Title: Out of Gas

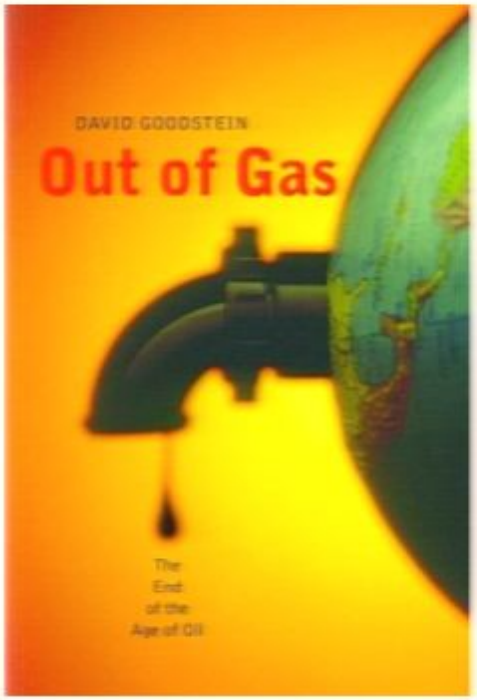
Date: Feb 05, 2009 04:00 PM

URL: http://pirsa.org/09020006

Abstract: The world will start to run out of cheap, conventionally produced oil much sooner than most people expect, possibly within the next decade. This talk will discuss the reasoning that leads to that conclusion and the likely consequences if it is correct. It may be possible, with considerable difficulty to substitute other fossil fuels for the missing oil, but if we do that we may do irreparable damage to the Earthâ€™s climate. And even then we would start to run out of all fossil fuels, including coal, probably within this century. Can civilization survive if that happens? We will consider the possibilities.

Out of Gas

The end of the age of oil



David Goodstein

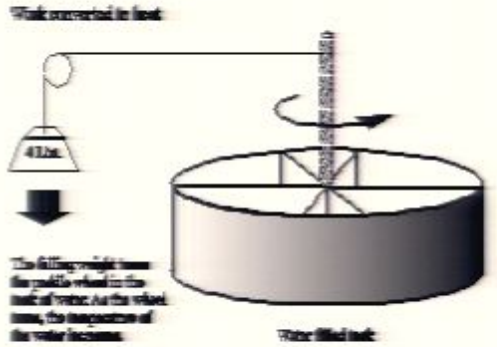
University of Waterloo, February 5, 2009

Energy Myths

- $4.00 a gallon is too much to pay for gasoline
- Oil companies produce oil.
- We must conserve energy. Otherwise we'll have an energy crisis.
- When we run out of oil, the marketplace will ensure that it's replaced by something else.
- There's enough fossil fuel in the ground to last for hundreds of years.
- Nuclear energy is dangerous.
- The greenhouse effect and global warming are bad.

A Brief History of Energy

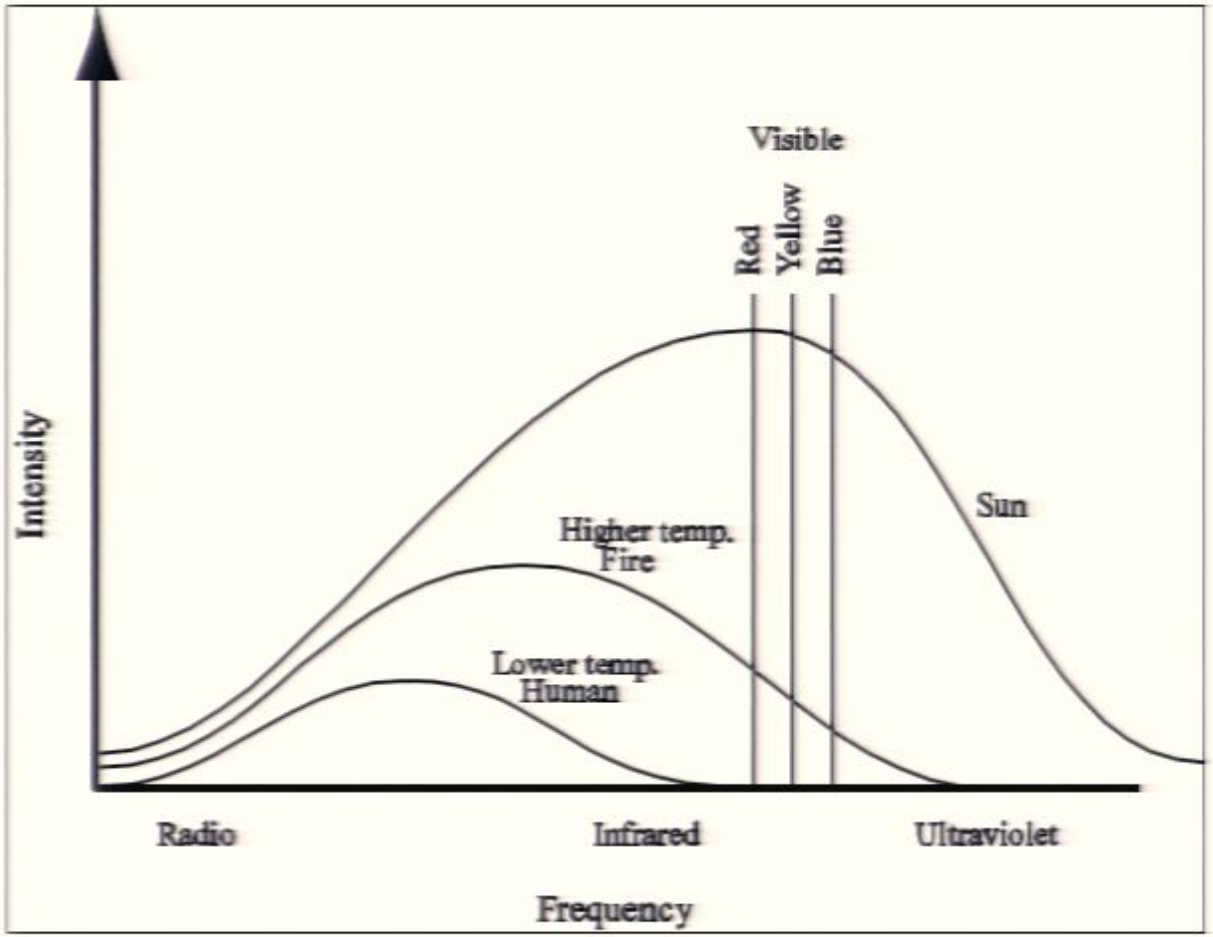
Caloric
Count Rumford (Sir Benjamin Thompson), 1753-1814
Many others
Credit
James Prescott Joule, 1818-1889



Forms of Energy

- Kinetic
  - Organized
  - Random (Temperature)
- Potential
  - Gravitational
  - Chemical
  - Nuclear
  - etc.

Thermal Radiation



The Sun-Earth System

30% reflected
70% absorbed

The Sun-Earth System

Earthrise on the Moon

30% reflected
70% absorbed

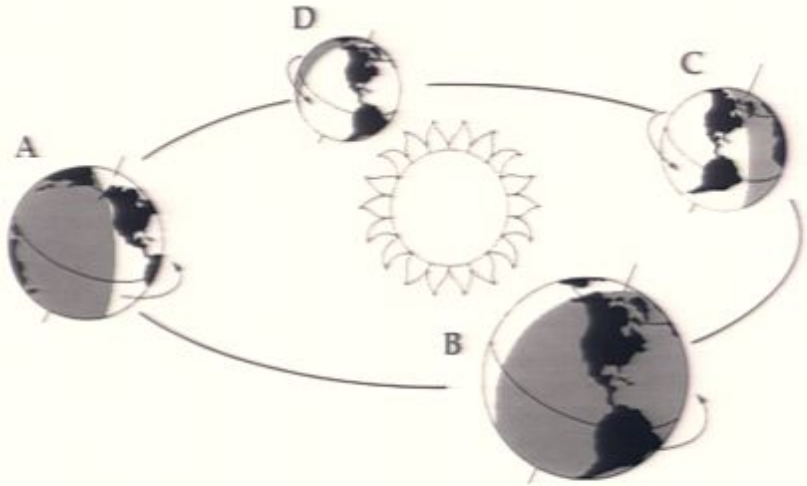
The Sun-Earth System

30% reflected
70% absorbed

$T = 255\ K = -18\ ^{o}C = 0\ ^{o}F$

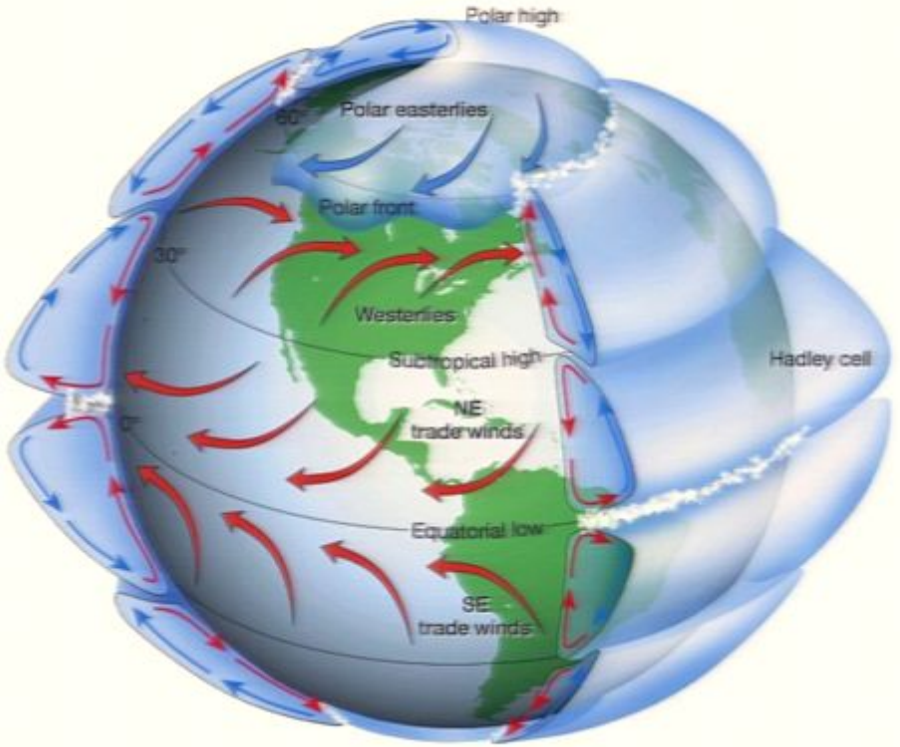
Earth's Climate

- **The tilted axis**



Earth's Climate

- The tilted axis
- The El Niño Cycle



Earth's Climate

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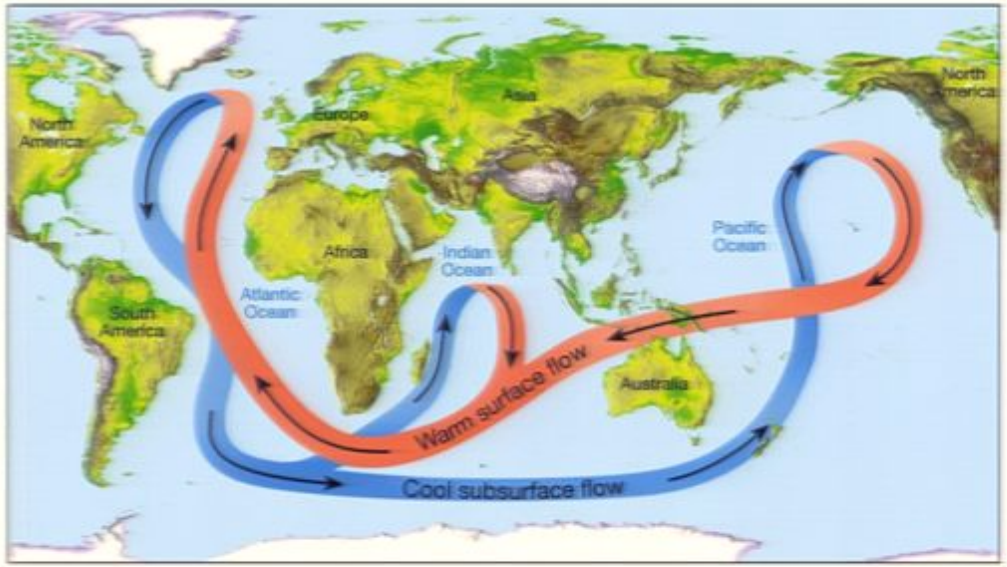
- The Thermohaline Flow



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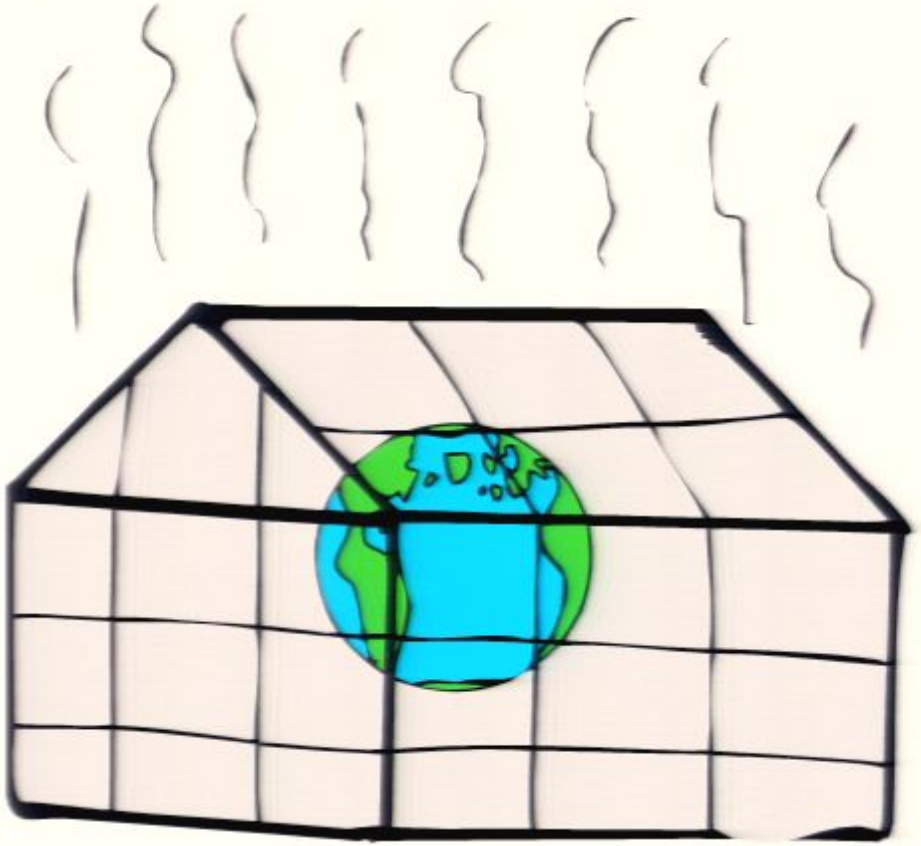
- The tilted axis
- The El Niño Cycle
- The Thermohaline Flow
- The Greenhouse Effect



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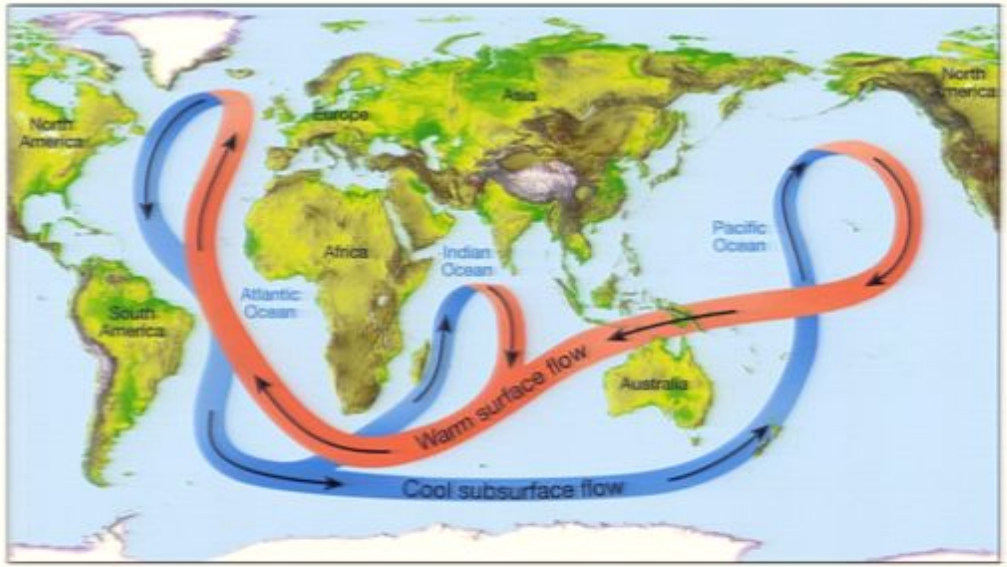

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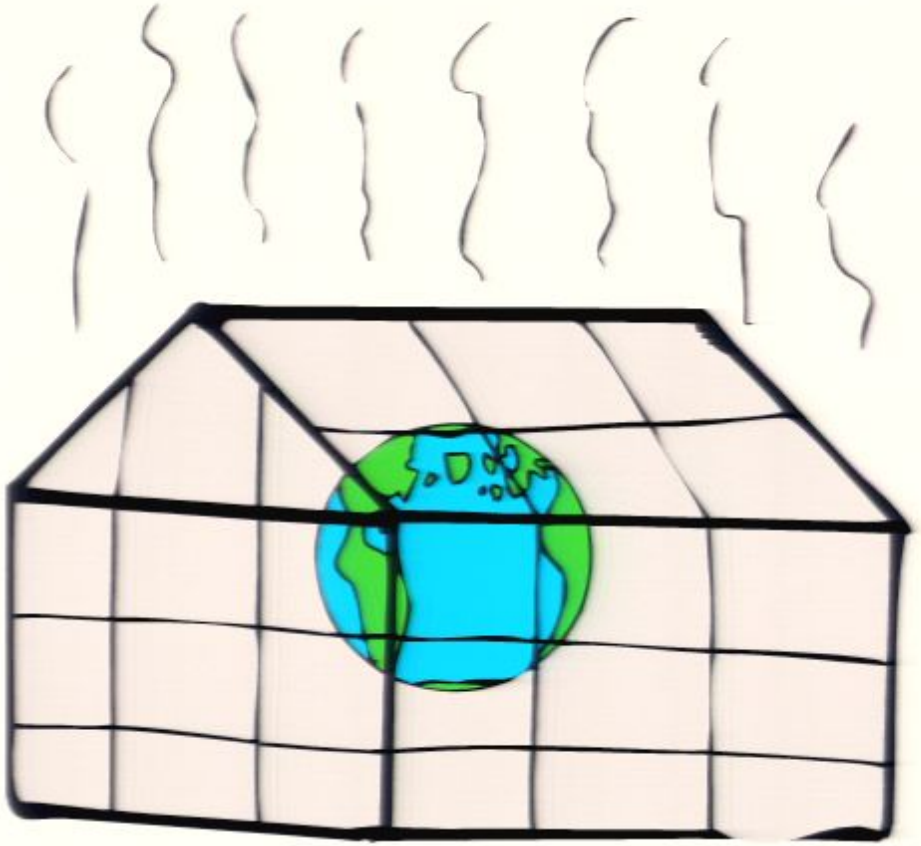


The Greenhouse Effect

(Preindustrial)

From the Sun: 343 W/m^2

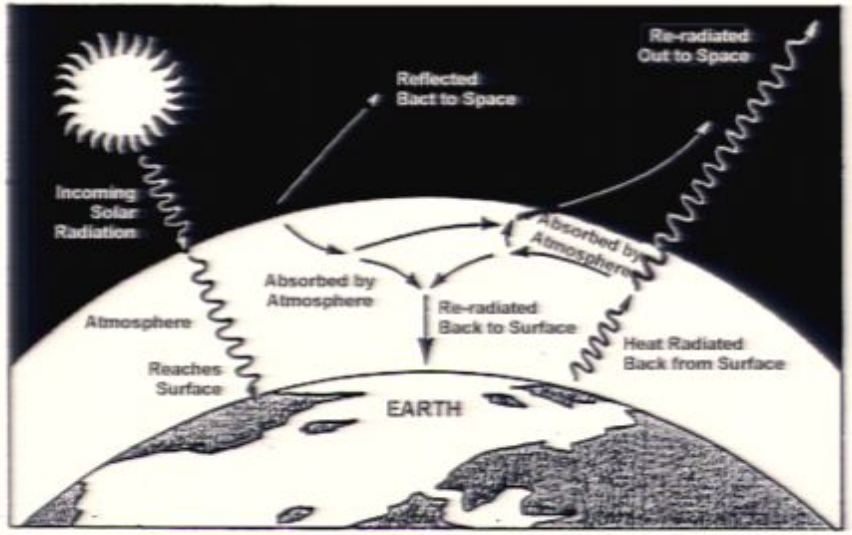
Water vapor, methane, Carbon dioxide, etc.

88% Greenhouse

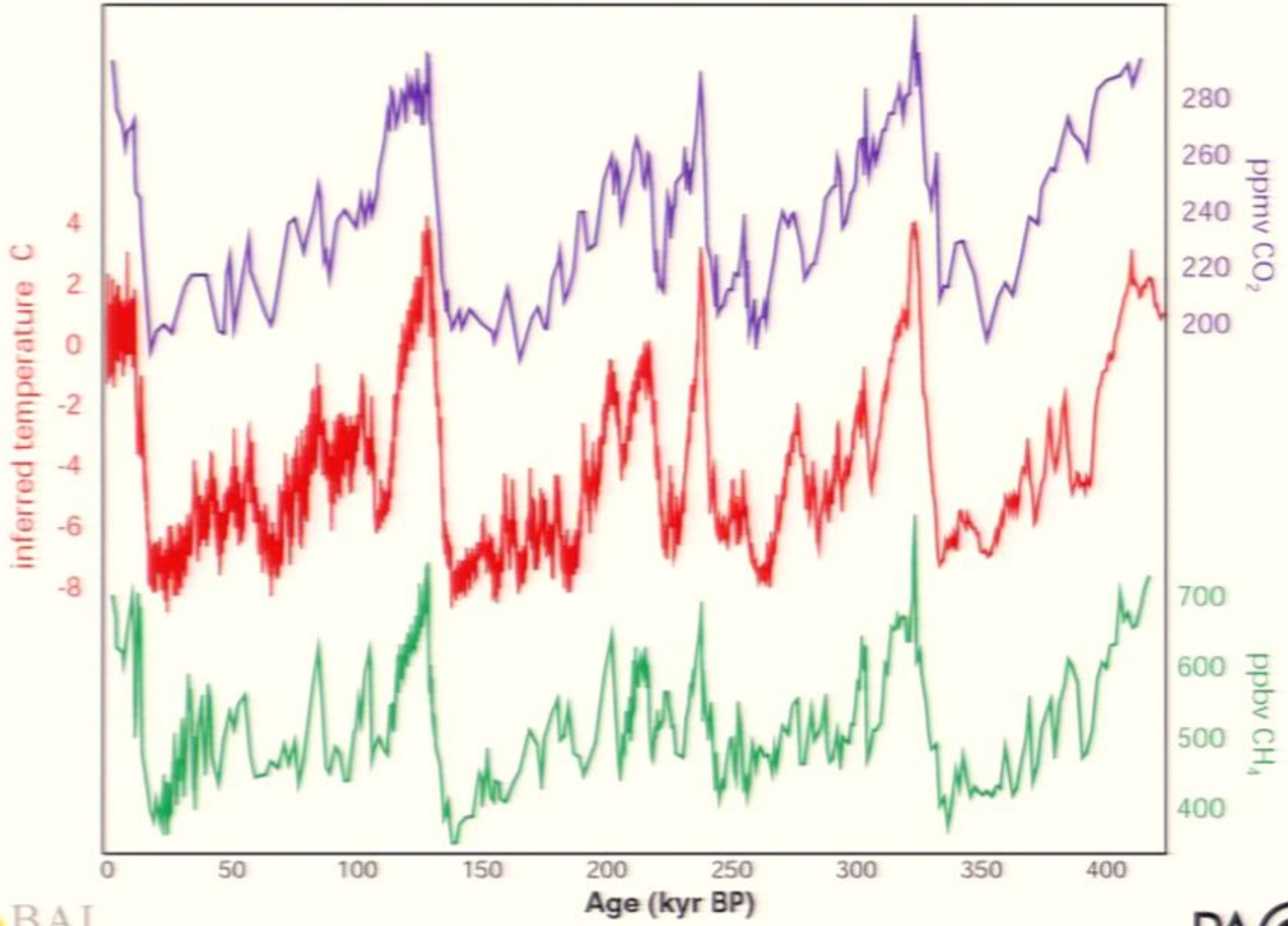
T = 287K= 14^{o}C = 57^{o}F

Feedback effects

Limiting cases



4 glacial cycles recorded in the Vostok ice core



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

GLOBAL CHANGE IGBP

PAGES PAST GLOBAL CHANGES

Sources of Useful Energy

Before 1800:

Light from the Sun

Coal

Oil seeps

Swamp gas

Nineteenth Century

Coal

Whale Oil

E. L. Drake, 1859, Titusville, PA.

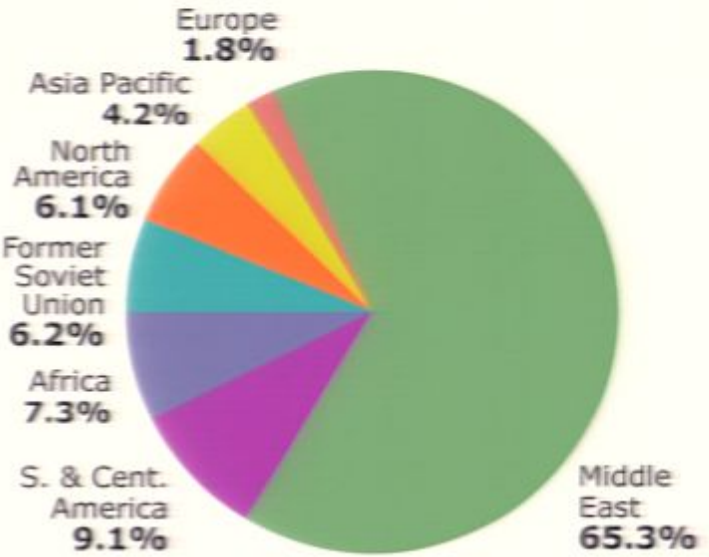
Illumination, Lubrication

Fuel

We can no longer live on light from the Sun

charts of distribution of proved oil reserves 2001

Thousand million barrels %



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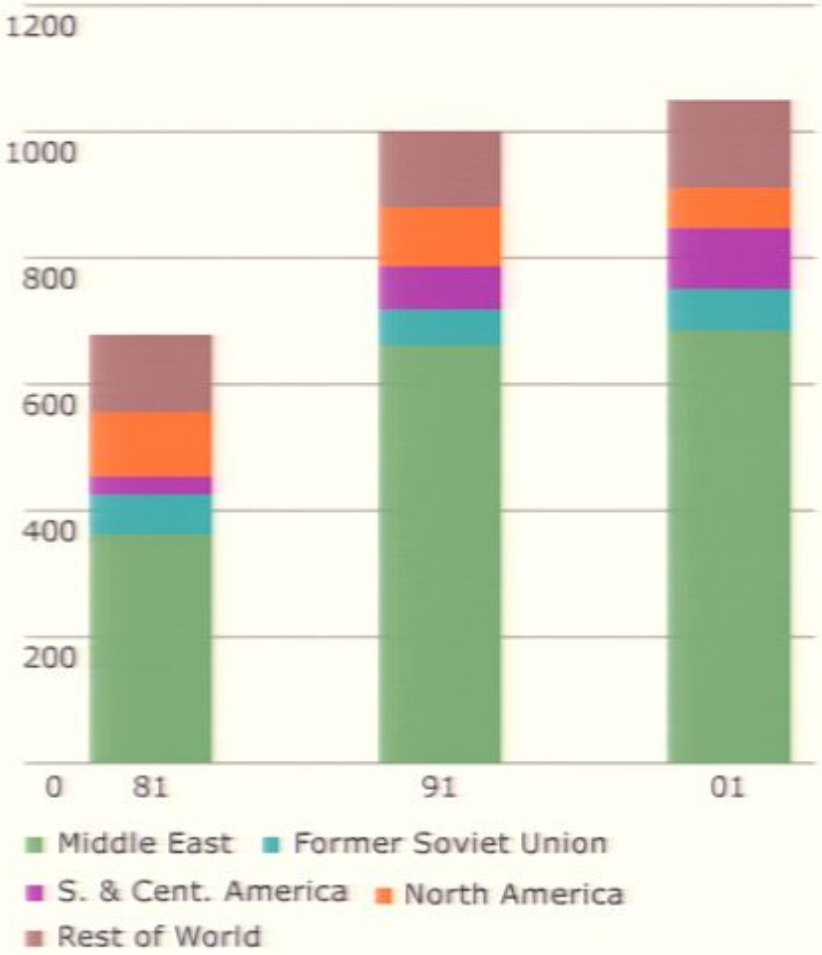
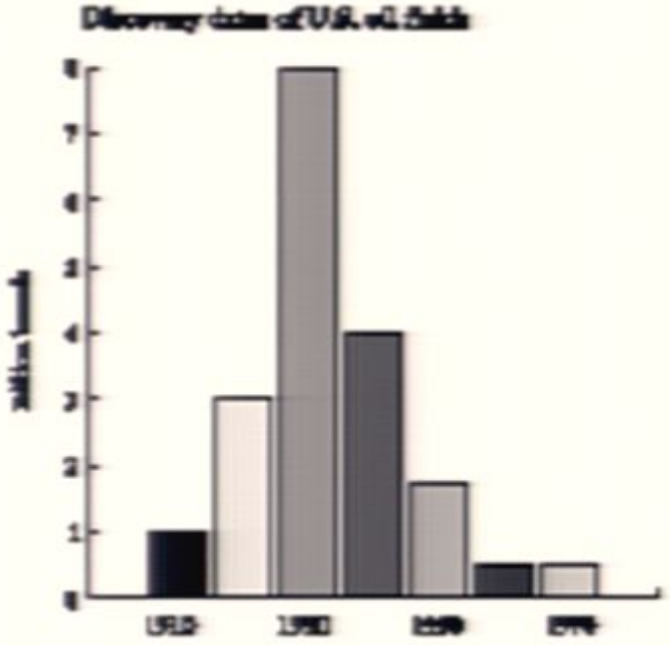


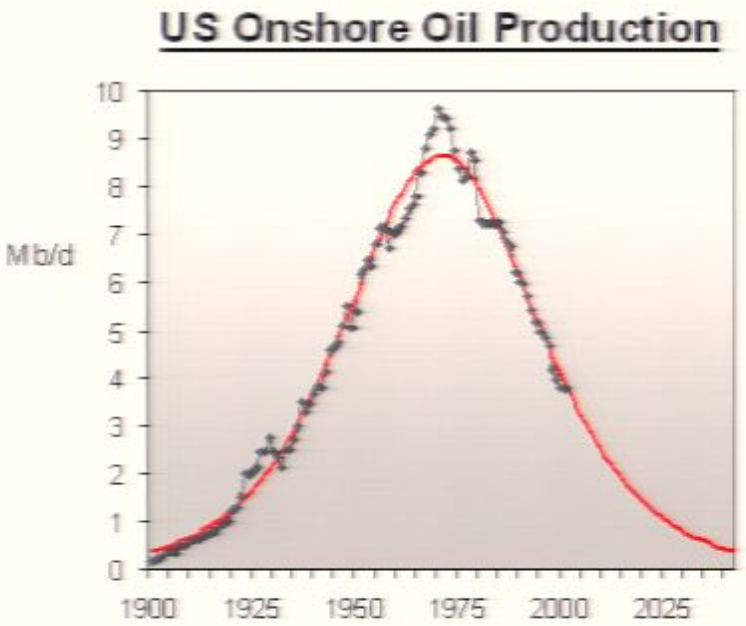
bp statistical review of world energy 2002

M. King Hubbert



Fitting the data—Hubbert's Peak

Hubbert Curves



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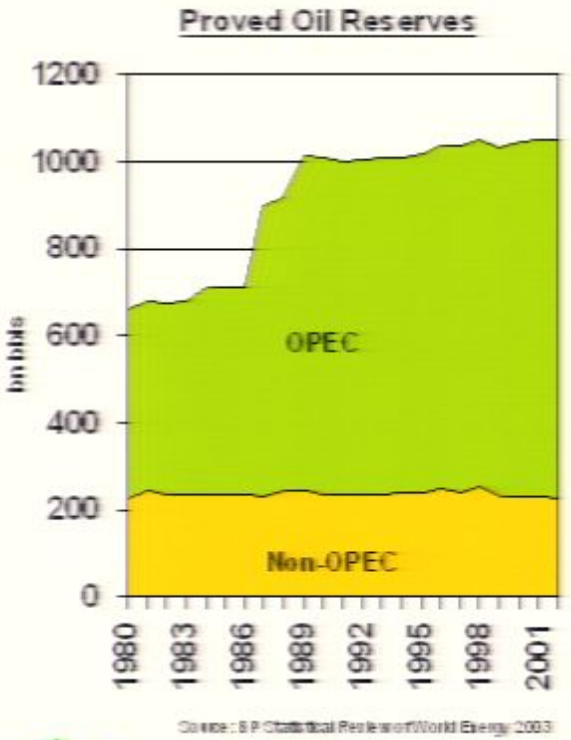
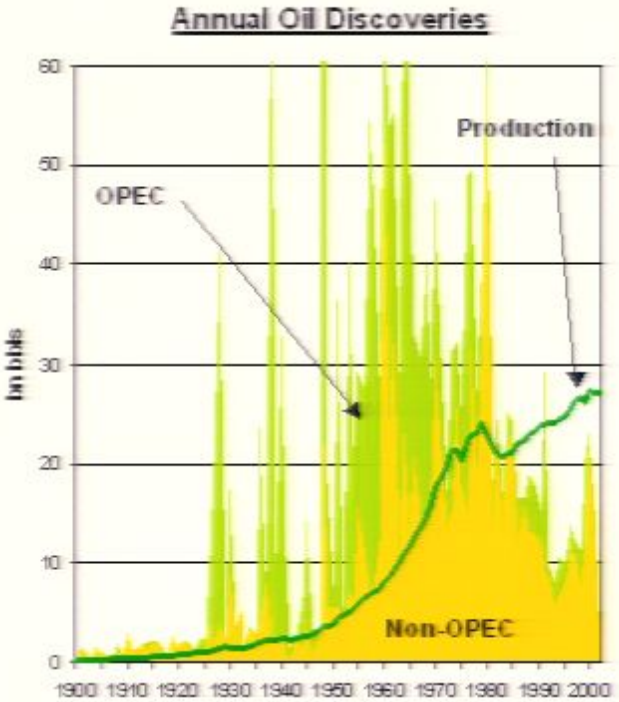
Reserves and Discovery

Oil Reserve Data



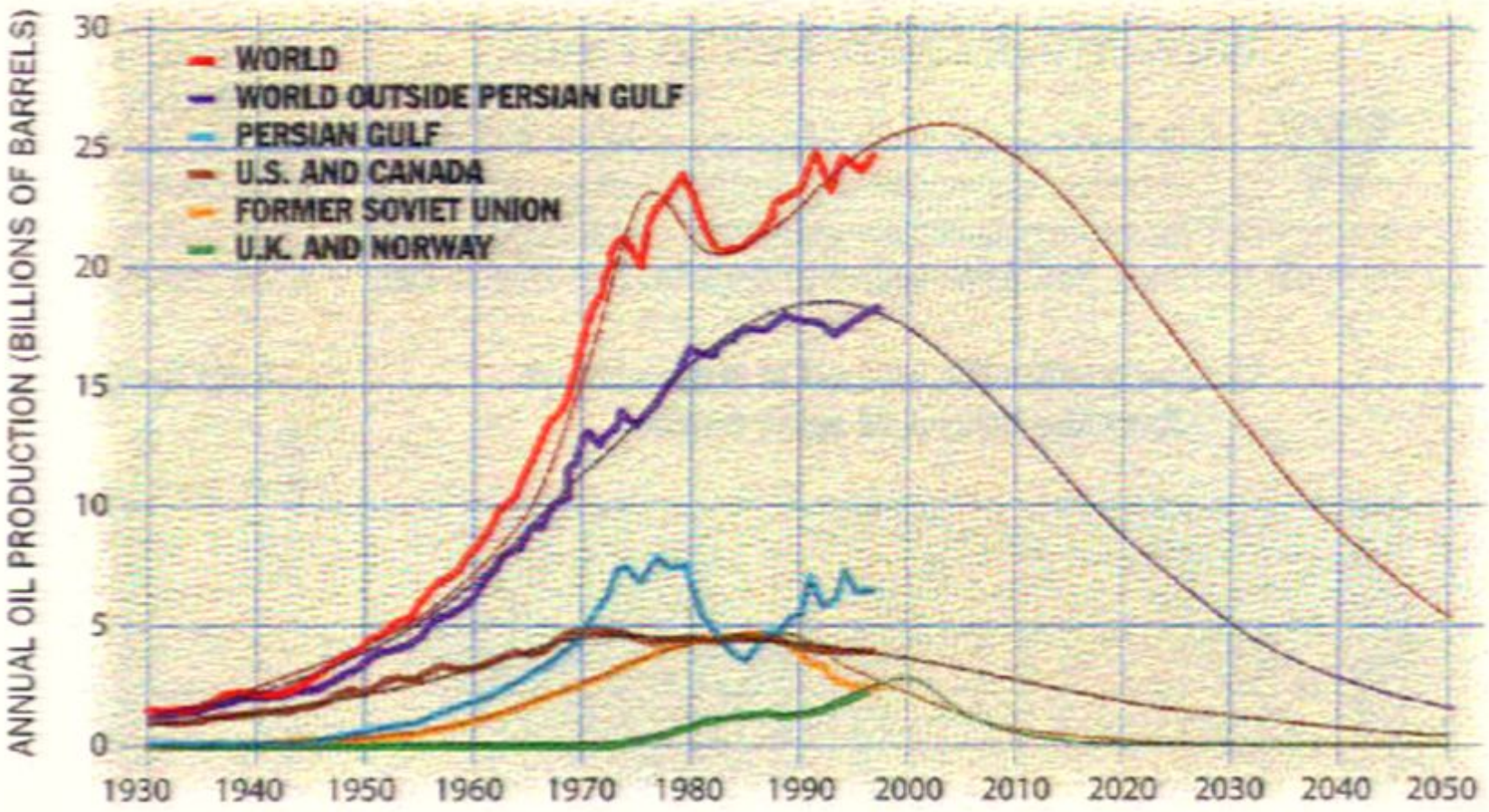


Source : BP Statistical Review of World Energy 2003

bp

Model Calculation

Colin J. Campbell and Jean H. Laherrère Sci. Amer., 1998



Caution

- Used 1.8 trillion
- Technology = Discovery
- Increasing price makes more available
- “Reserve” numbers very soft
- Basic idea is right

Kenneth Deffeyes:

The Texas Railroad Commission announced a 100% allowable for next month

The San Francisco Chronicle, 1971

The New York Times, **February 24, 2004**

Forecast of Rising Oil Demand Challenges Tired Saudi Fields

By JEFF GERTH

…the country's oil fields now are in decline, prompting industry and government officials to raise serious questions about whether the kingdom will be able to satisfy the world's thirst for oil in coming years.

…

Some economists are …optimistic that if oil prices rise high enough, advanced recovery techniques will be applied, averting supply problems.

But privately, some Saudi oil officials are less sanguine.

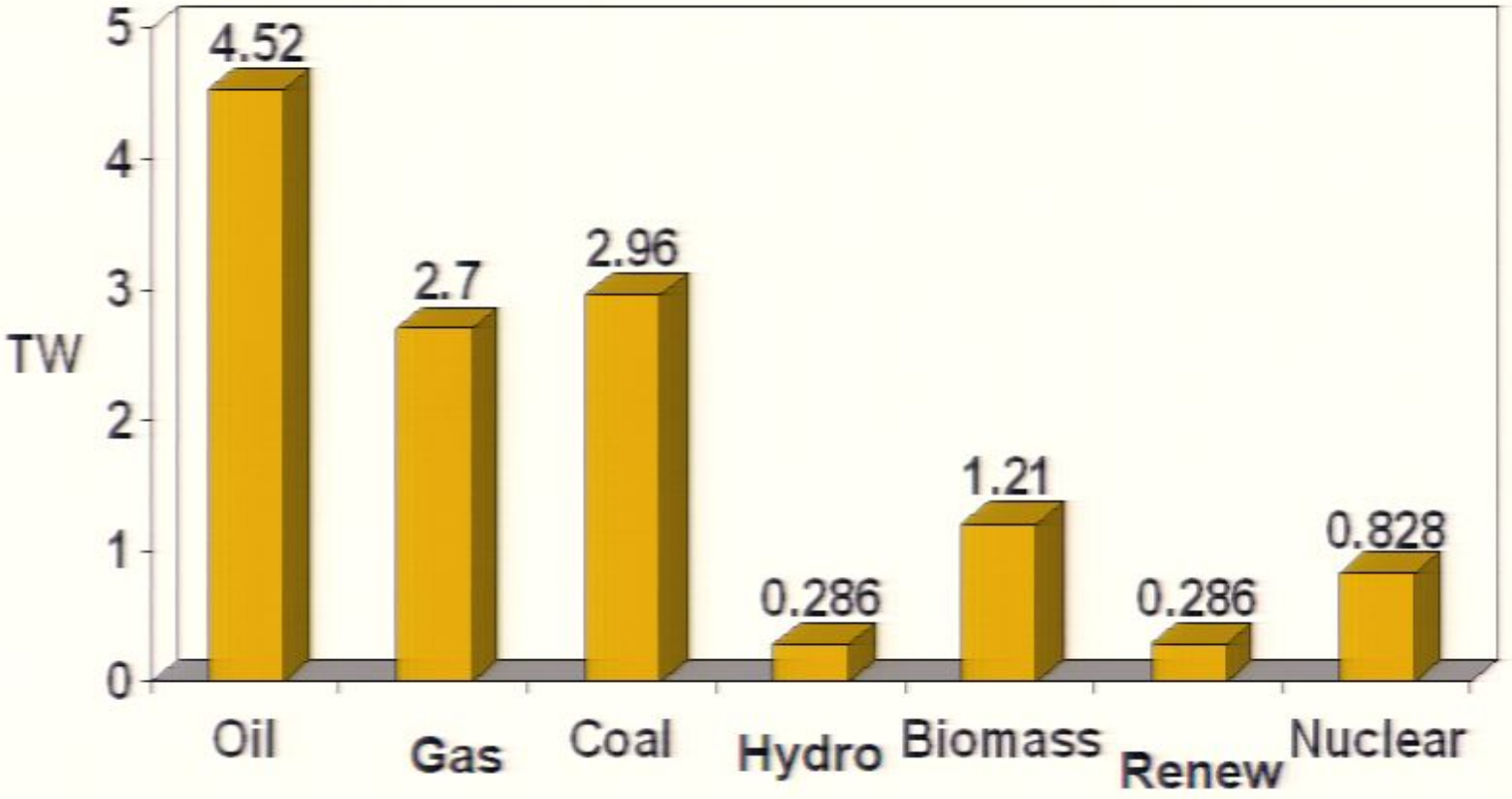
New York Times, March 5, 2007
Oil Innovations pump new life into old wells. By Jad Mouawad

- Many oil executives say that…peak oil theorists fail to take into account the way that sophisticated technology combined with higher prices make searching for new oil more affordable.
- Typically oil companies can only produce one barrel for every three they find. (This) represents a tremendous opportunity.

Oil Users

- Petrochemicals
- Stationary power plants
- Home heating
- Transportation
  - Cars
  - Trucks
  - Planes
  - Ships
  - Trains

Global Energy Consumption, 1998



Total: 12.8 TW U.S.: 3.3 TW (99 Quads)

Fossil Fuels

Oil

Natural gas

Shale oil

Methane hydrate

Coal

Coal

- Hundreds, maybe thousands years ***at present rate***
- Largest deposits in US
- Can be liquified substitute oil

But

- Dirty (mercury, arsenic, sulfur)
- Greenhouse effect
- Increase rate x5 replace oil
- Increasing population
- Higher standard of living
- Hubbert's peak.—This century

What does the future hold?

- Oil crisis very soon
- Fossil fuel will run out
- Unknown consequences for the climate
- Solar and nuclear
- Dilemma
  - Social, political
  - Technical

Conservation

(Amory Lovins, Rocky Moutain Institute)

- Ultra light/strong materials
- Hybrids
- Efficient buildings, factories
- Fuel from switchgrass, poplar, sugar cane
- More efficient use electricity
- Feebates
- Etc.

Technological Fixes
Greenhouse Effect

- Parasol at L1
- Sequester CO_2

Solar

- Hydro
- Wind
- Biomass
- PV

(10 TW = 220,000 km^2)

Total Solar Flux =

20,000 x 10 TW

- Scientific American Magazine - December 16, 2007
- **A Solar Grand Plan**
- **By 2050 solar power could end U.S. dependence on foreign oil and slash greenhouse gas emissions**
- By Ken Zweibel, James Mason and Vasilis Fthenakis

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Nuclear

- Geothermal

- Fission

(10 TW = 10,000 GW plants)

- Fusion

(1 gallon sea water = 300 gallons gasoline)

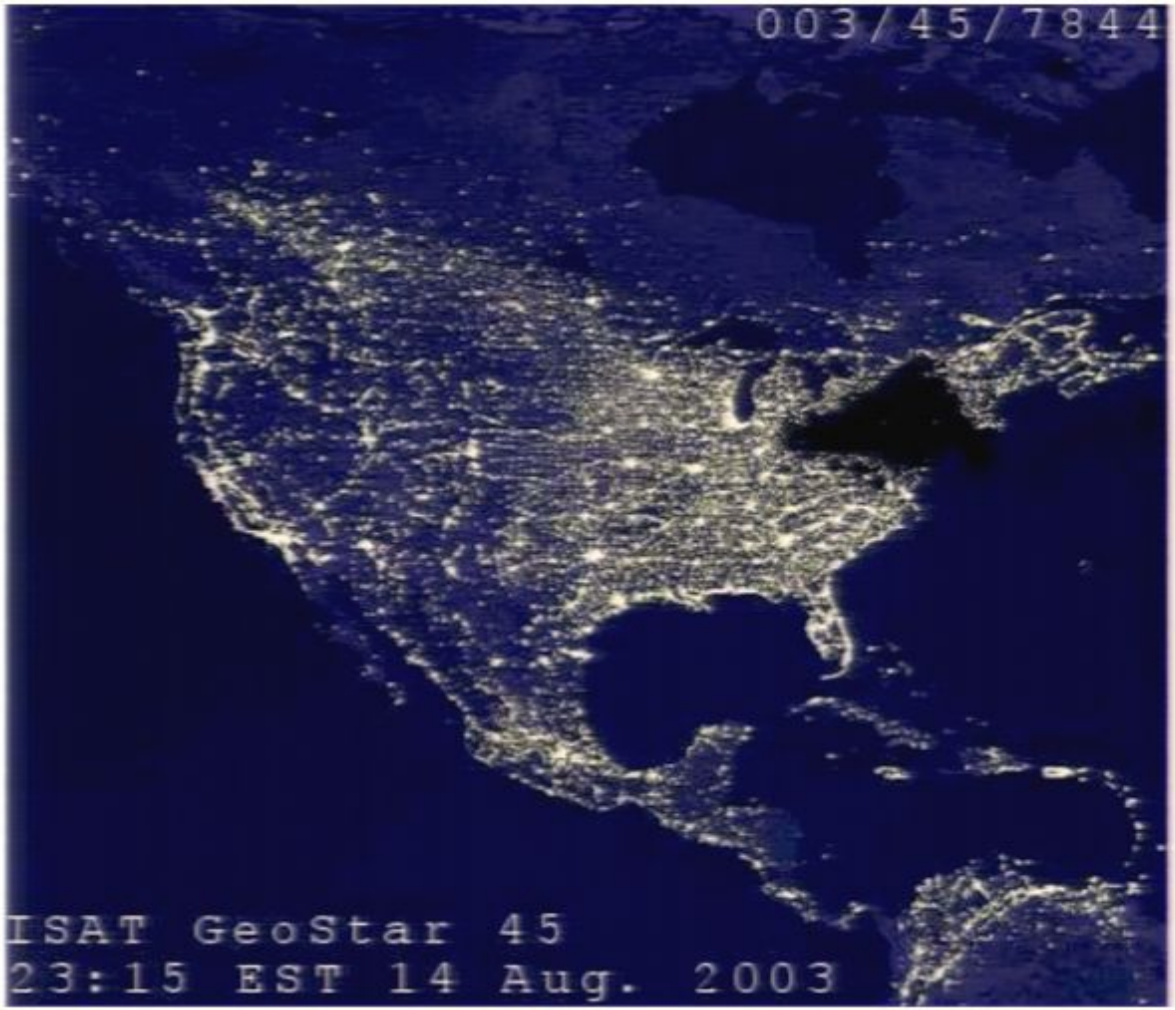
Transportation

- Advanced batteries
- Hydrogen
- Other fuels

We understand the basic principles

2008 State of the Union Address:

- To build a future of energy security, we must trust in the creative genius of American researchers and entrepreneurs and empower them to pioneer a new generation of clean energy technology. Our security, our prosperity and our environment all require reducing our dependence on oil.


003/45/7844
ISAT GeoStar 45
23:15 EST 14 Aug. 2003

Prediction

Civilization as we know it will come to an end sometime in this century, when the fuel runs out.

Out of Gas

The end of the age of oil

David Goodstein