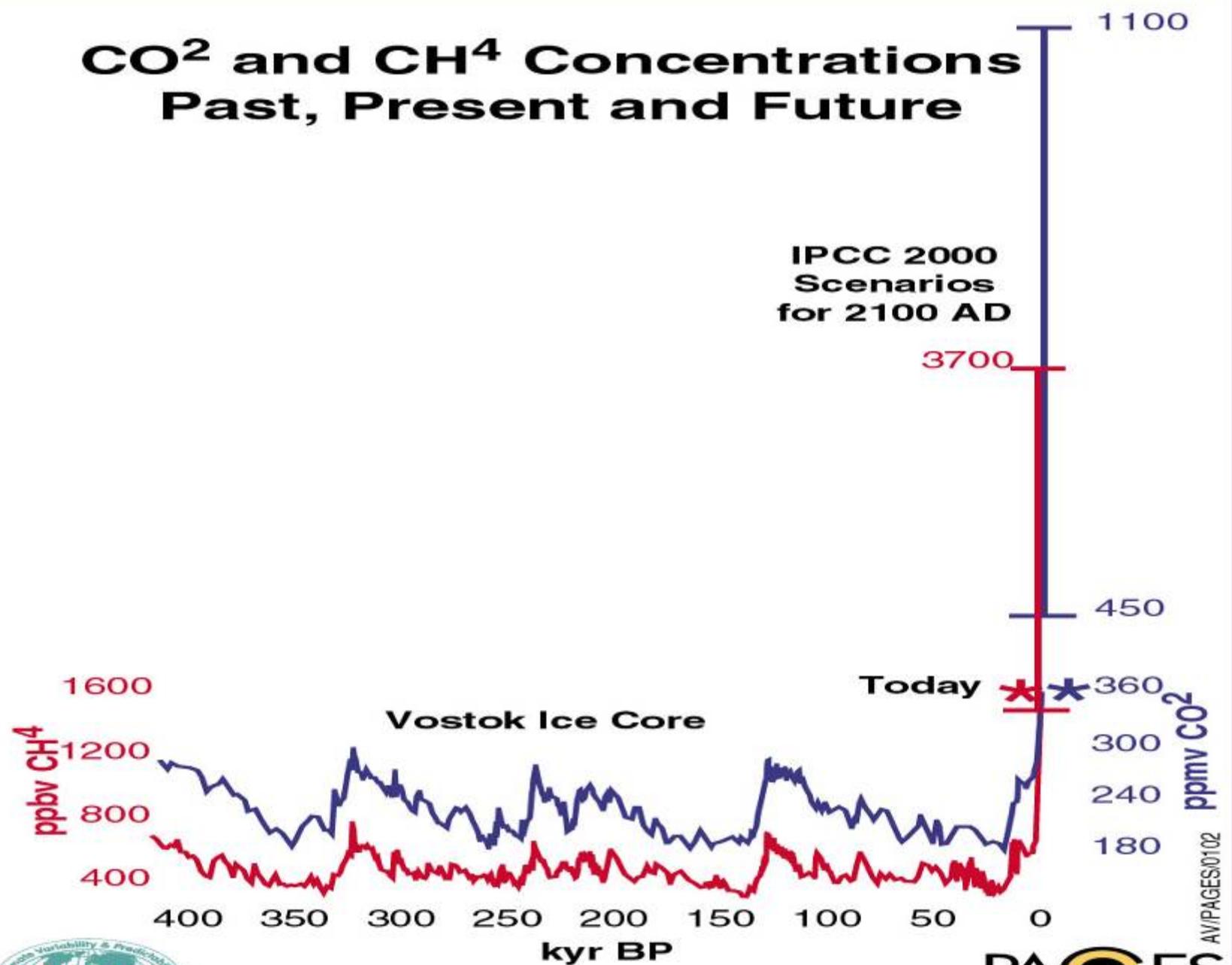
## 4 glacial cycles recorded in the Vostok ice core



# IPCC 3<sup>rd</sup> Assessment Report (2001)



# CO<sub>2</sub> and CH<sub>4</sub> Concentrations Past, Present and Future

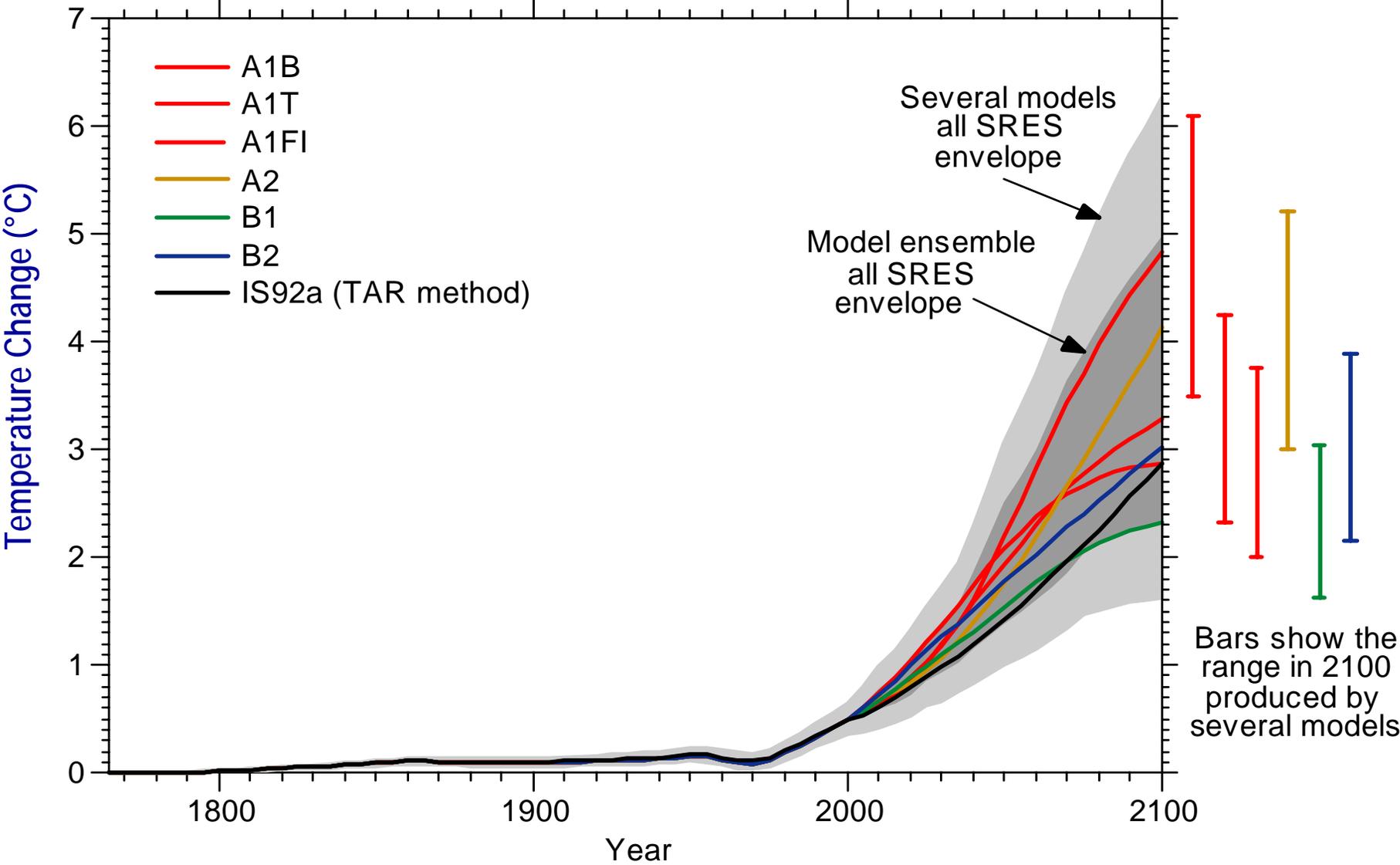


Compiled by K. Alverson, PAGES IPO



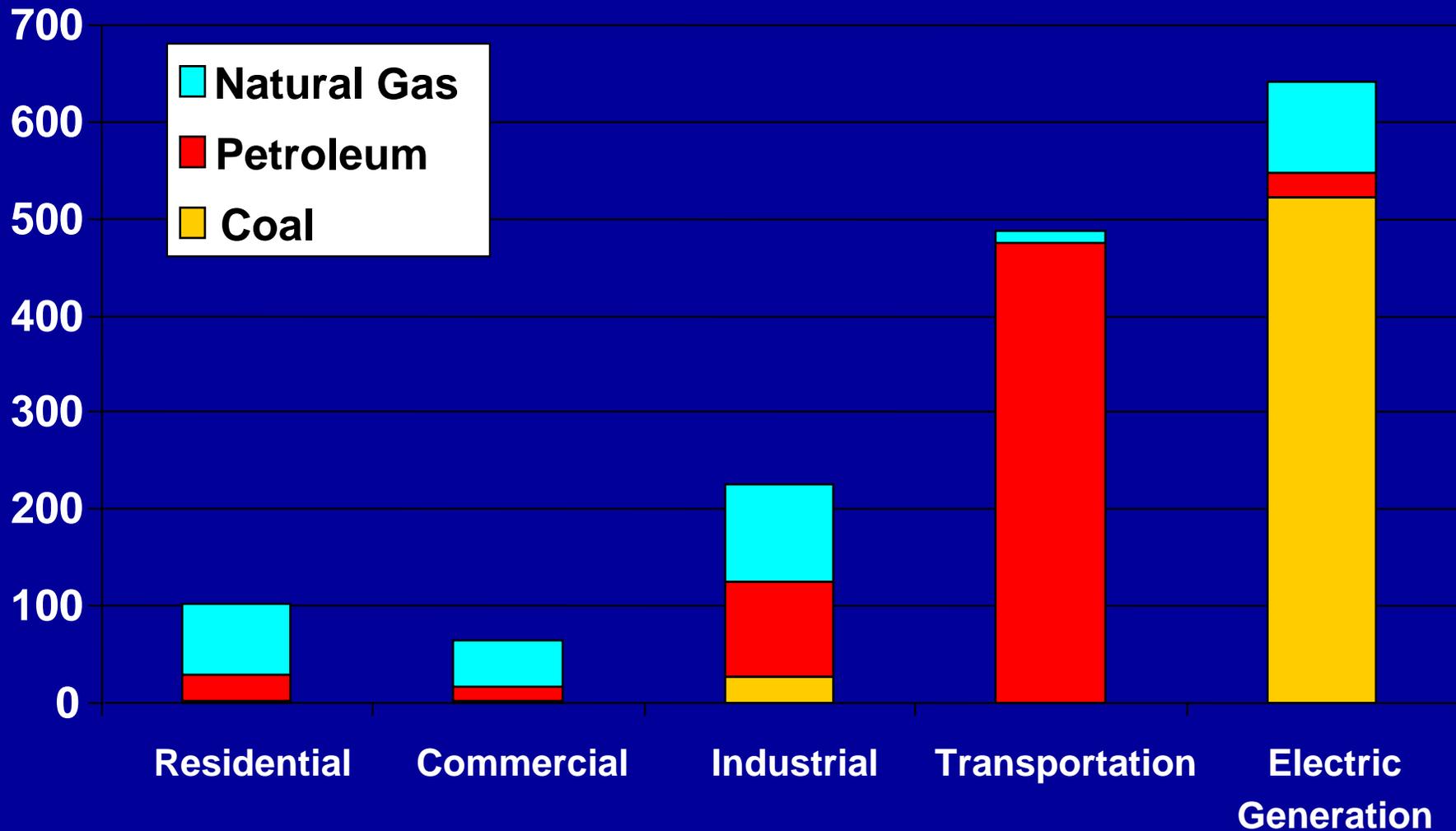
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# IPCC 3rd Assessment Report (2001) – Projected Global Temperature Change



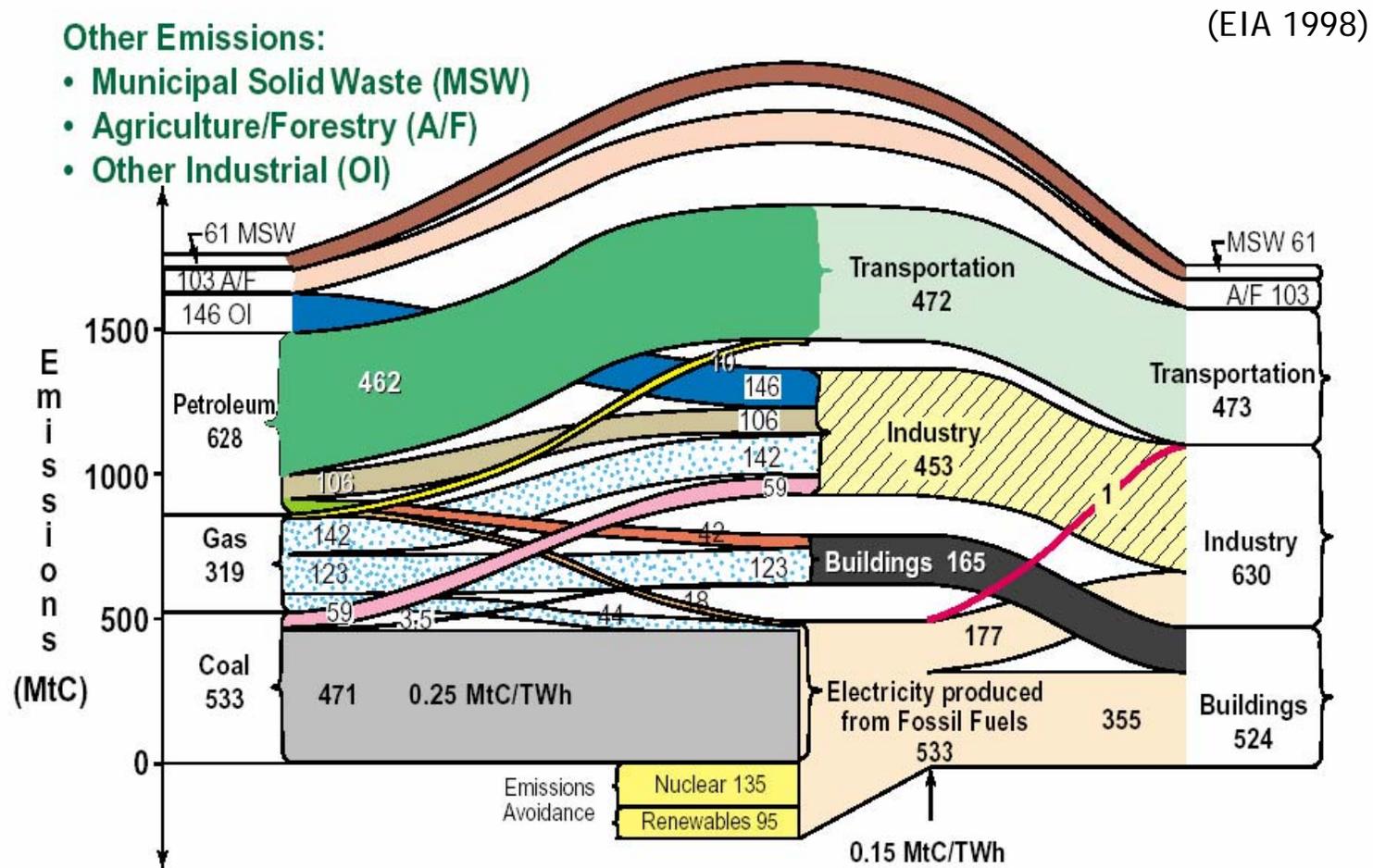
# United States CO<sub>2</sub> Emissions by Sector and Fuels 2000

Millions of metric tons per year carbon equivalent

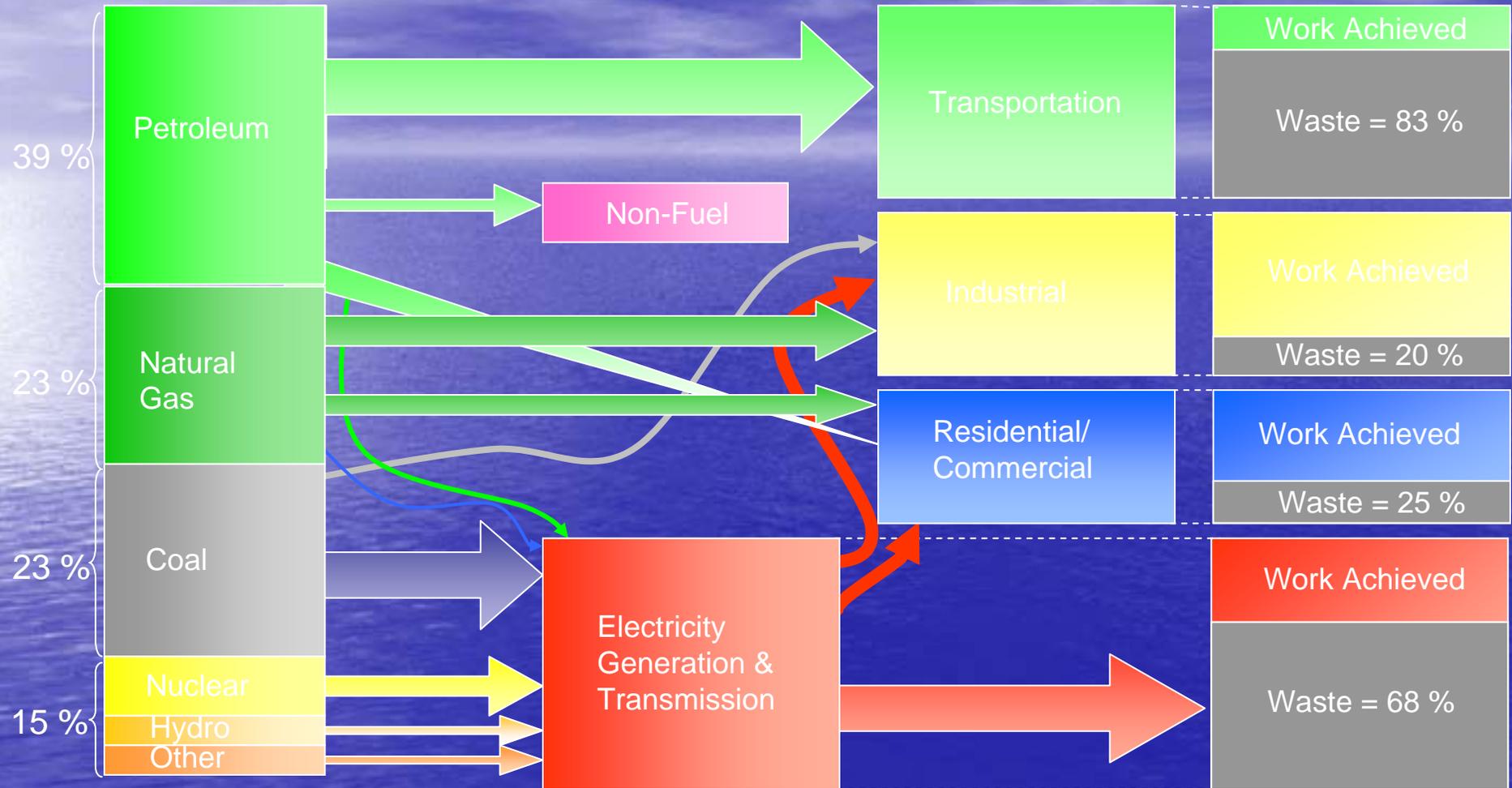


Source: U.S. EPA Inventory of Greenhouse Gas Emissions, April 2002

# Carbon Flow in the U.S. in 1995



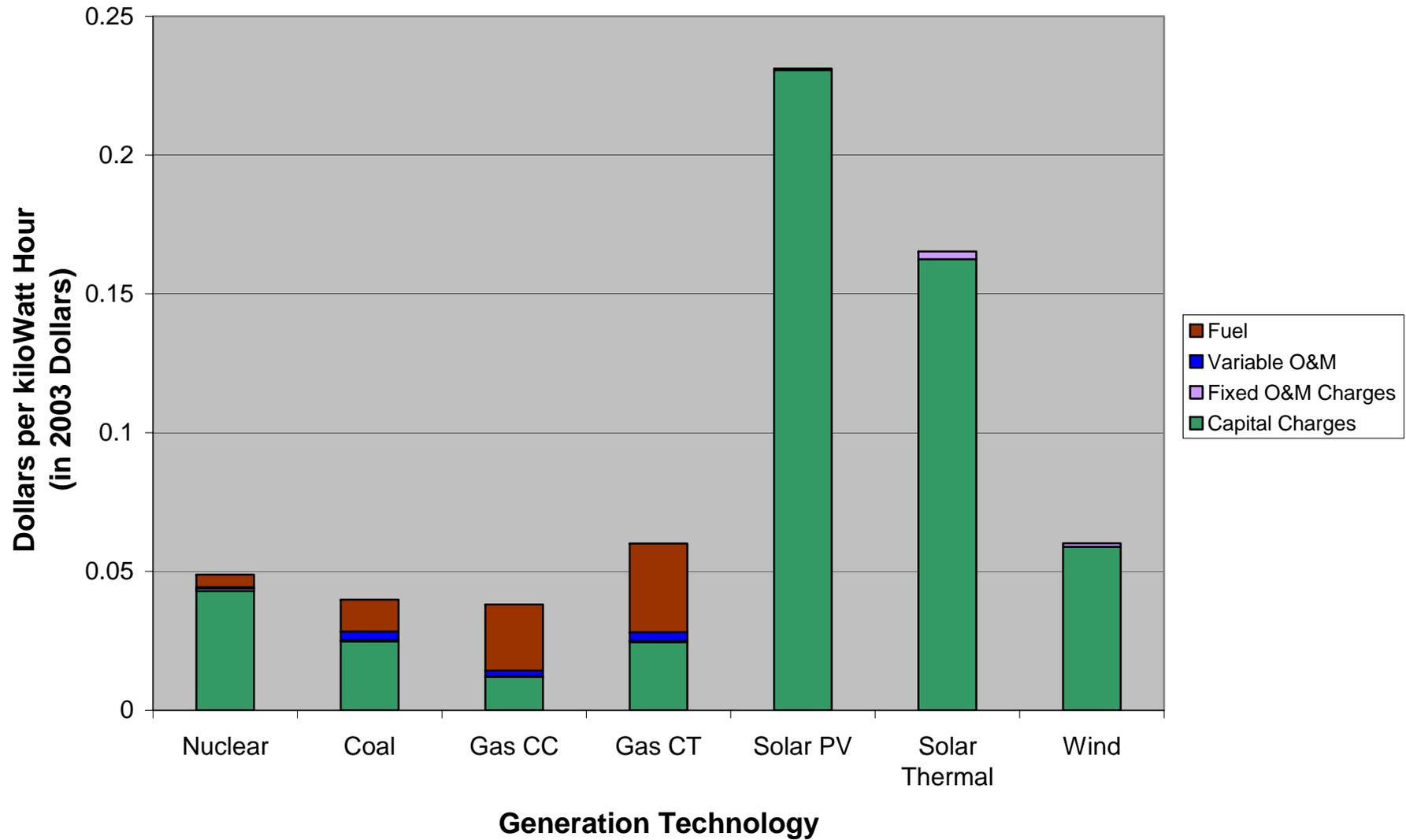
# CURRENT U.S. ENERGY FLOW



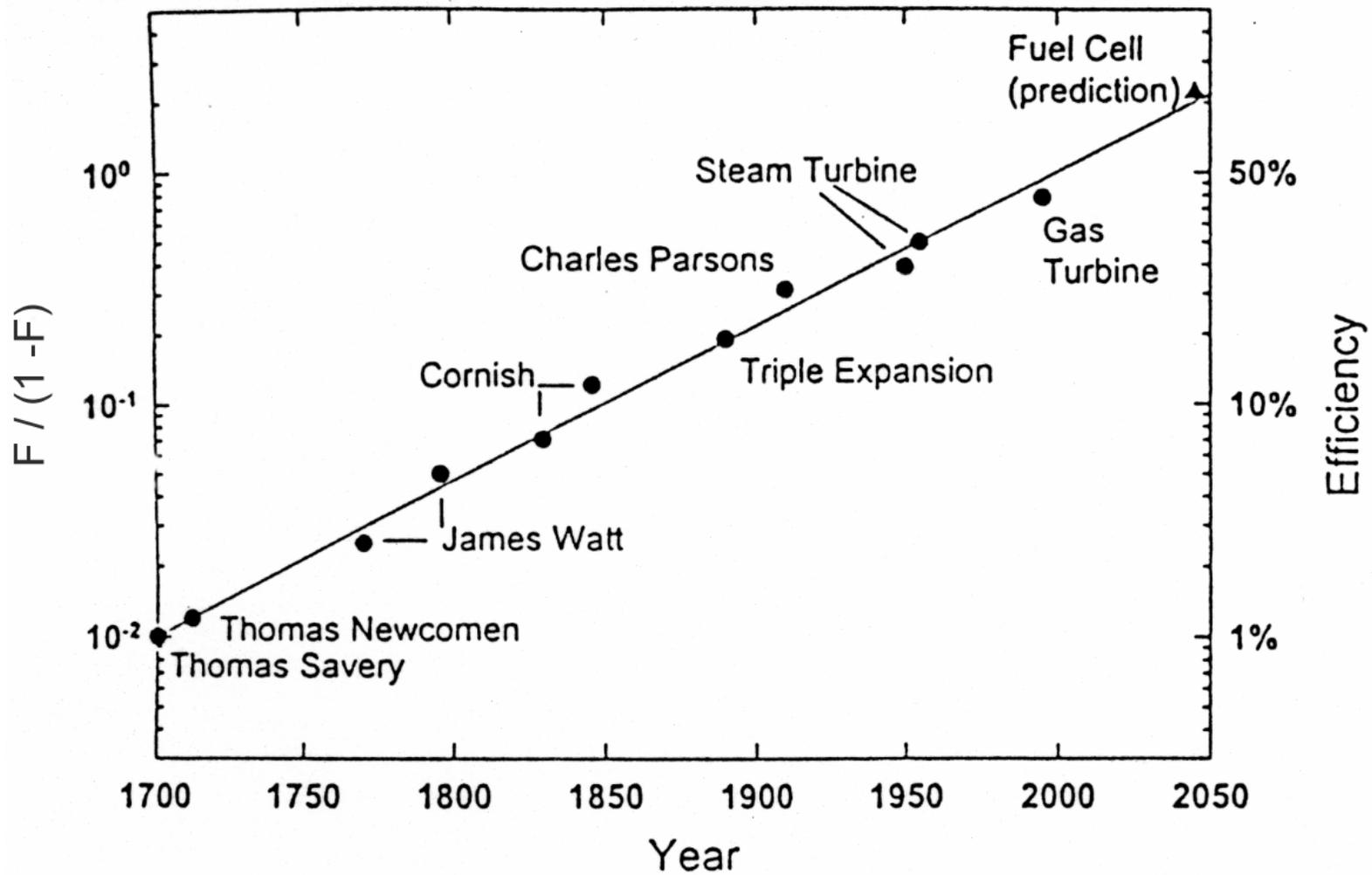
- Overall energy efficiency for U.S. is only 45%
- Transportation and power generation have greatest opportunities for improvement

Source: LLNL/DOE

# Levelized Cost Comparison for Electric Power Generation

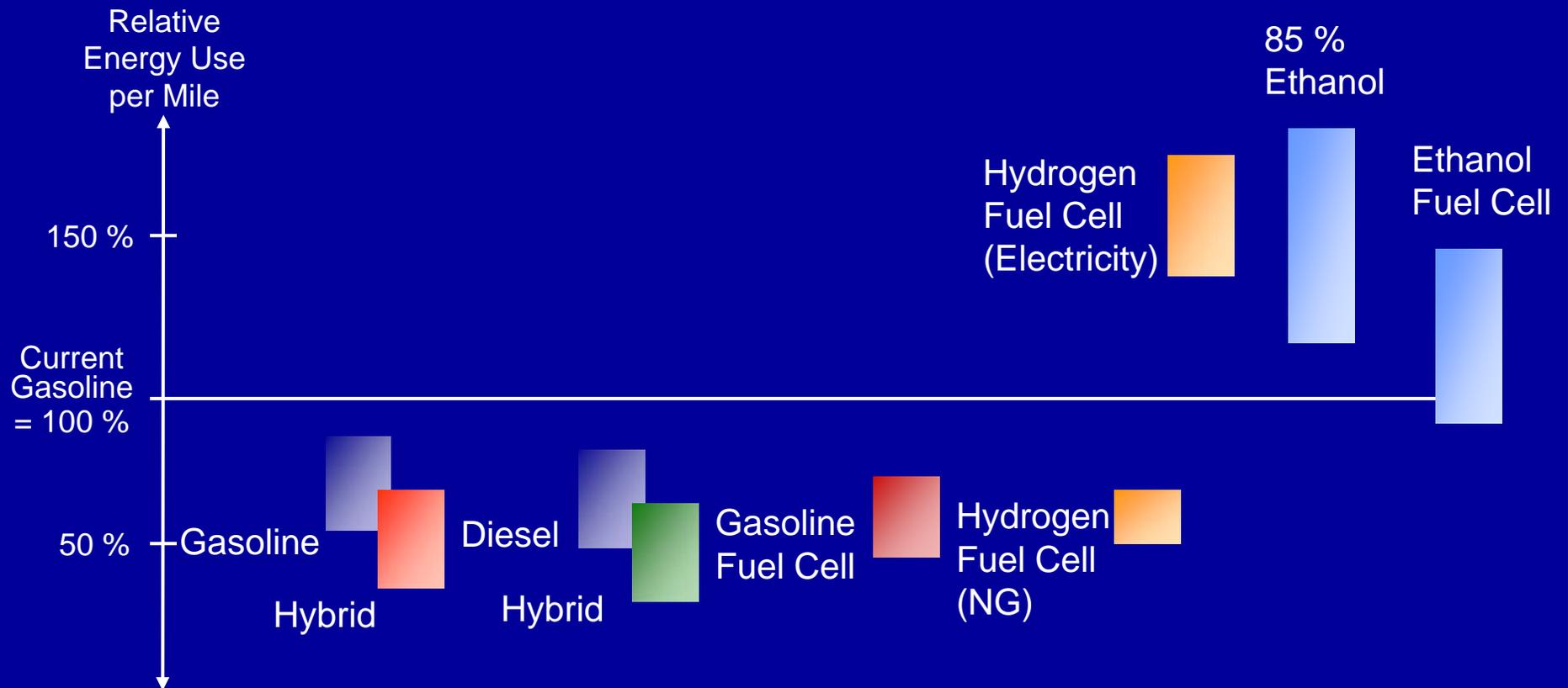


Source: Weyant, Stanford Energy Modeling Forum



After Ausubel, Marchetti

# Well to Wheel Energy Use



Source: ANL et al.