Global Climate and Energy Project

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"This is the century that human beings will have to come to grips with whether they can continue to live on this planet…"

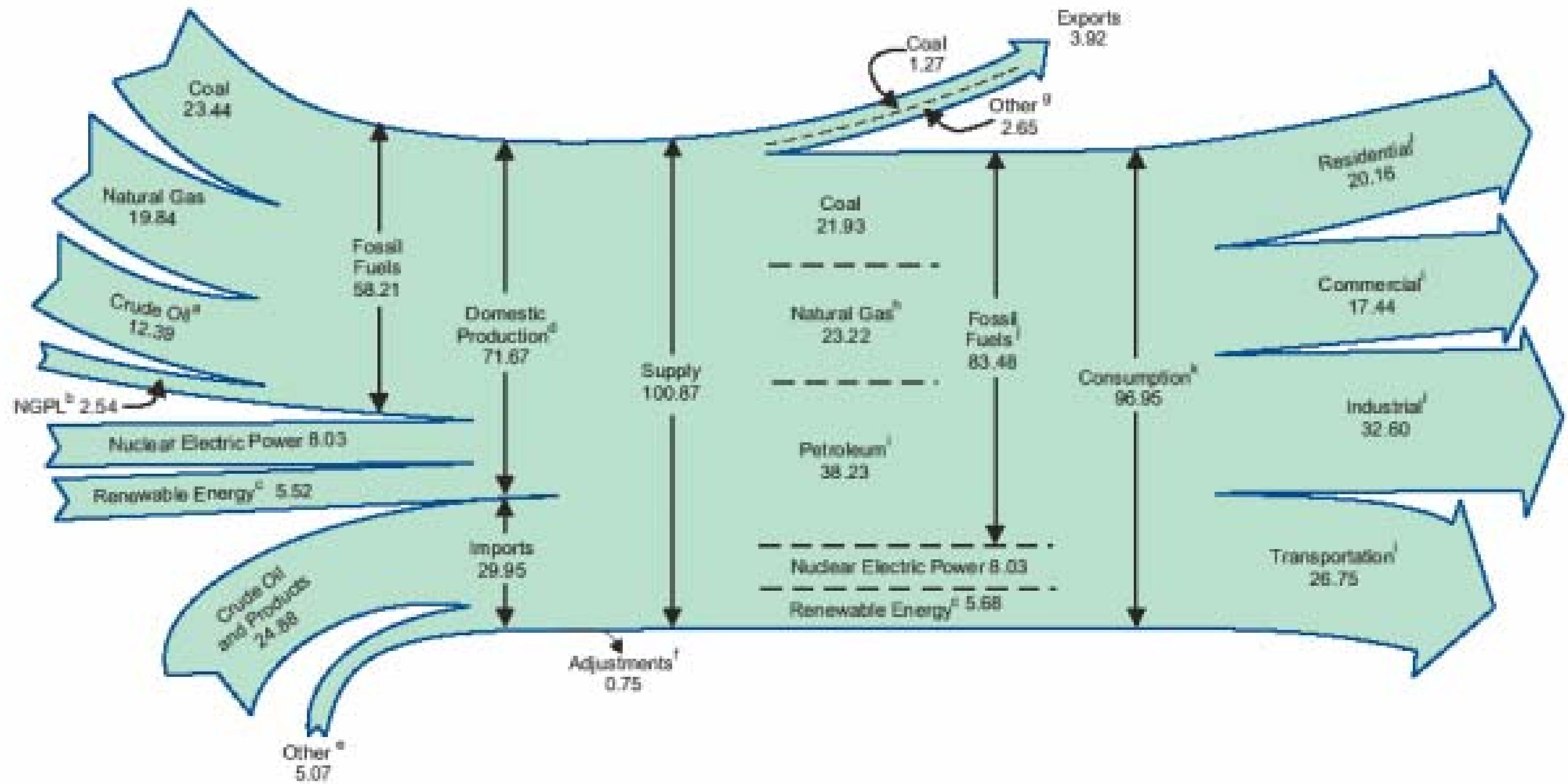
Franklin M. Orr

(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)



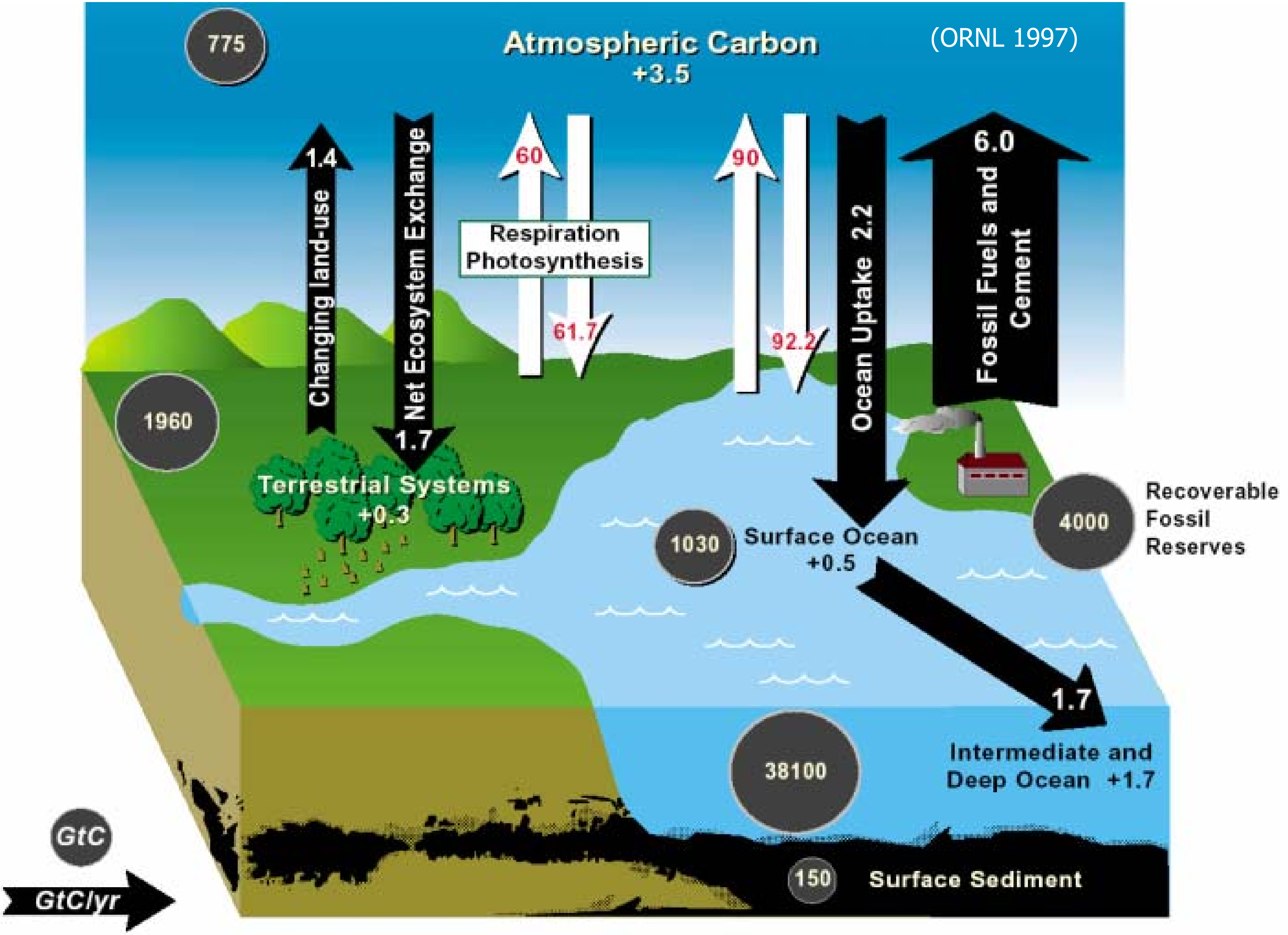
[a] Includes lease condensate.
[b] Natural gas plant liquids.
[c] Conventional hydroelectric power, wood, waste, ethanol blended into motor gasoline, geothermal, solar, and wind.
[d] Includes -0.09 quadrillion Btu hydroelectric pumped storage.
[e] Natural gas, coal, coal coke, and electricity.
[f] Stock changes, losses, gains, miscellaneous blending components, and unaccounted-for supply.
[g] Crude oil, petroleum products, natural gas, electricity, and coal coke.
[h] Includes supplemental gaseous fuels.
[i] Petroleum products, including natural gas plant liquids.
[j] Includes, in quadrillion Btu, 0.04 coal coke net imports and 0.05 electricity net imports from fossil fuels.
[k] 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.
[l] 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.


(ORNL 1997)
775
Atmospheric Carbon
+3.5
1.4
Changing land-use
Net Ecosystem Exchange
1.7
60
Respiration
Photosynthesis
61.7
90
92.2
Ocean Uptake 2.2
6.0
Fossil Fuels and Cement
1960
Terrestrial Systems
+0.3
1030
Surface Ocean
+0.5
4000
Recoverable Fossil Reserves
1.7
38100
Intermediate and Deep Ocean +1.7
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.

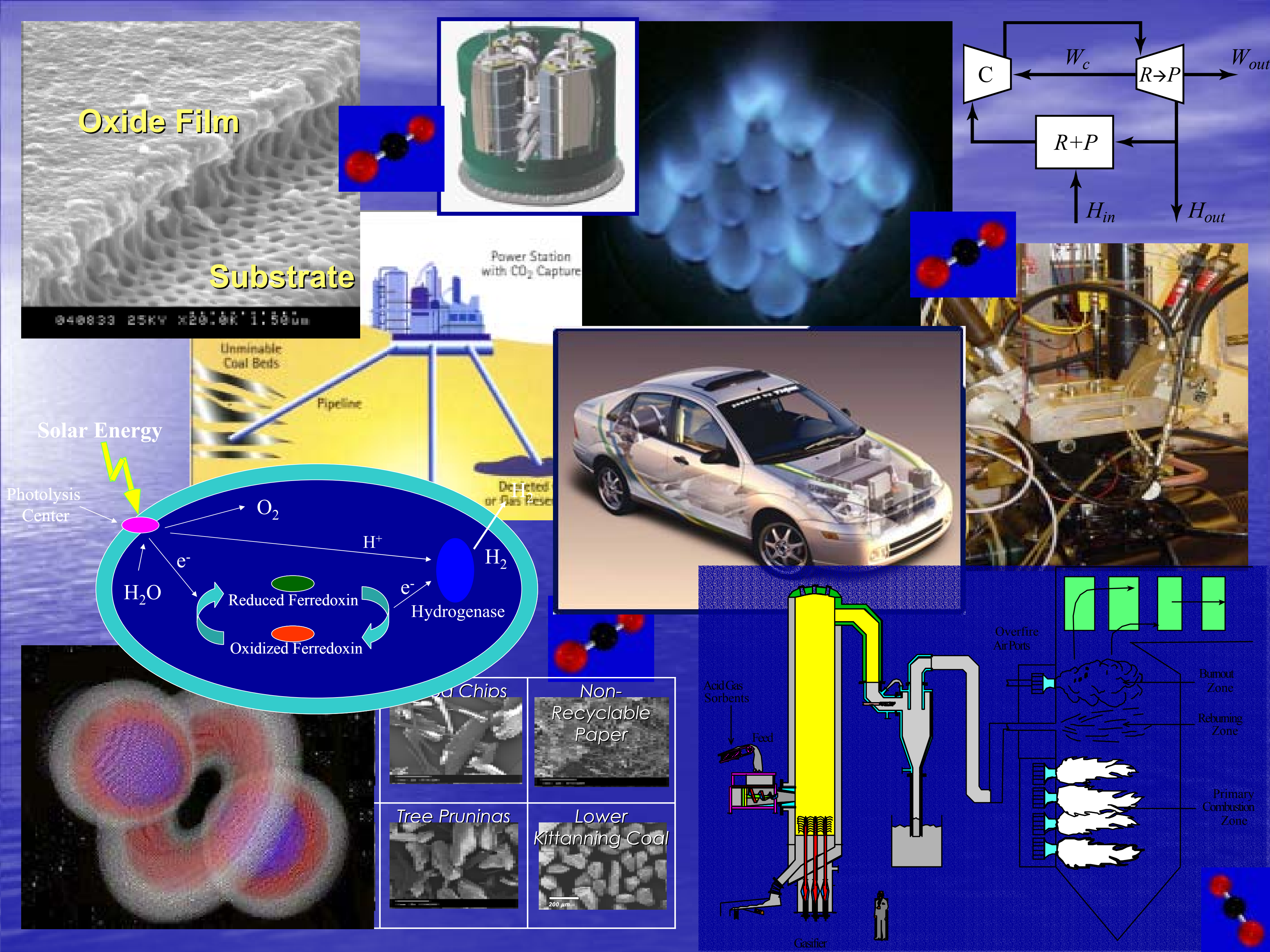
Uncertainty

- 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

GCEP

- 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.



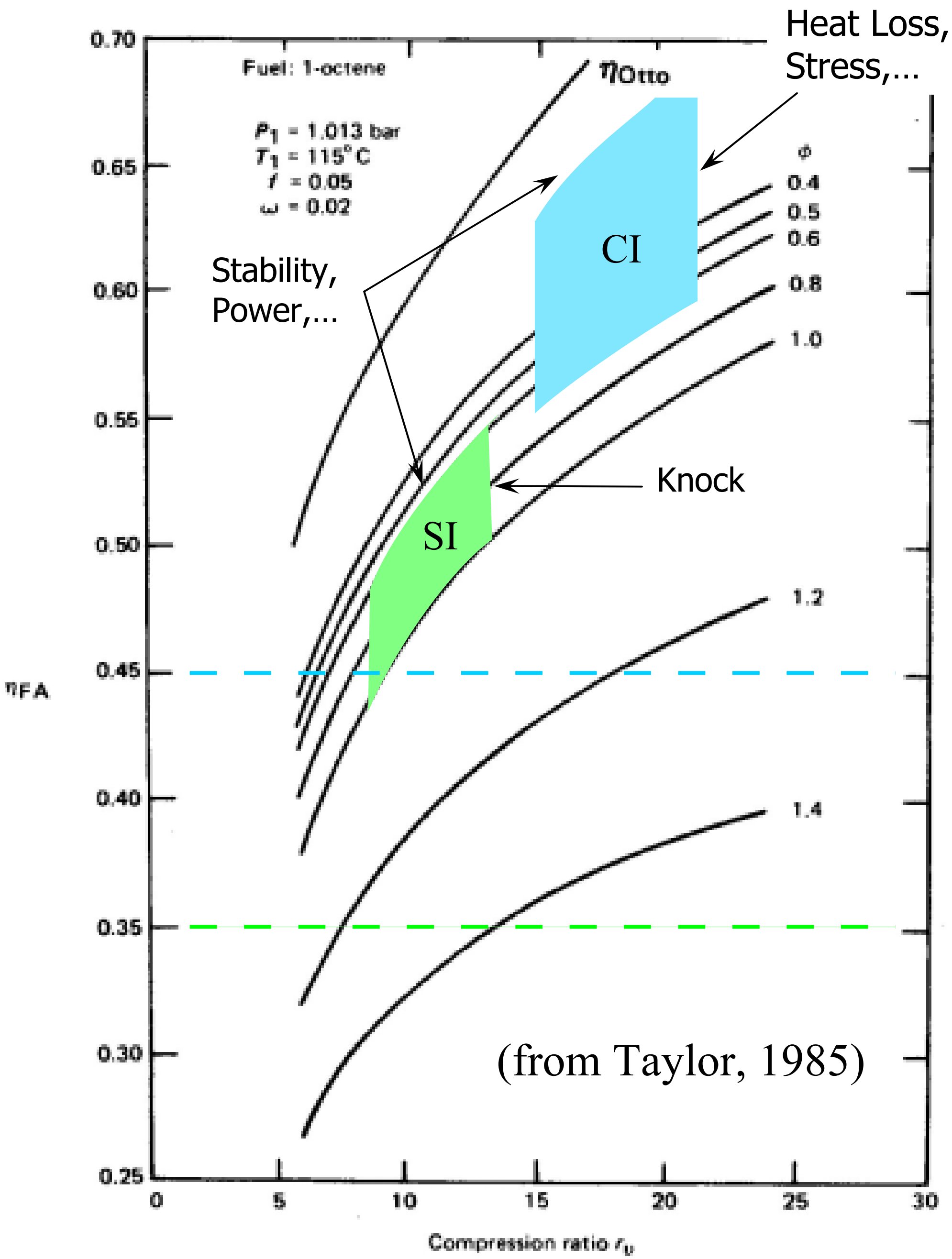
Oxide Film
Substrate
040833 25KV x20.0K 1.50um
Power Station with CO_2 Capture
Unminable Coal Beds
Pipeline
Depleted or Gas Reser
C
W_c
R→P
W_{out}
R+P
H_{in}
H_{out}
Solar Energy
Photolysis Center
O_2
H^+
e^-
H_2O
Reduced Ferredoxin
Oxidized Ferredoxin
Hydrogenase
H_2
Non-Recyclable Paper
Tree Prunings
Lower Kittanning Coal
200 µm
Overfire Air Ports
Burnout Zone
Reburning Zone
Primary Combustion Zone
Acid Gas Sorbents
Feed
Gasifier

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

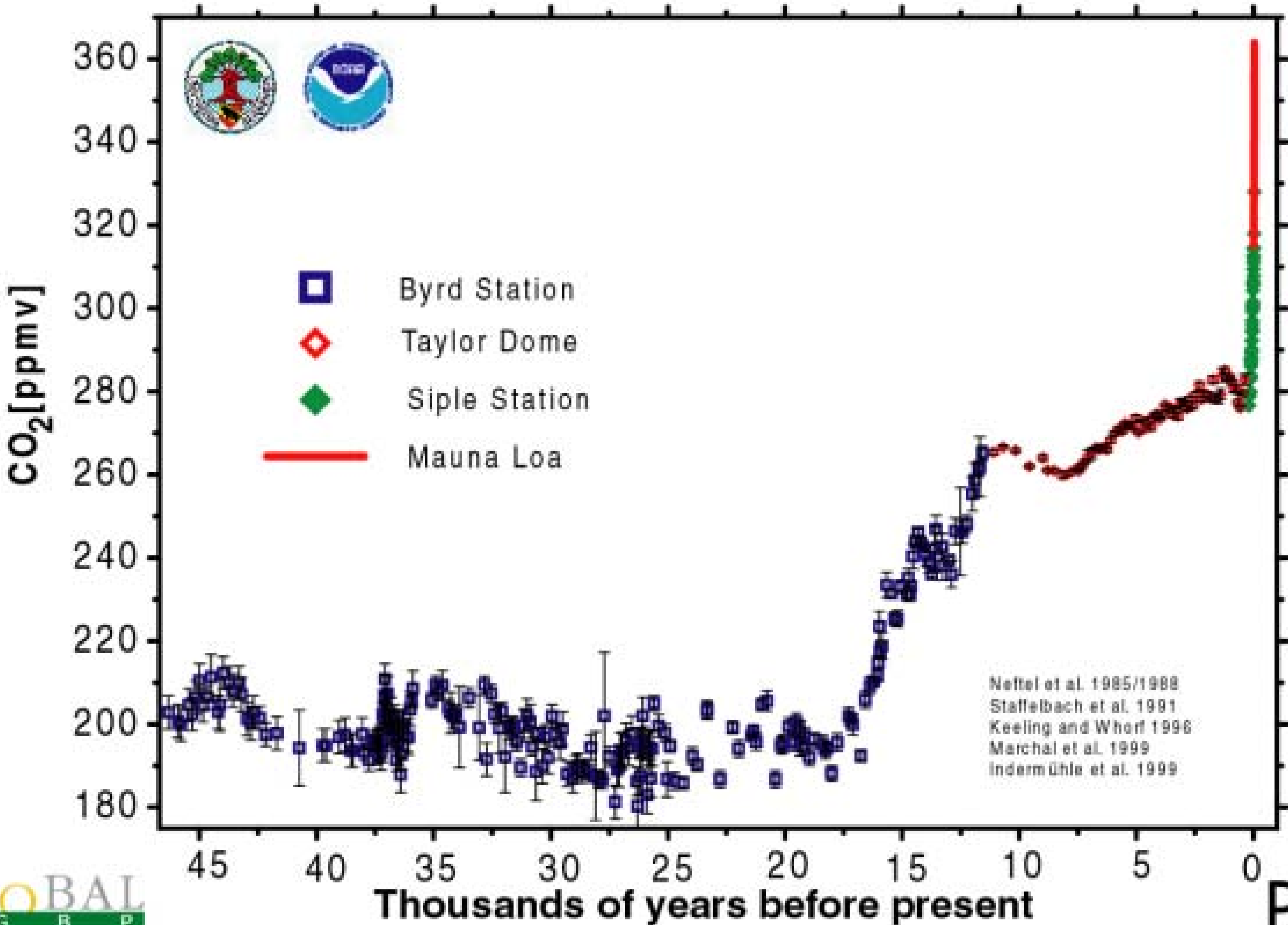
- EGR, Injection Control…
- HCCI…
- Aftertreatment…
- Other…

Carbon Emissions

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

Atmospheric CO_2 Concentration

Last Glacial Maximum to present

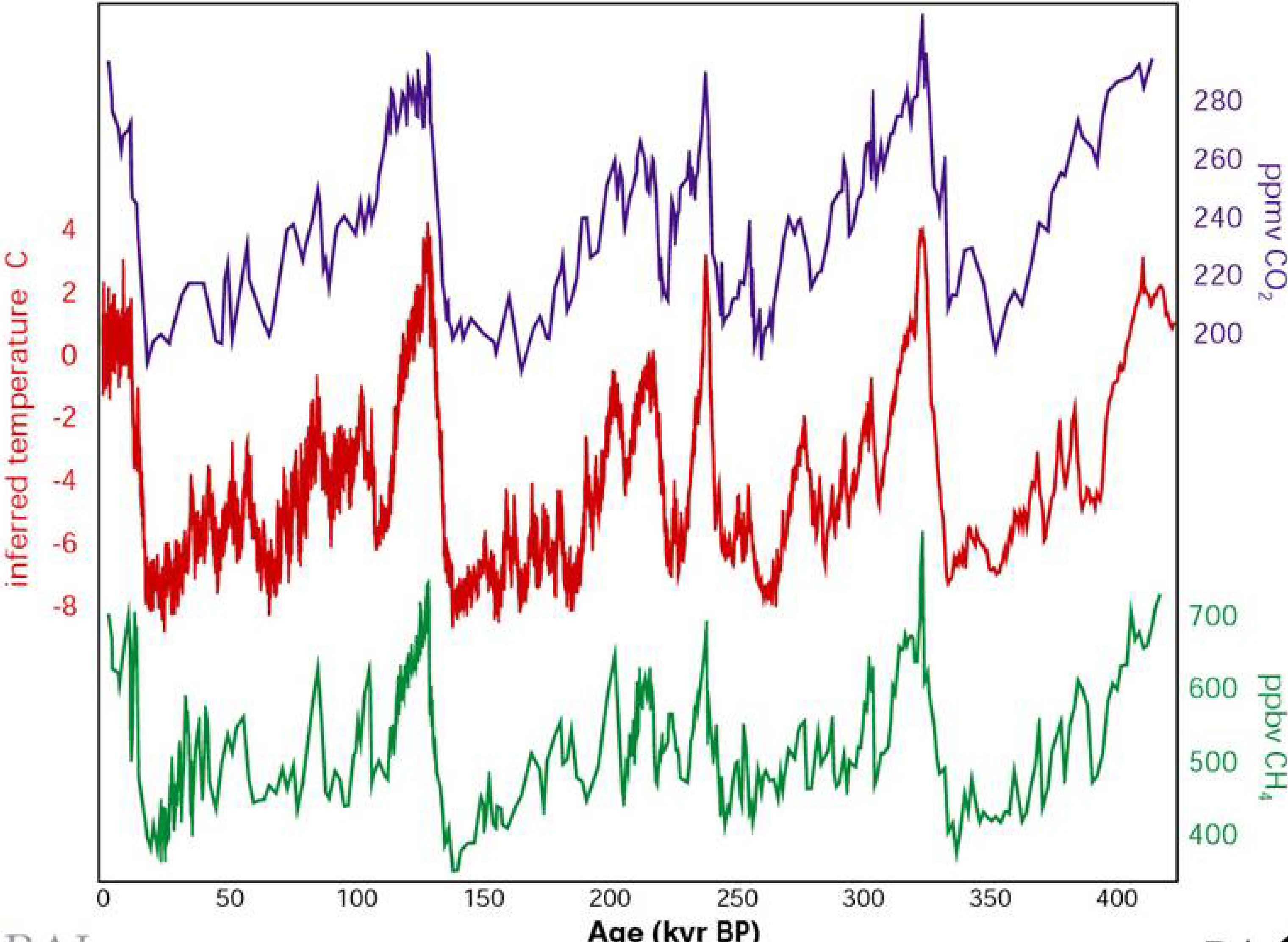


GLOBAL IGBP CHANGE

Adapted from: http://www.climate.unibe.ch/gallery_co2.html

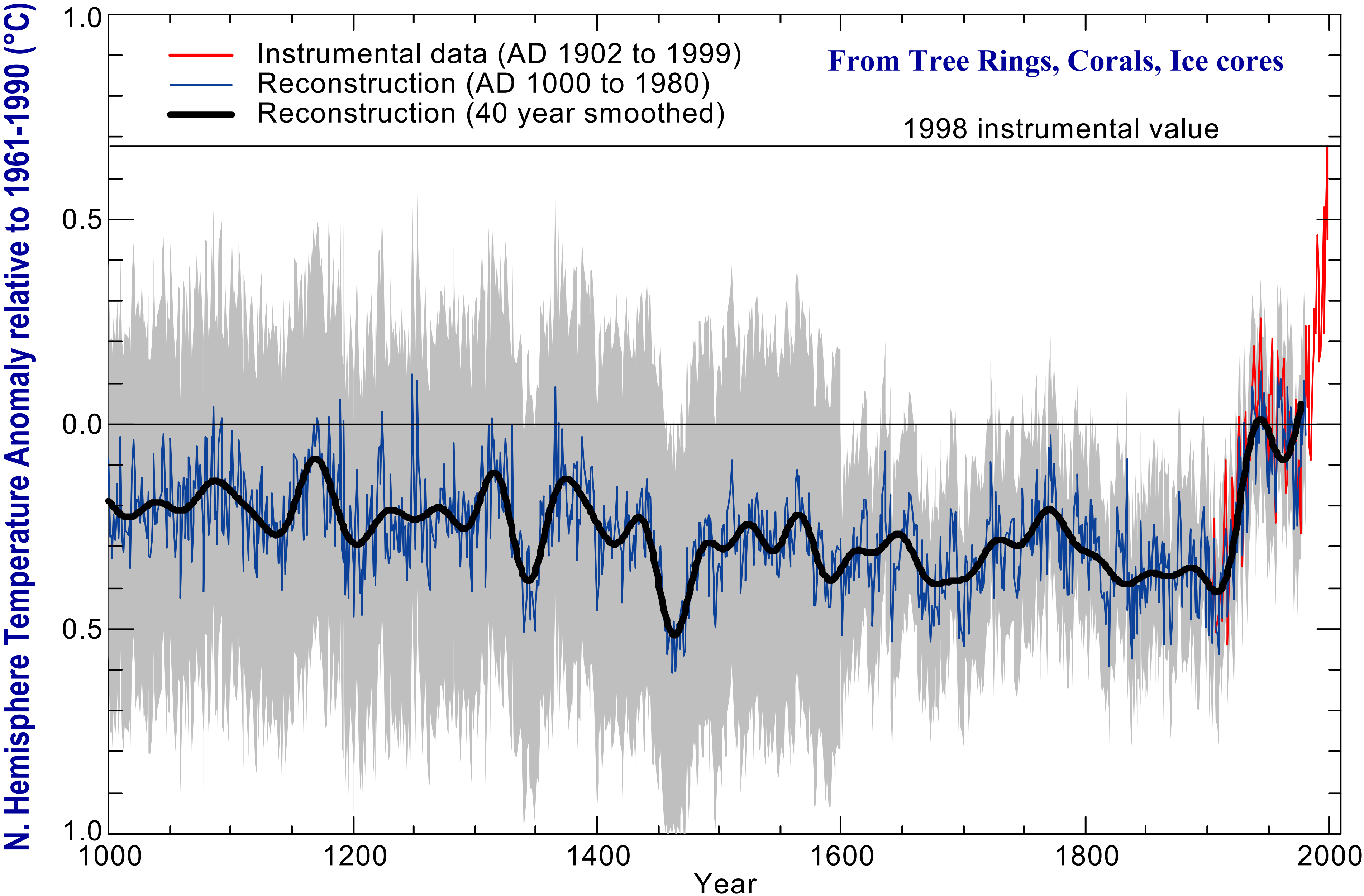
PAGES PAST GLOBAL CHANGES

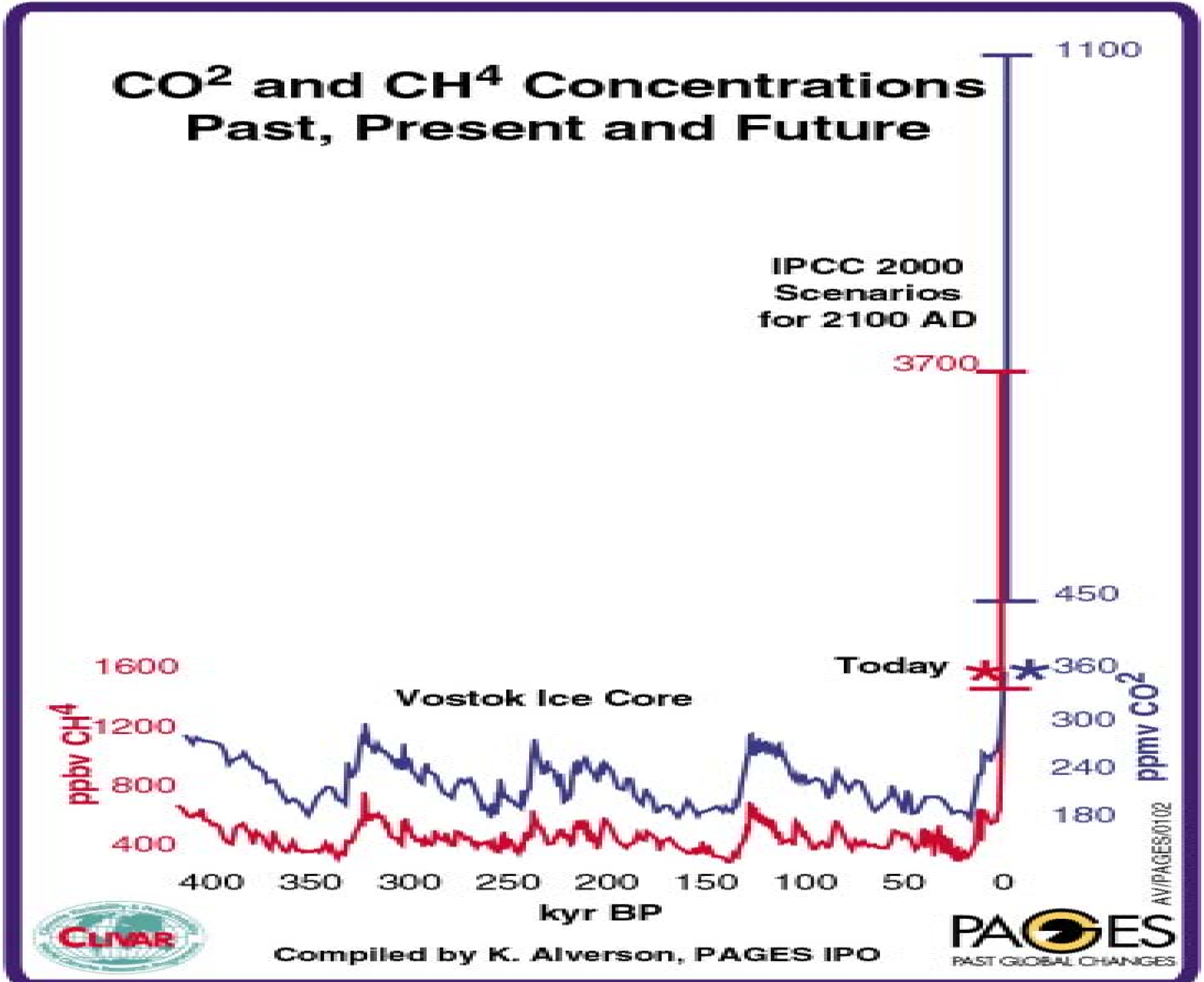
4 glacial cycles recorded in the Vostok ice core



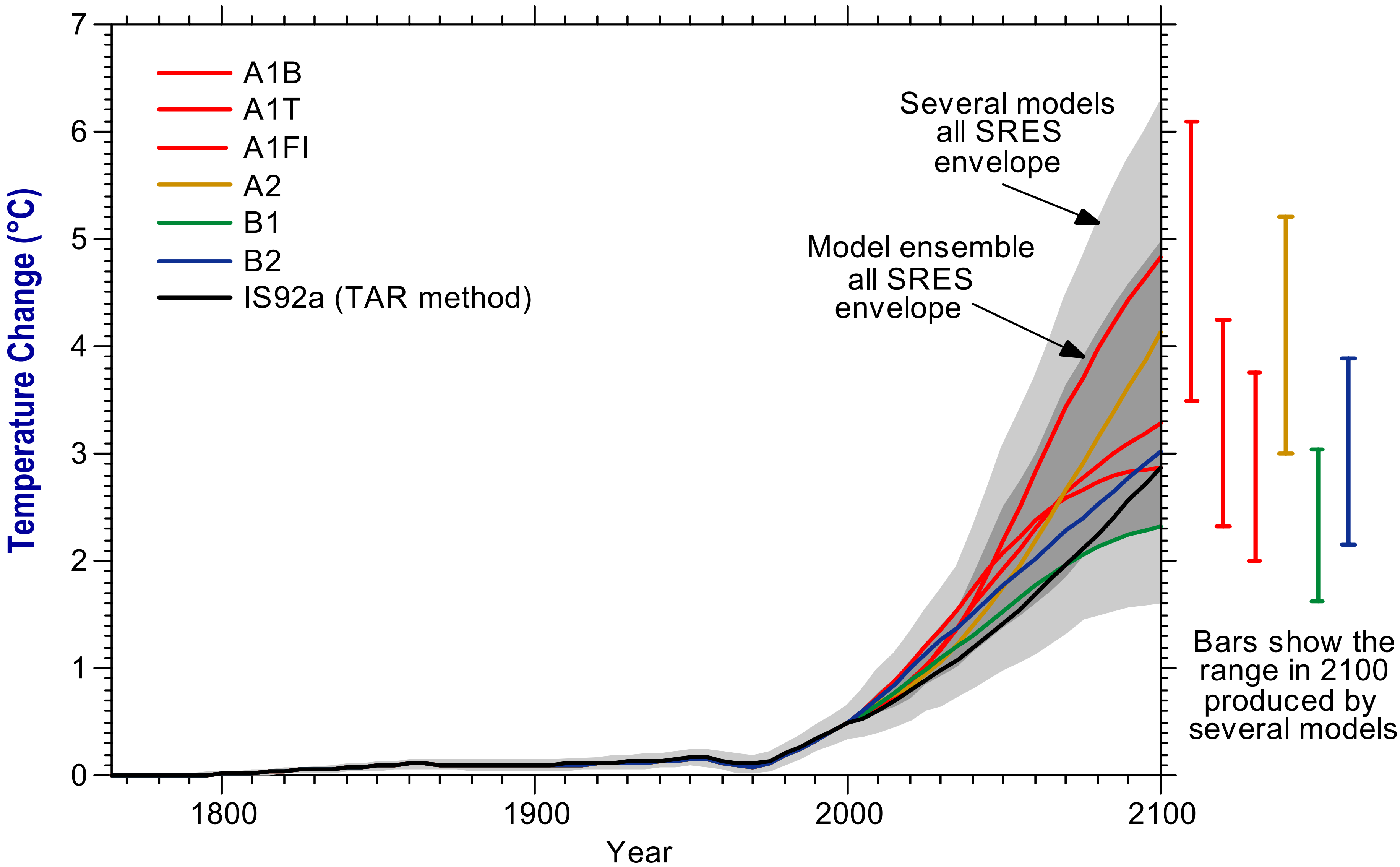
J.R. Petit et al., *Nature,* **399**, 429–36, 1999.

IPCC 3rd Assessment Report (2001)

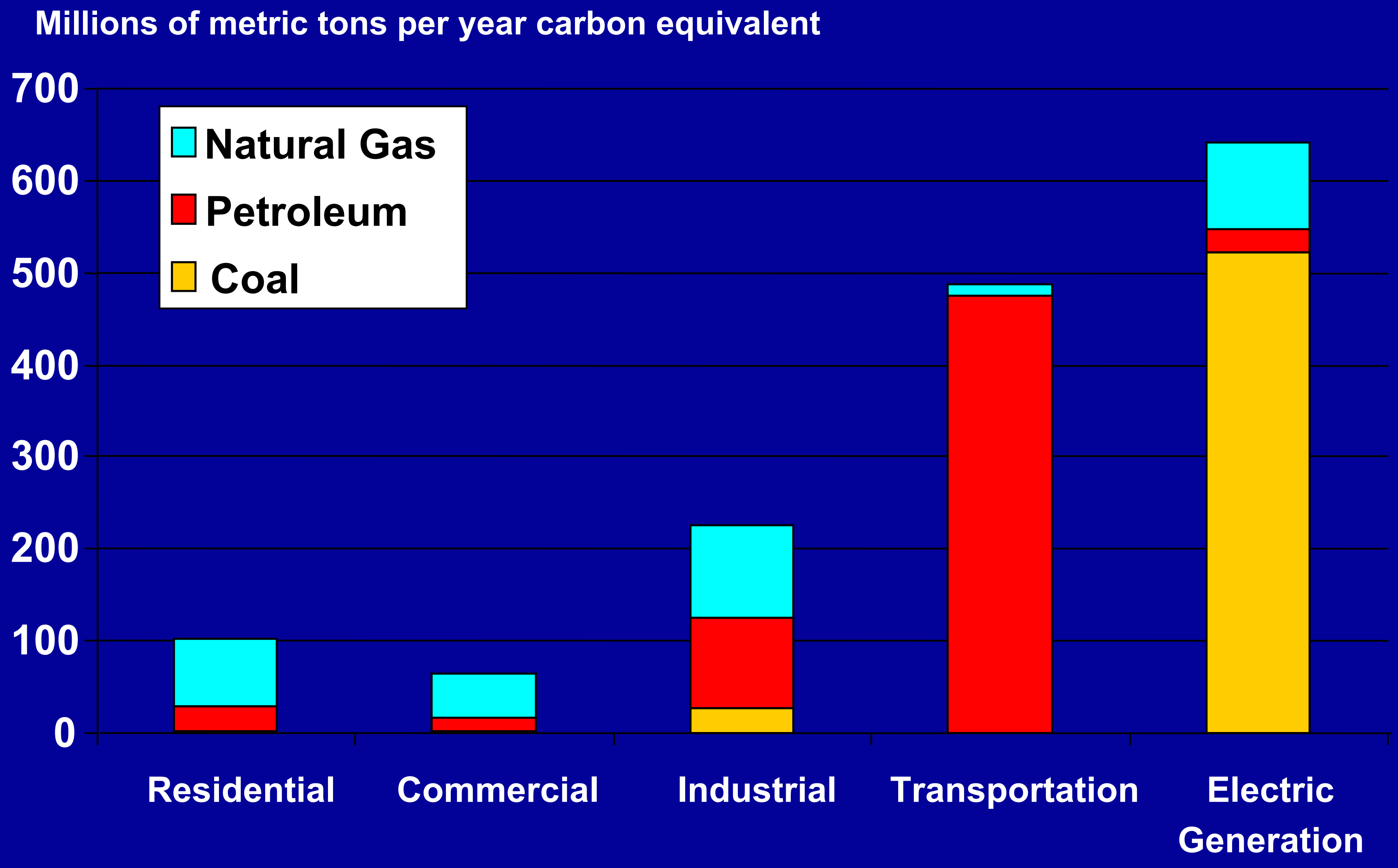



CO2 and CH4 Concentrations
Past, Present and Future
1100
IPCC 2000
Scenarios
for 2100 AD
3700
450
Today
1600
360
Vostok Ice Core
ppbv CH4
1200
300
ppmv CO2
800
240
180
400
AV/PAGES/0102
400 350 300 250 200 150 100 50 0
kyr BP
CLIVAR
Compiled by K. Alverson, PAGES IPO
PAGES
PAST GLOBAL CHANGES

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



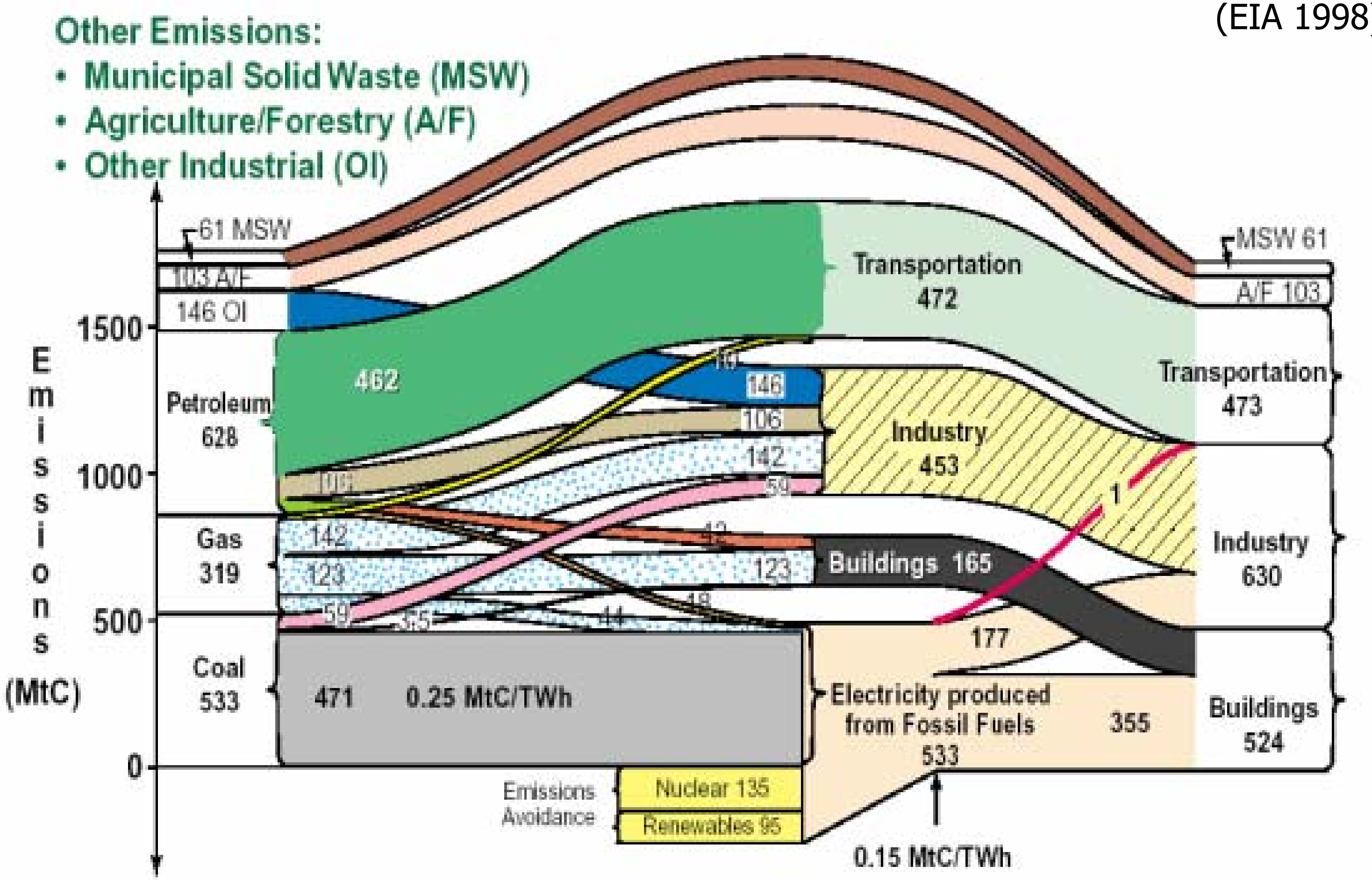
United States CO_2 Emissions by Sector and Fuels 2000



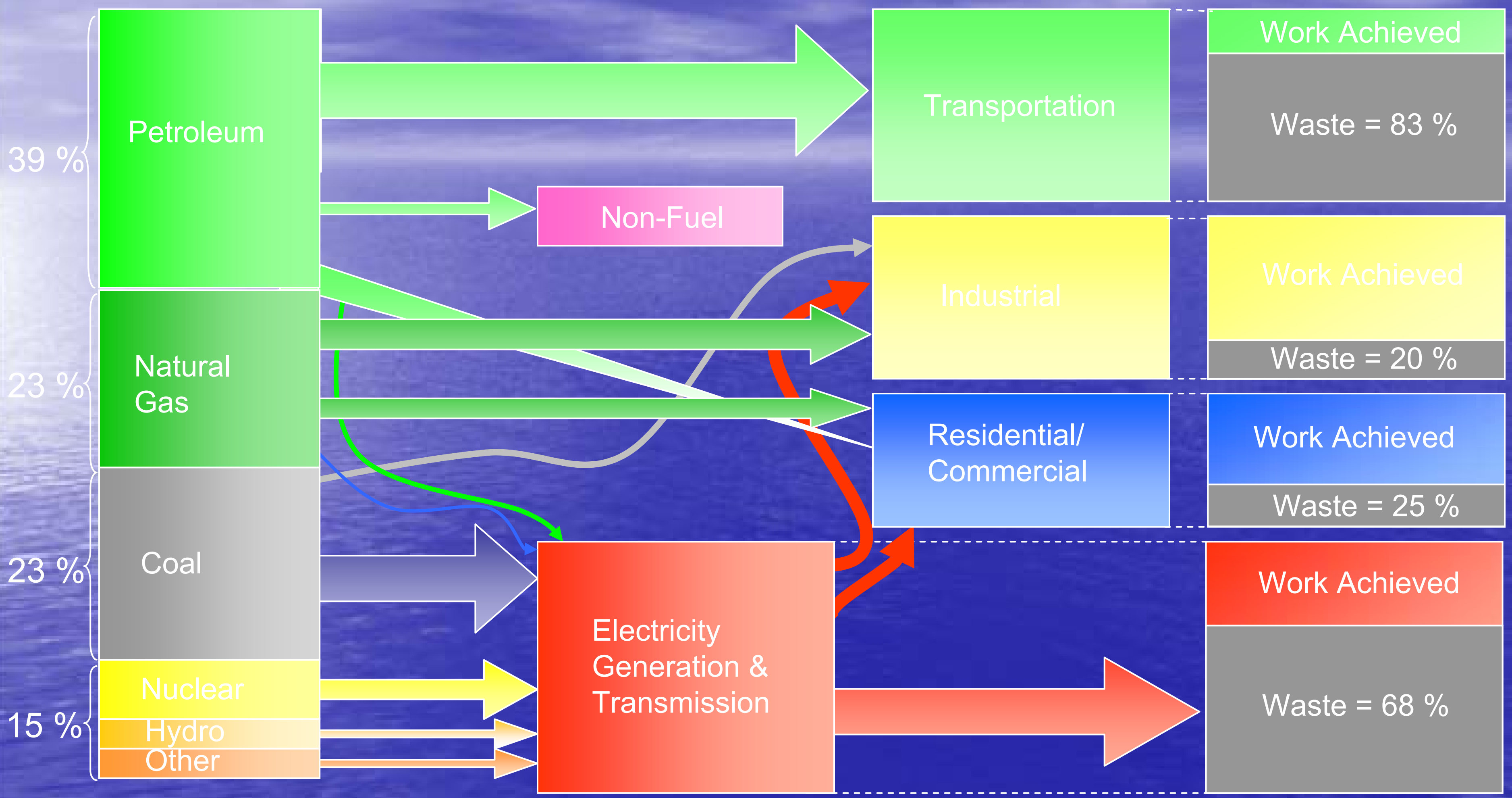
Source: U.S. EPA Inventory of Greenhouse Gas Emissions, April 2002

Carbon Flow in the U.S. in 1995

(EIA 1998)



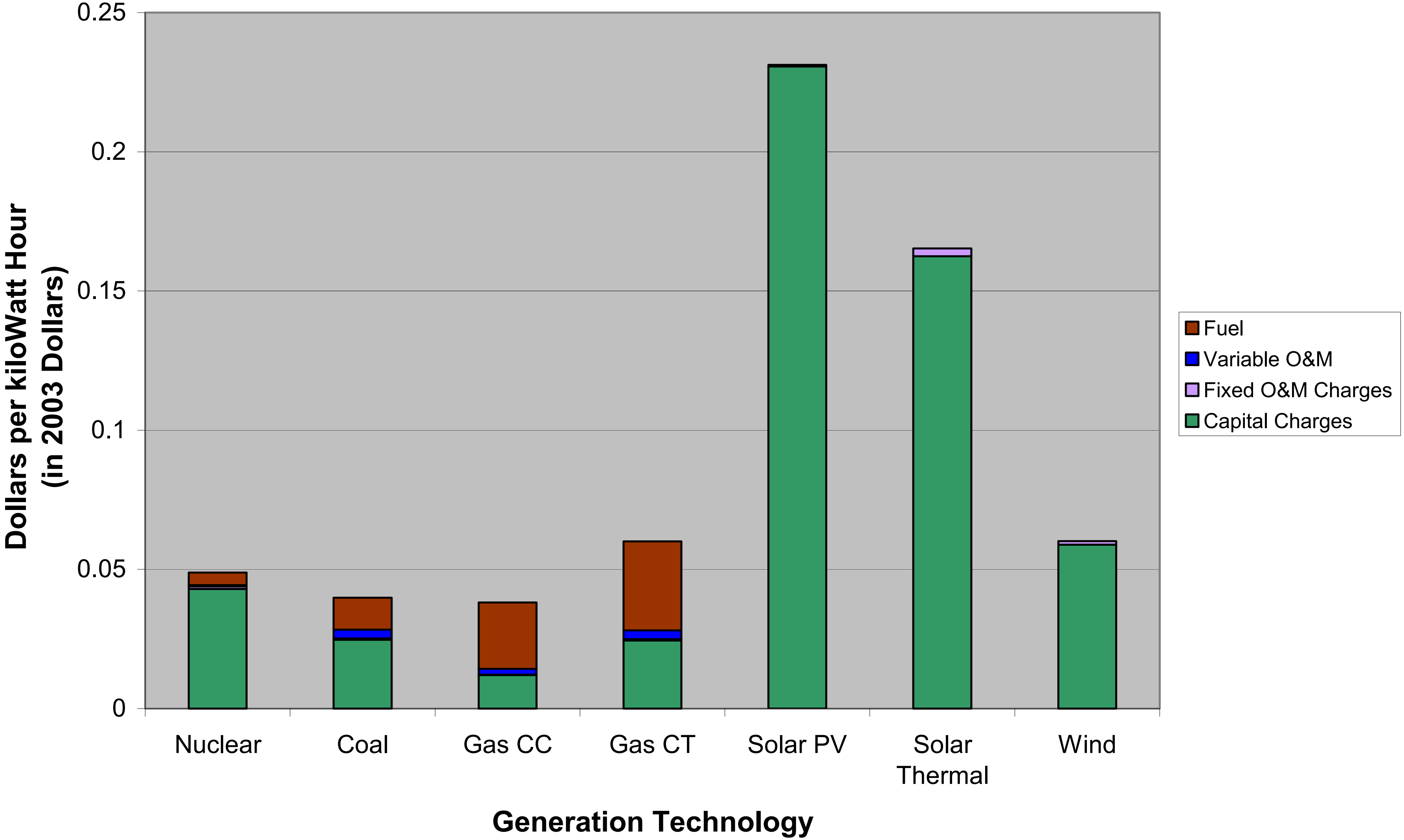
CURRENT U.S. ENERGY FLOW



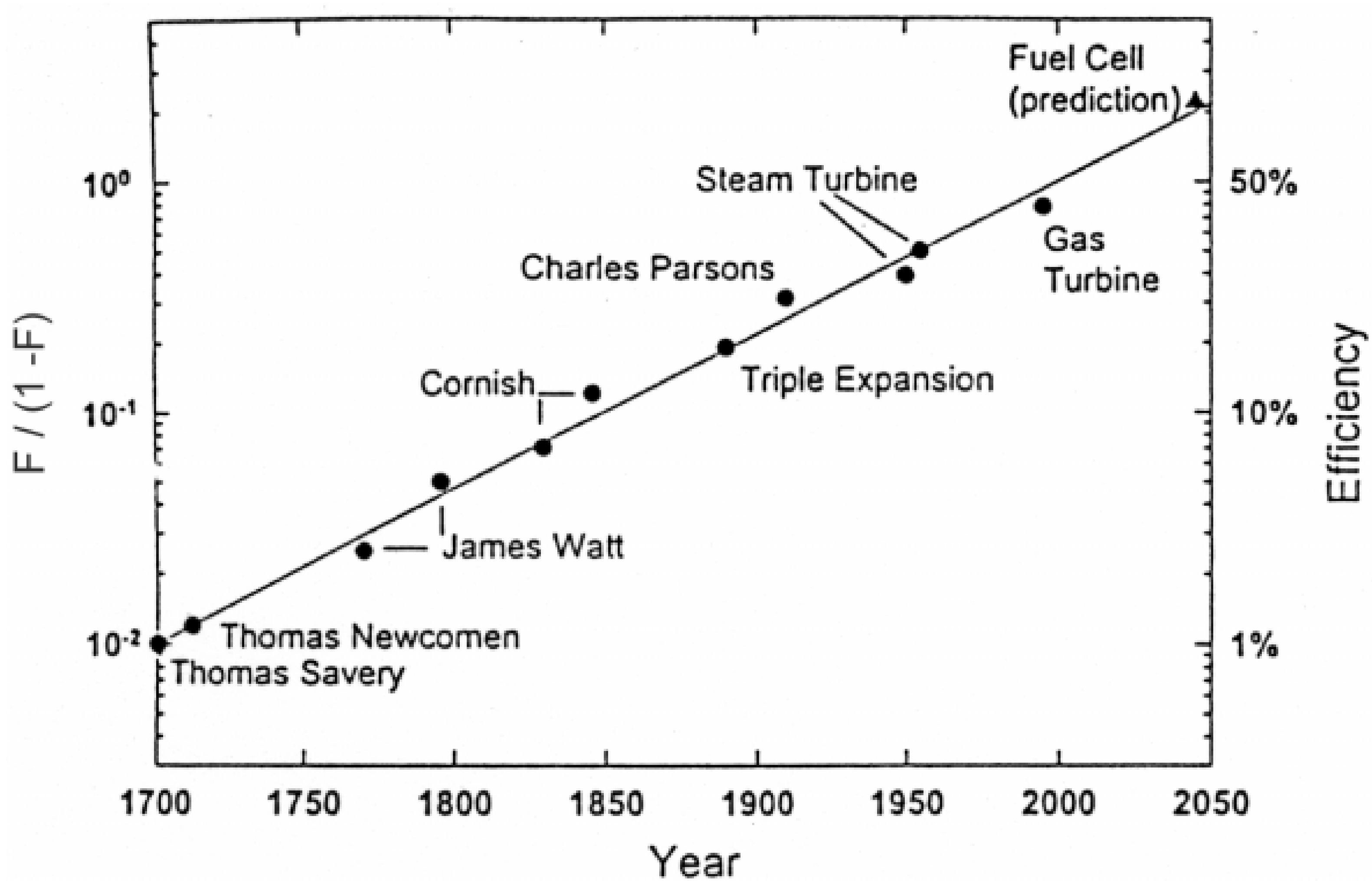
- **Overall energy efficiency for U.S. is only 45%**
- **Transportation and power generation have greatest opportunities for improvement**

Source: LLNL/DOE

Levelized Cost Comparison for Electric Power Generation

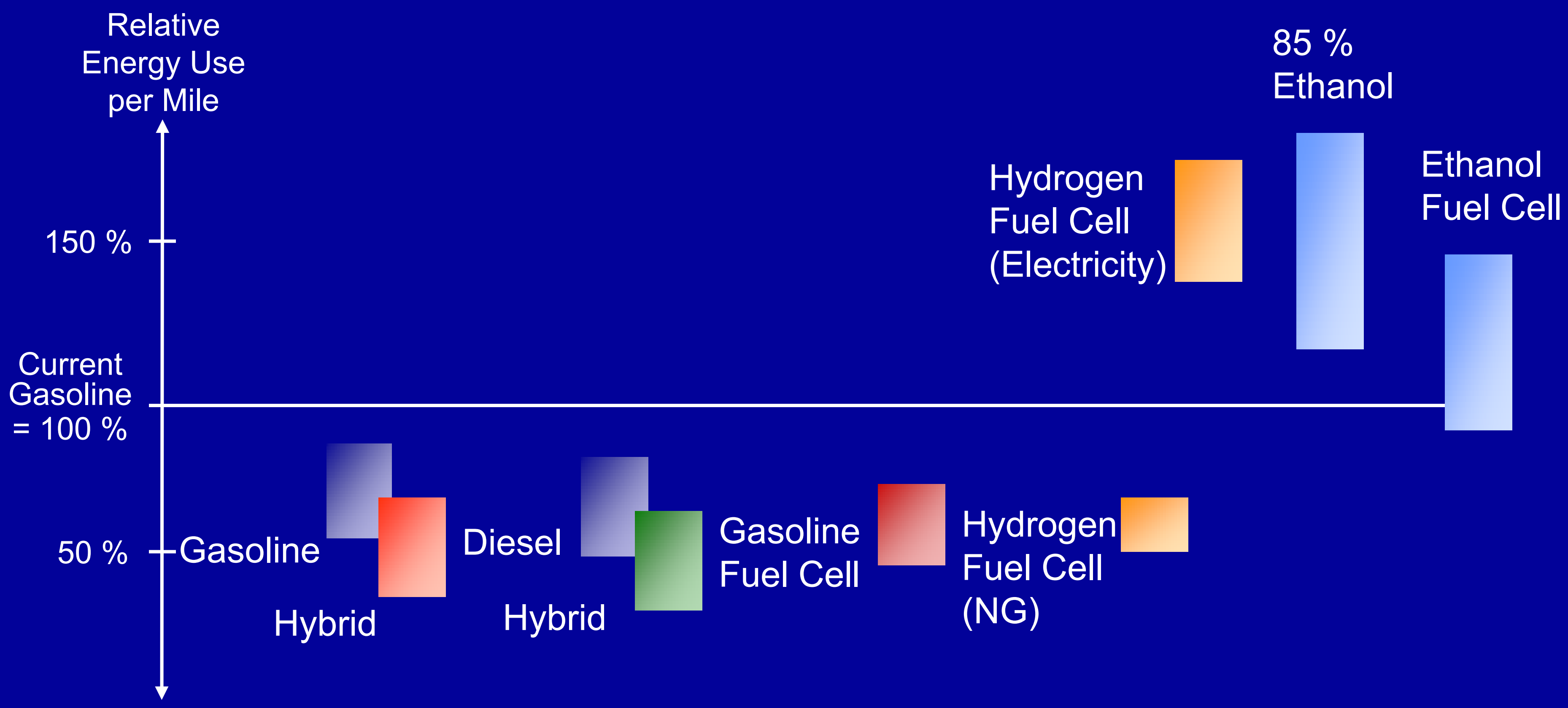


Source: Weyant, Stanford Energy Modeling Forum



After Ausubel, Marchetti

WELL TO WHEEL ENERGY USE



Source: ANL et al.