

# Energy & the Environment: *The Central Challenge of Sustainability*

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*Business Advisory Committee Meeting*

NU Transportation Center

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**Key to addressing**

**Sustainability**

**is to**

**Define it.**



The definition of *Sustainable Development* according to the World Commission on the Environment & Development (1987) is:

*"To meet the needs of the present without compromising the ability of future generations to meet their own needs"*

Future = 2 generations = 50 years

Social justice



# Update:

“Yet in the end, sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs. . .Painful choices have to be made. Thus in the final analysis, sustainable development must rest on political will.



WCED 1987, Our Common Future

# Define Sustainability – simply

- Universal goal – survive and prosper, indefinitely
  - Corporations – sustainable enterprises
  - Societies – sustainable social systems
  - Ecosystems – sustainable ecological systems
- Yet, there is some reluctance (although this is waning) to embrace sustainable development because of sense that it is “anti-growth,” static?
- What is sustainable growth?



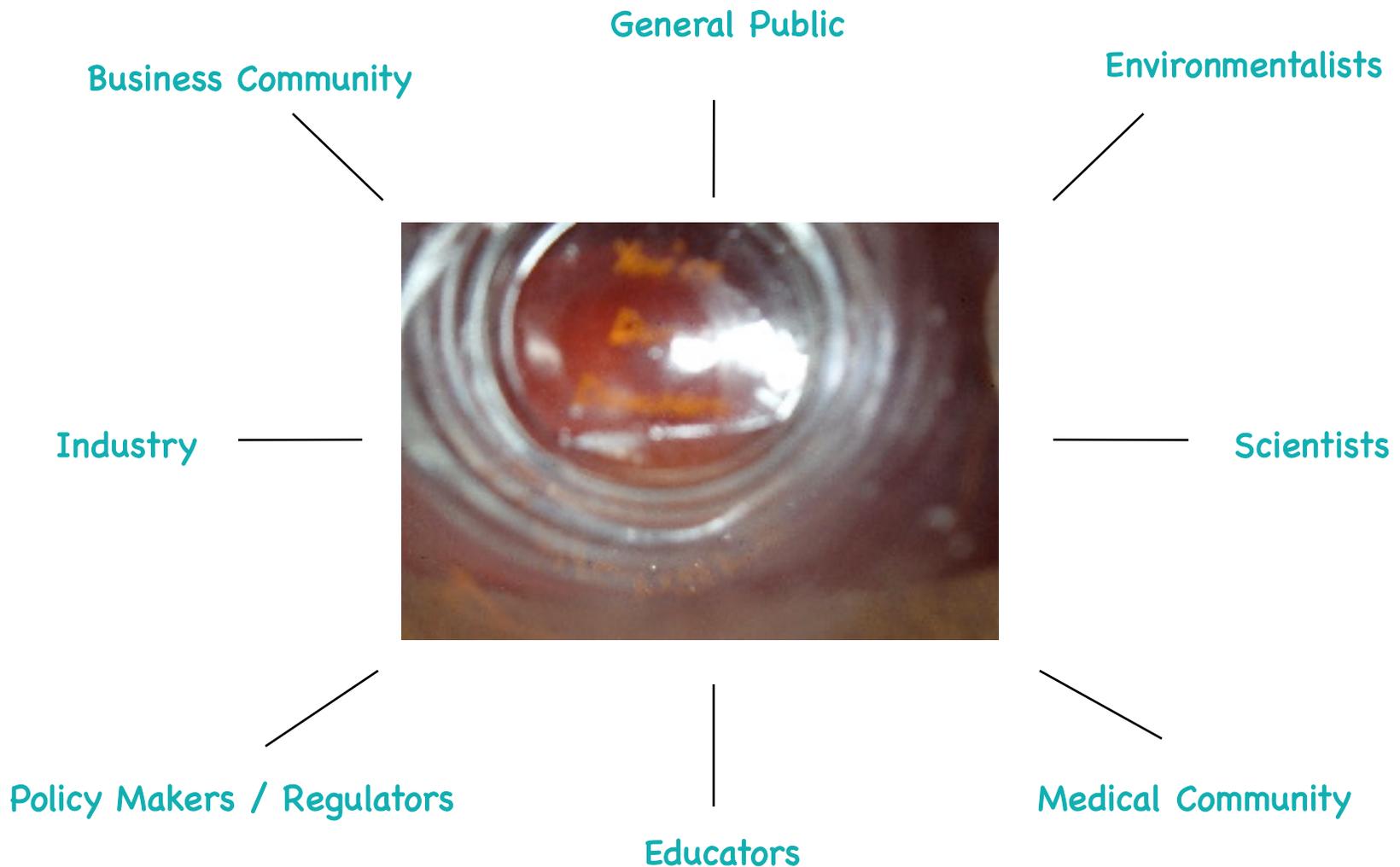
# Define Sustainability



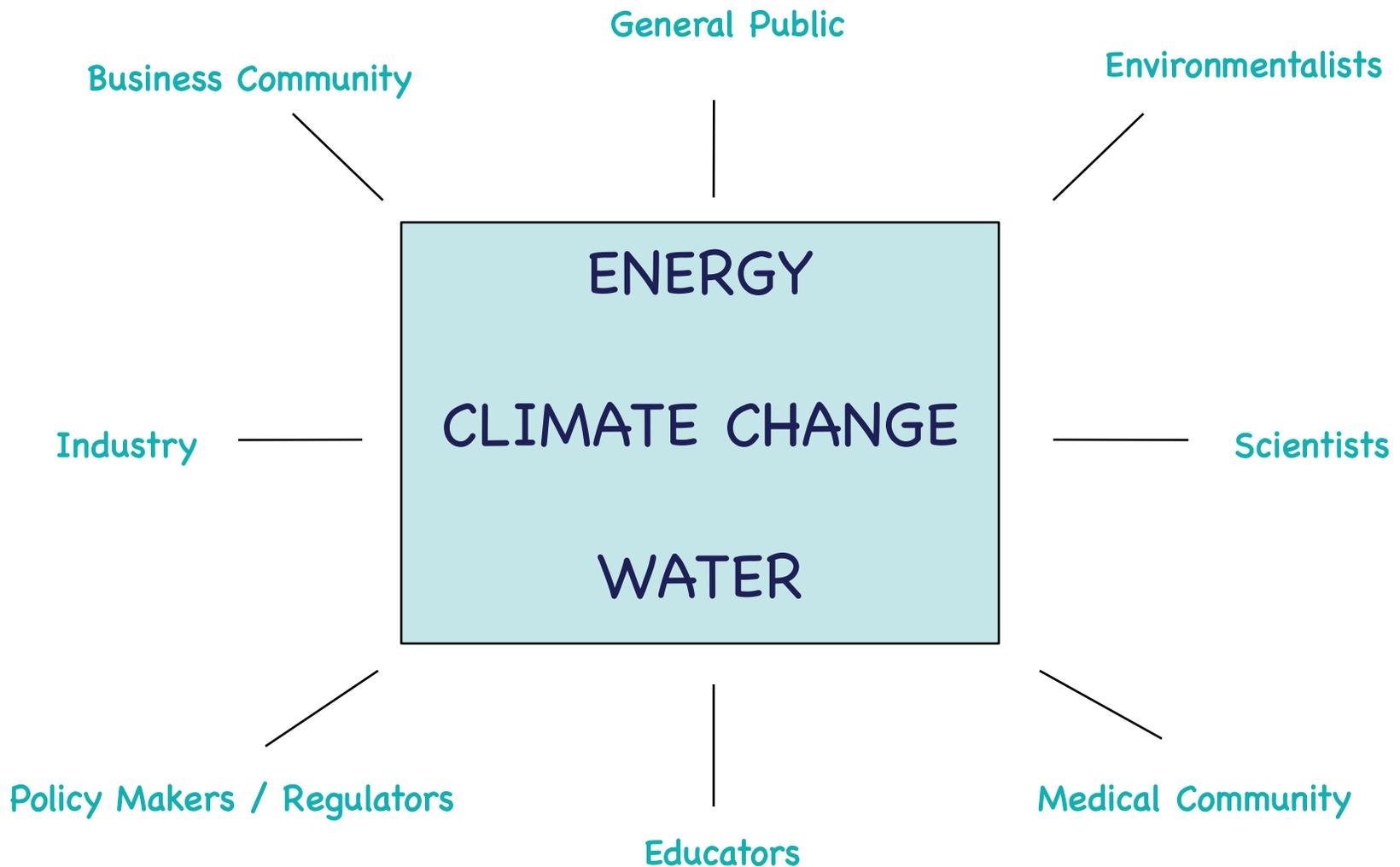
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- What is sustainable growth?

**Create value without depleting non-renewable resources or causing irreparable environmental damage**

Depending on our perspective, our understanding of  
issues and appropriate action is highly  
**VARIABLE**



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# Energy, Climate Change & Water Tightly Coupled

- Climate Change-Water: Floods (Midwest region of USA)  
Droughts (Western USA)

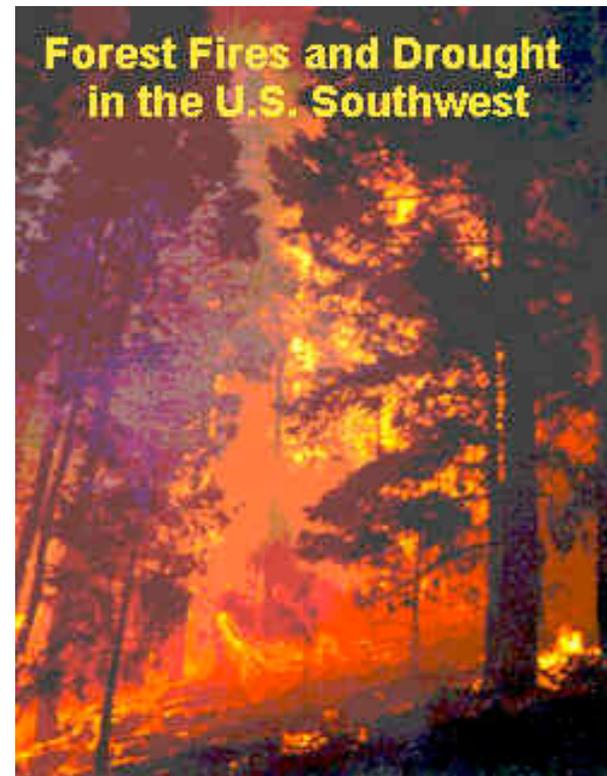


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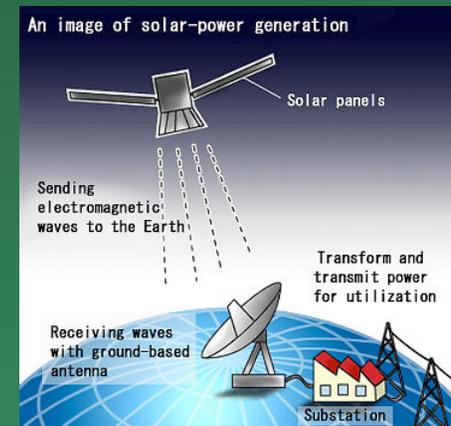


Lake Powell, Arizona/Utah



# Case for Sustainability:

# ENERGY

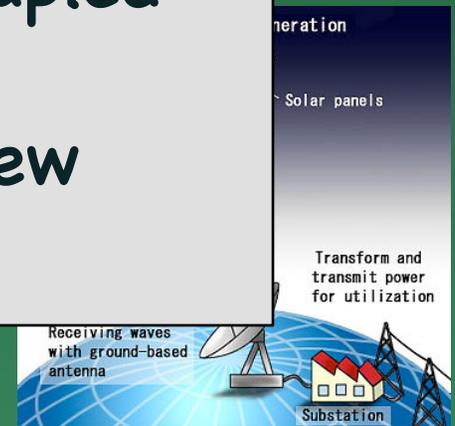


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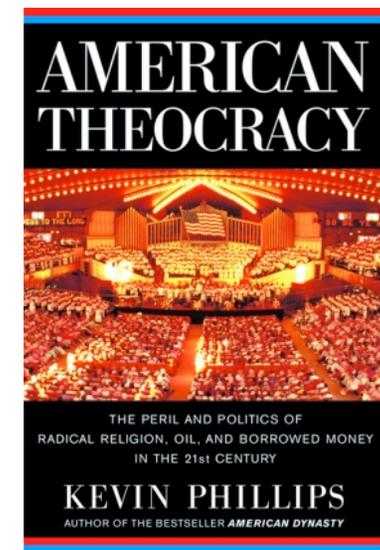
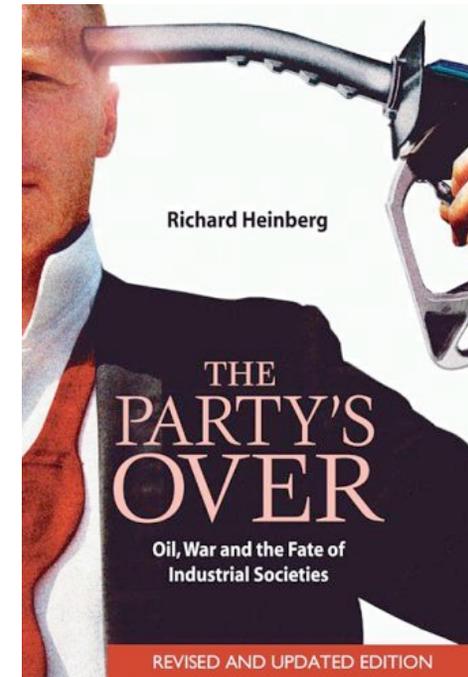
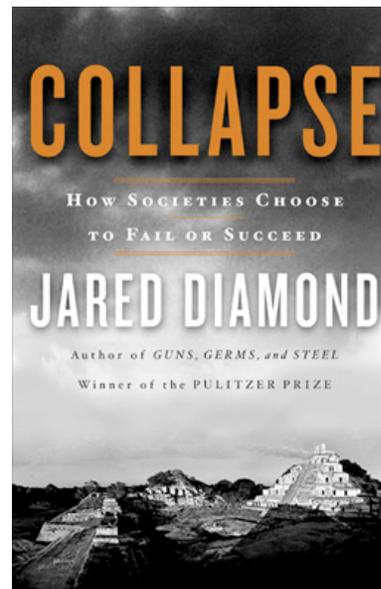
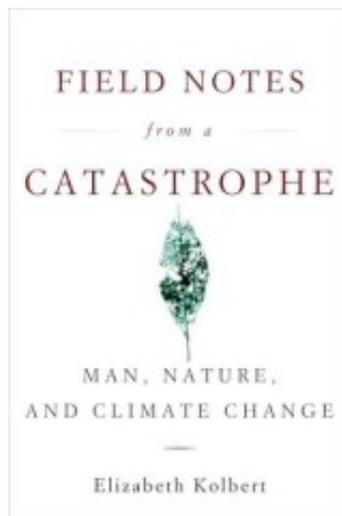
Issues – Highly connected & coupled

Solutions – Require system view



# How sustainable is current energy use?

- Supply & Demand
- Security
- Earth's Tipping Point



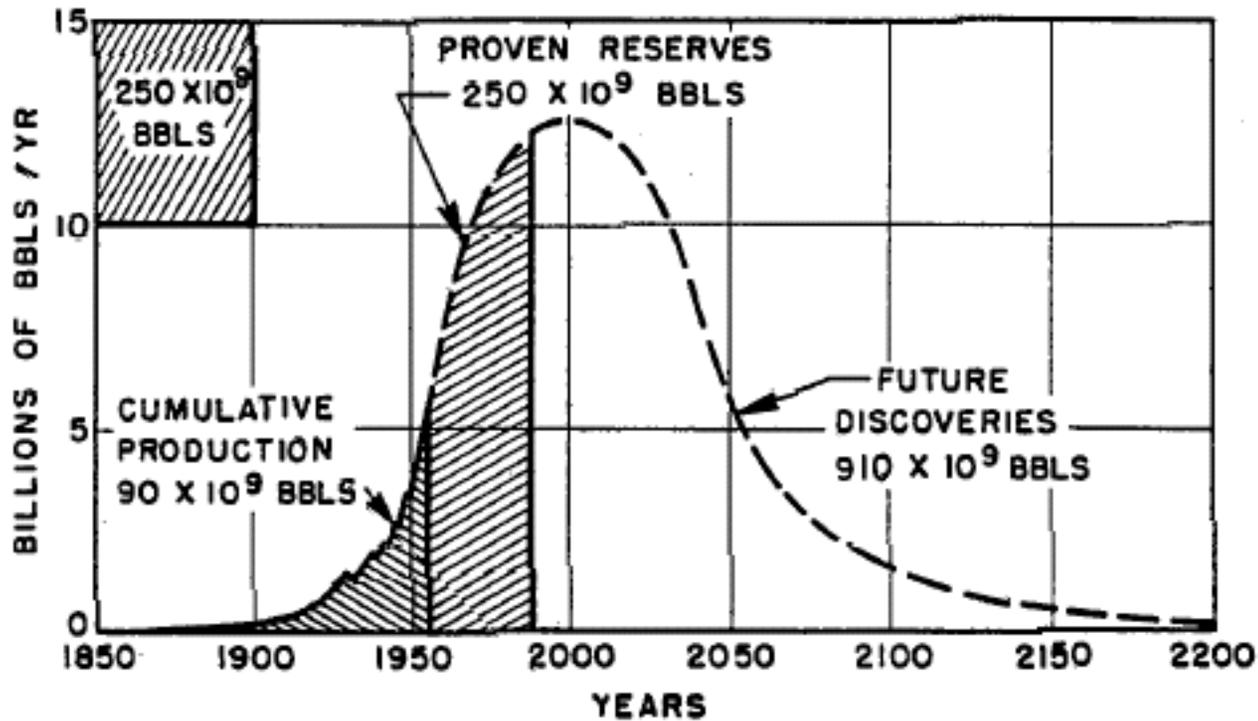


# SUPPLY

Is there an energy crisis?

Is this your father's energy crisis?





Hubbert peak graph from the 1956 paper. Ultimate world crude-oil production curve based on initial reserves of 250 billion barrels.

- Currently between 1-5 barrels of oil recovered for each barrel used in recovery
- Typical depletion rate of oil fields - 3%, in mature fields - 5-8%
- 35% of oil in field extracted (1980 was 22%)
- Advanced recovery - increase from 35-50% (flood w/H<sub>2</sub>O + CO<sub>2</sub>)

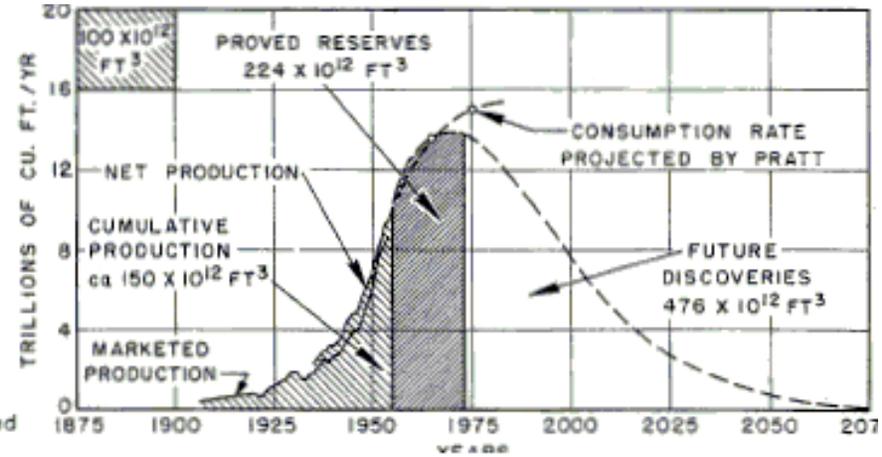
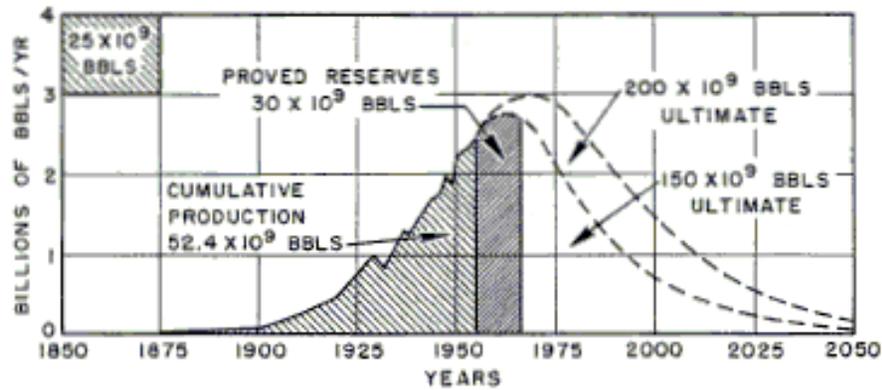
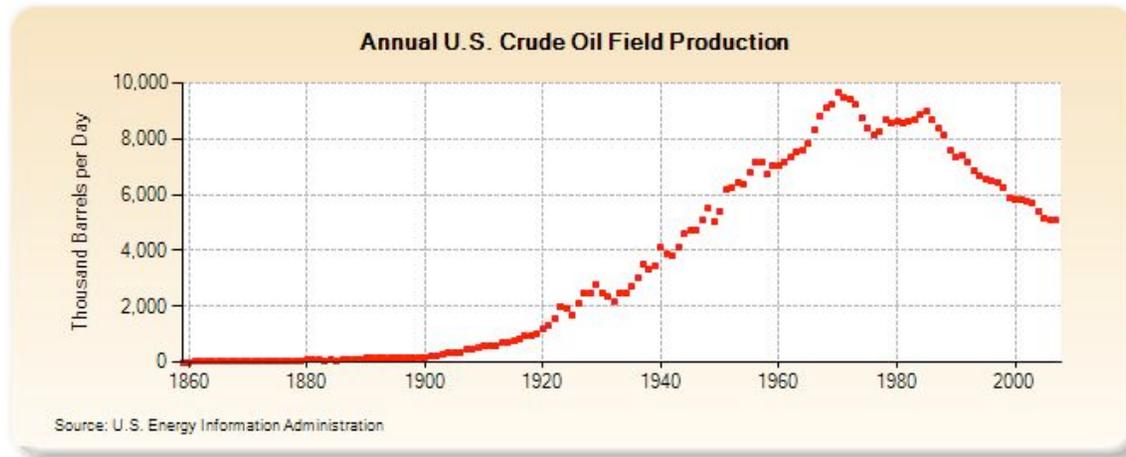


Figure 21 - Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

King Hubbert

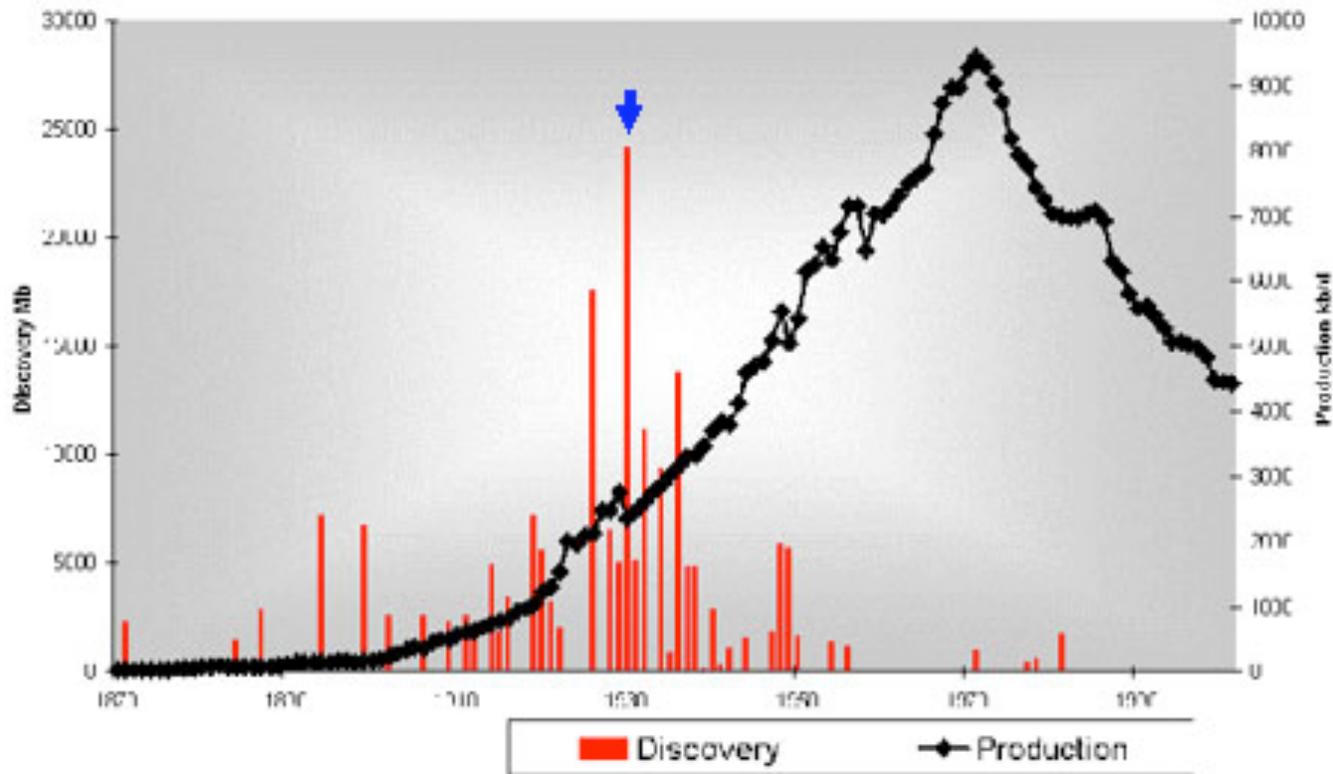
"Nuclear Energy and the Fossil Fuels" Presented before the Spring Meeting of the Southern District Division of Production, American Petroleum Institute, San Antonio, Texas, March 8, 1956. Publication No. 95. Houston: Shell Development Company, Exploration and Production Research Division, 1956.

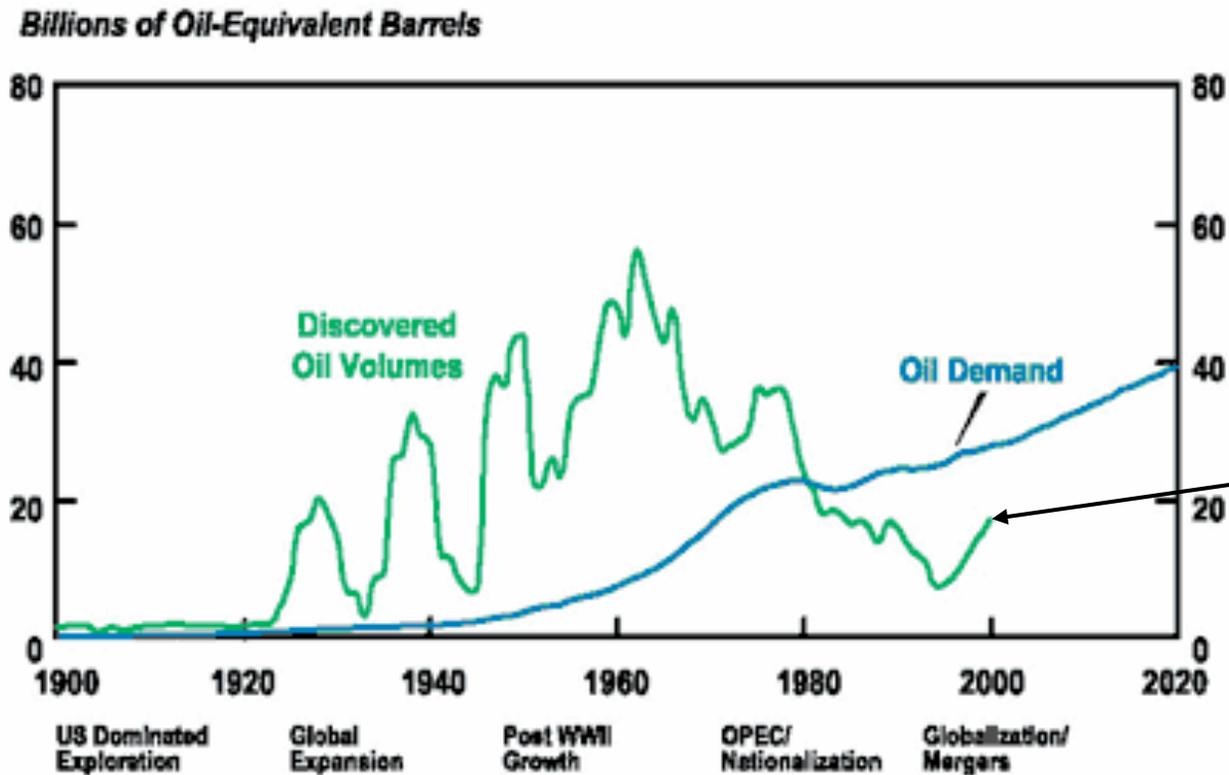
<http://www.hubbertpeak.com/hubbert/Bibliography.htm>



<http://tonto.eia.doe.gov/dnav/pet/hist/mcrfps2a.htm>

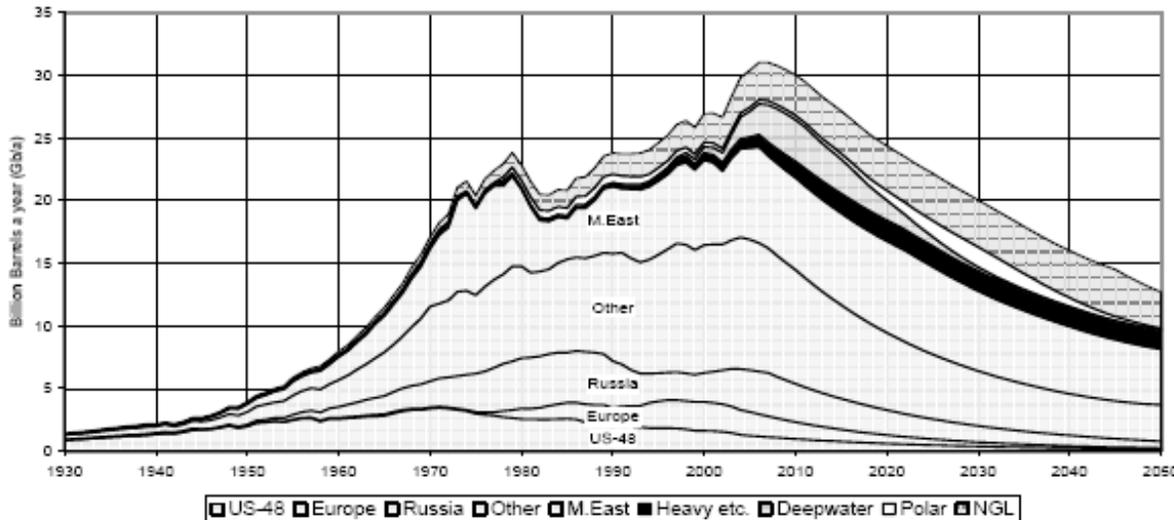
# U.S. Oil Discovery and Production



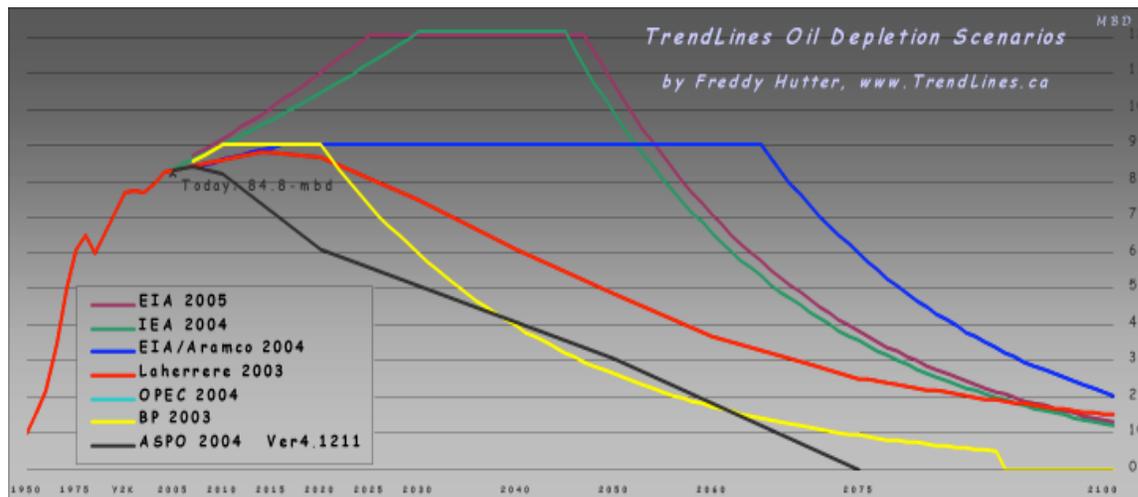


Discoveries in Kazakhstan, since 2001 back in decline

- Source: Henry Longwell, VP for Exploration of Exxon-Mobile
- Drawing Down - At this point, we are now extracting about 5 times as much oil each year as we discover.
- A FIT OF PEAK - Of 45 major oil-producing countries around the world, roughly 25 of them are past their production peaks.
- According to Chevron - 32 of 48 major oil-producing countries have peaked
- According to Peak Oil- > 50 major oil-producing countries have peaked



The Association for the Study of Peak Oil and Gas, or ASPO, is a network of scientists, affiliated with European institutions and universities, having an interest in determining the date and impact of the peak and decline of the world's production of oil and gas, due to resource constraints. ASPO was founded by [Colin Campbell](#) in [2000](#). It is the most influential organization supporting the "[peak oil](#)".

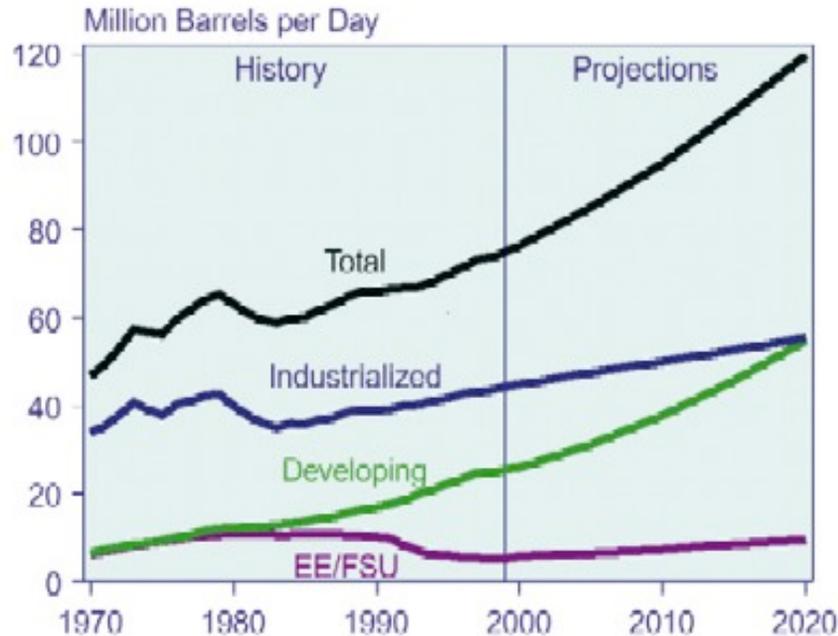


Campbell's critics, like Michael C. Lynch, argue that his research data are sloppy. They point to the date of the coming peak, which was initially projected to occur by the year 2000, but has now been pushed back to 2007.

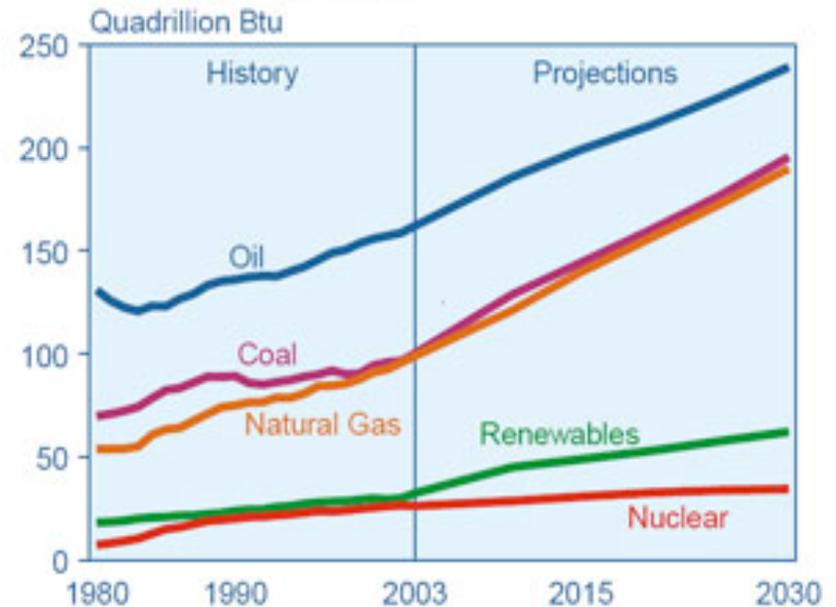
**What is important: Determining *when* or Realizing that it *will* occur at some future point**

## EIA, 2001 World Oil Consumption 1970-2020

**World Oil Consumption by Region, 1970-2020**



**Figure 3. World Marketed Energy Use by Energy Type, 1980-2030**



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site [www.eia.doe.gov/iea/](http://www.eia.doe.gov/iea/). **Projections:** EIA, *System for the Analysis of Global Energy Markets* (2006).

**Note:** 2003, China - 11,000 new cars/d; 4M/y; -- >by 2015 - 150 M cars (18 M more than driven in US in 1999)

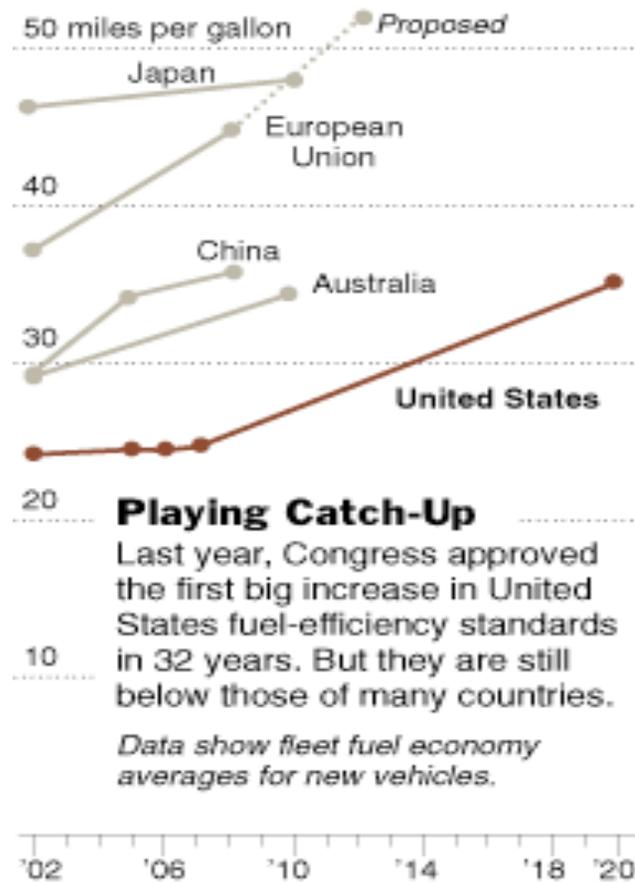
If China=US in oil consumption - need 80M barrel/d world production above current level

# It's the flows, stupid (Production limits 100M B/d, by 2012 demand will reach this level)

- Don't know true OPEC reserves; only 7000 wells, under-explored
- Likely OPEC peak - 2018-2025
- Non-OPEC - ~ 2015 or sooner  
currently supplies 60% of oil globally  
boosted output 35% over last 25 years  
will not be able to continue boosting production  
(Kuwait recently? Russia, Mexico peaked)
- US reserves - ~29B barrels (10B + 18B + 15B\*)
- Saudia Arabia - > 250B barrels
- Consumption figures - 1000 gal/s (Science, 05); 80M barrels/d; 30B barrels/y; **in US - 7.6 B barrels of oil/y (2007);**
- Growth in consumption - ~2%, hit 2.6T barrels by 2030
- Decrease consumption, **shift to alternatives - 20-30 yrs**

# American Energy Policy, Asleep at the Spigot

If increase fuel efficiency to 40-60 mpg - save 5M barrels/day (2B/y)



## Playing Catch-Up

Last year, Congress approved the first big increase in United States fuel-efficiency standards in 32 years. But they are still below those of many countries.

*Data show fleet fuel economy averages for new vehicles.*

Source: Pew Center on Global Climate Change

THE NEW YORK TIMES

***“The stone age did not end because the world ran out of stones. . .  
And the oil age will not end because the world will run out of oil.”***  
**Sheikh Zaki Yamani, Saudian Arabian Oil Minister – 30 yrs. ago**

- We know there is a limit to fossil fuels, just don't know what it is, nor when it will occur.
- Existing global fossil fuel infrastructure is \$12 trillion
- **Public attention to peak oil production - very small**
- Policy focus on supply
- Bridge economy:
  - Deffeyes: 100s million years for oil to form and accumulate, most of oil will be drilled within 100s of years. . . Hubbert's Peak is a short bump on geological time line; **Fossil fuels are a one time gift that lifted us from subsistence agriculture and should eventually lead to a future based on renewable resources.**
  - Roberts - 1) increase natural gas supply; 2) adopt a carbon penalty (stimulate clean coal development); 3) cut energy demand

IF THIS IS THE

**CHEAP**



WHAT'S NEXT ?

# Canadian Tar Sands/Heavy Crude

(2.5 T Barrels Alberta, 315 B Barrels Recoverable)

- Extraction: Between 2 to 4.5 volume units of water are used to produce each volume unit of synthetic crude oil (SCO) in an ex-situ mining operation. Despite recycling, almost all of it ends up in tailings ponds; currently 349M m<sup>3</sup>/y.

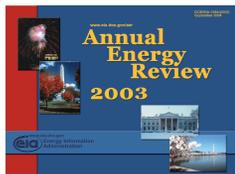
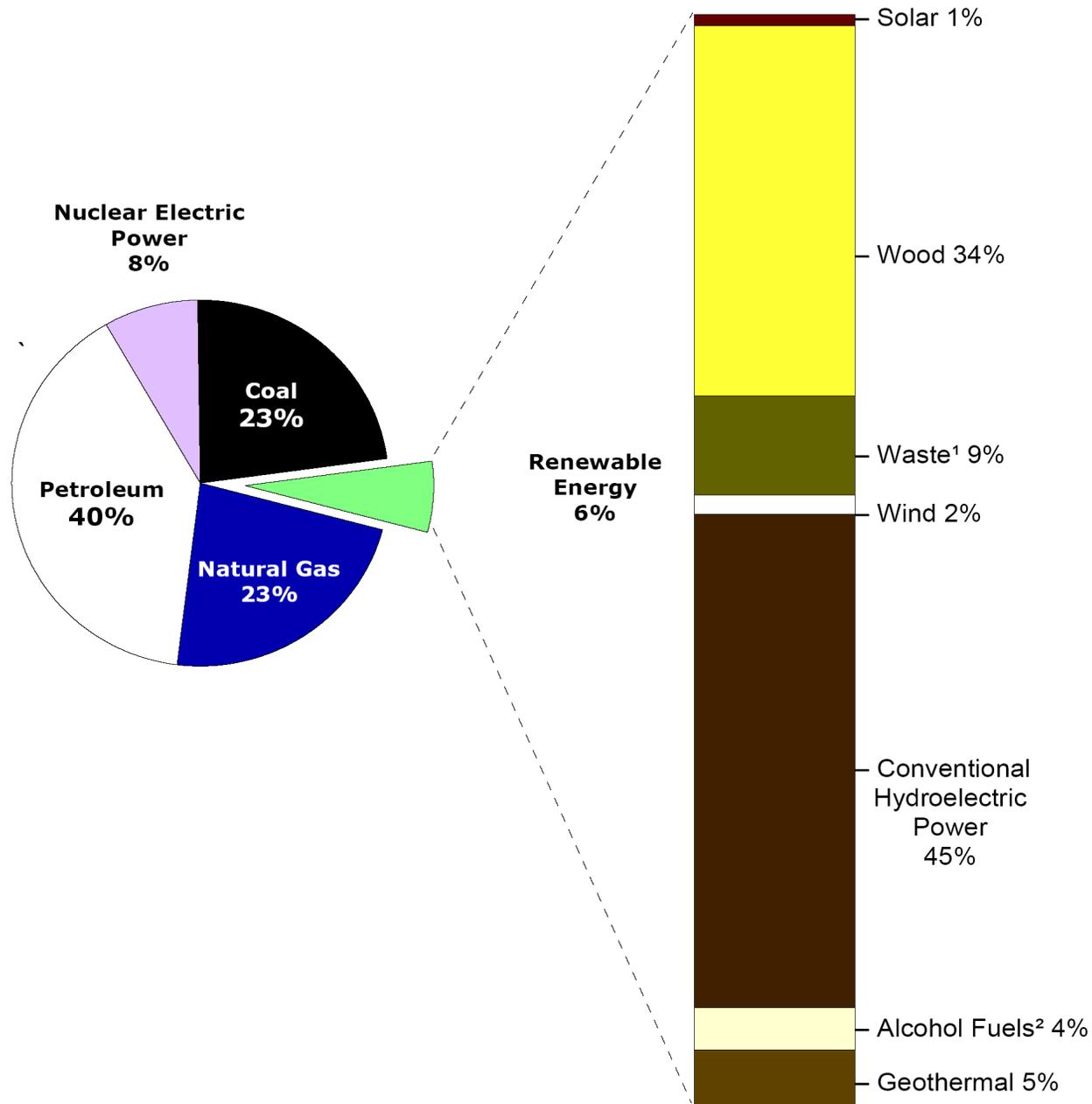
- Refining:

Emissions per Barrel Produced

Emission	Conventional Oil	Oil Sands
SO <sub>x</sub> (g)	43	106
NO <sub>x</sub> (g)	95	132
Greenhouse Gas (kg)	29	78
Water (barrels)	0	3-5



# Renewable Energy Consumption by Major Sources, 2003



## *Theoretical Global Potential of “Renewable” Energy*

- Hydroelectric (4.6 TW)
- Geothermal (40 TW)
- Ocean/Tides (3 TW)
- Wind (50 TW)
- Biomass (5-10 TW)
- Solar (100,000 TW)

# Biomass Potential

## Global: Top Down

Requires Large Areas Because Inefficient (0.3%)

3 TW requires  $\approx$  600 million hectares =  $6 \times 10^{12}$  m<sup>2</sup>

20 TW requires  $\approx$   $4 \times 10^{13}$  m<sup>2</sup>

Total land area of earth:  $1.3 \times 10^{14}$  m<sup>2</sup>

Hence requires  $4/13 = 31\%$  of total land area

Possible/likely that this is water resource limited

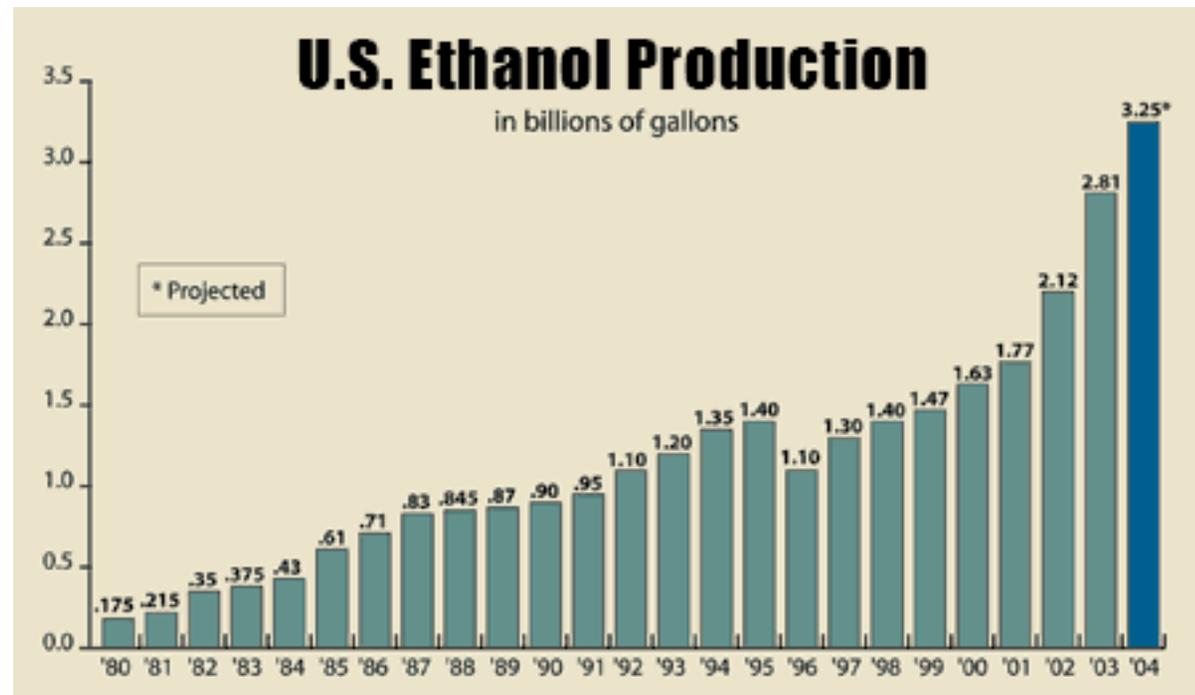
**Catalysis: cellulose to alcohol or CO + H<sub>2</sub>; alcohol fuel cells**

## Biofuels - Ethanol



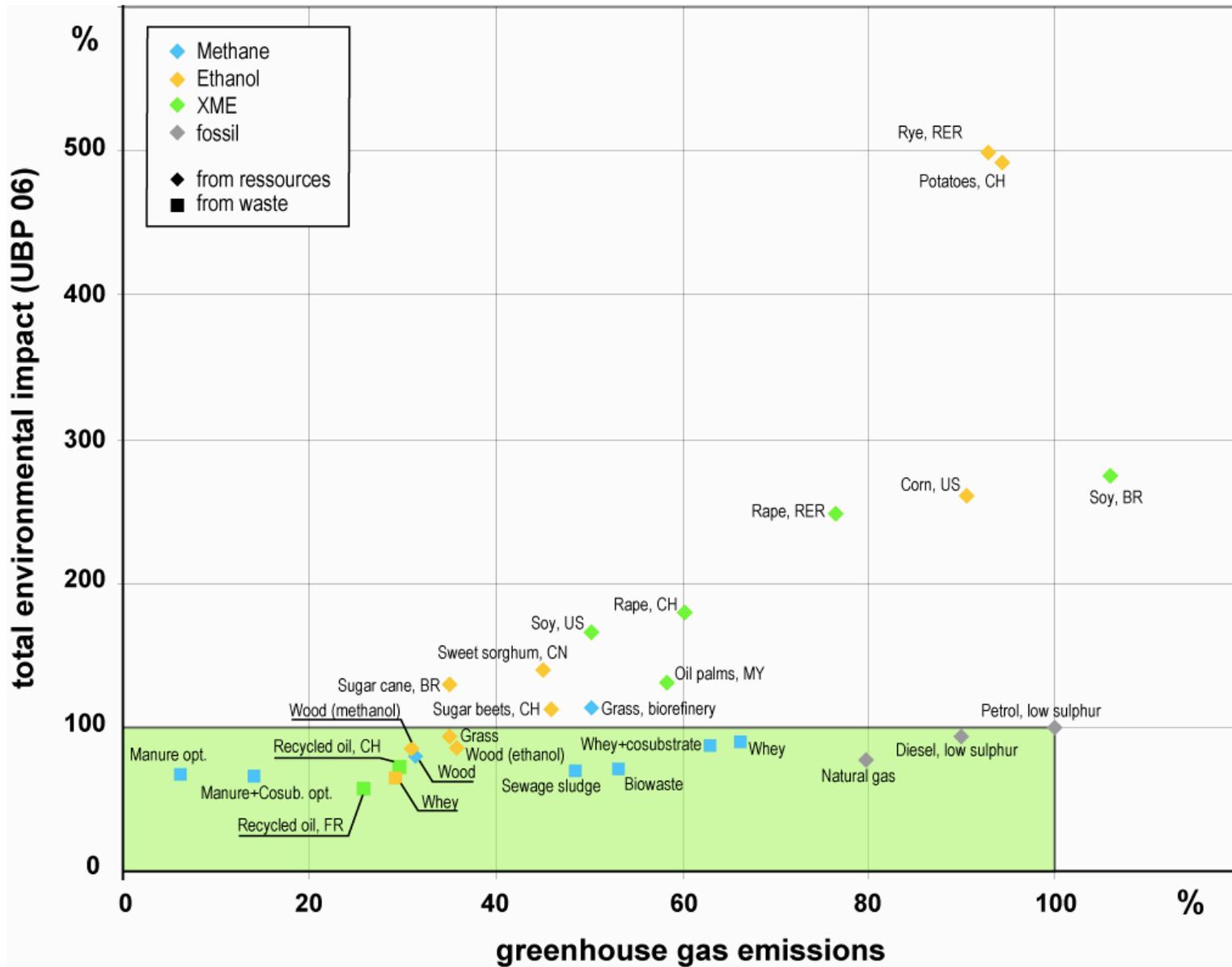
- **Brazil (4.4 B gallons):**
  - **Sugar Cane - ~8x more efficient than corn**
  - **Flex-fuel engines - >70% cars (\$150+)**
  - **13.5% energy use**
- **U.S. (9.0 B gallons - 2008)**
  - **Corn - mostly gasoline additive**
  - **Renewable energy - 6%;**  
**mostly hydropower for electricity**
  - **Future - cellulosic ethanol**

# EISA (2007)



- 2004 - 3.4 B gallons (~15.5 % increase over 2003)
- 2005 - 3.9 B gallons (2.9%); 2006 - 4.8 B gallons; 2007 - 6 B (4.3%); 2012 - 10-12 B gal (7.5% ) --- **36B gal (15-20%) in 2022** (21 B gal from cellulosic & advanced biofuels).
- 109 facilities operating, 64 under construction; 1/2 farmer owned
- Mostly from corn, but also use grain sorghum, wheat, barley, sugar cane beets, cheese whey, potatoes

<http://www.ethanol.org/production.html>

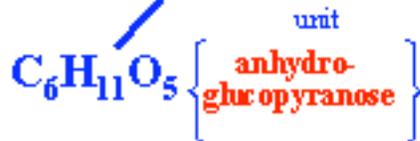
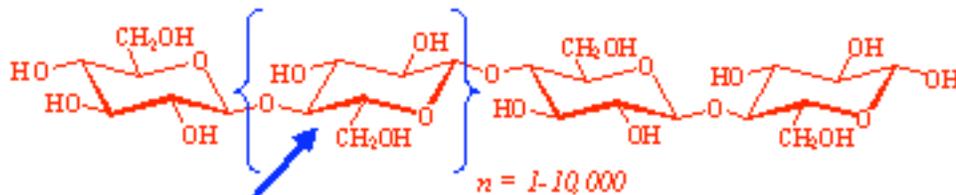


R. Zah et al, (2007) Life Cycle Assessment of Energy Products: Environmental Impact Assessment of Biofuels.

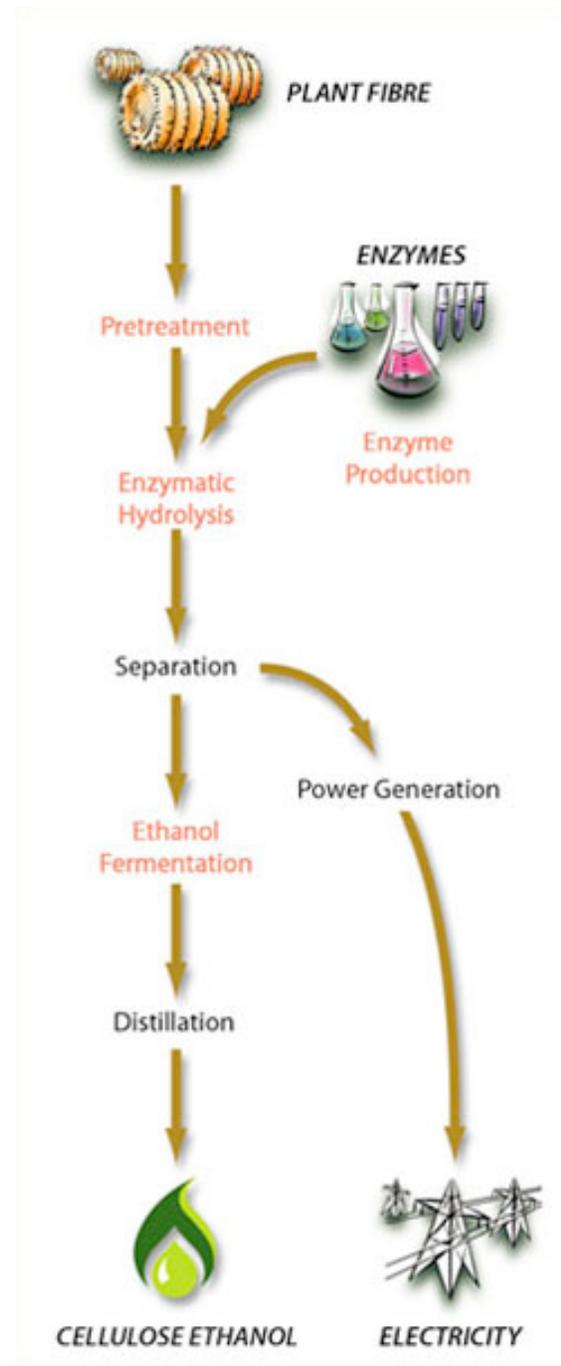
J.P. Scharlemann, W.F. Laurance (2008) "How Green Are Biofuels," *Science*, 319:43-44.

- Ethanol (29.7 kJ/g) vs. Gasoline (48 kJ/g)
  - Higher octane rating
  - Burns more completely, less emissions
  - 38% less energy/L than gasoline
- Use municipal waste, rice hulls, bagasse, small diameter trees, wood chips, switch grass

## *Molecular Structure of Cellulose*

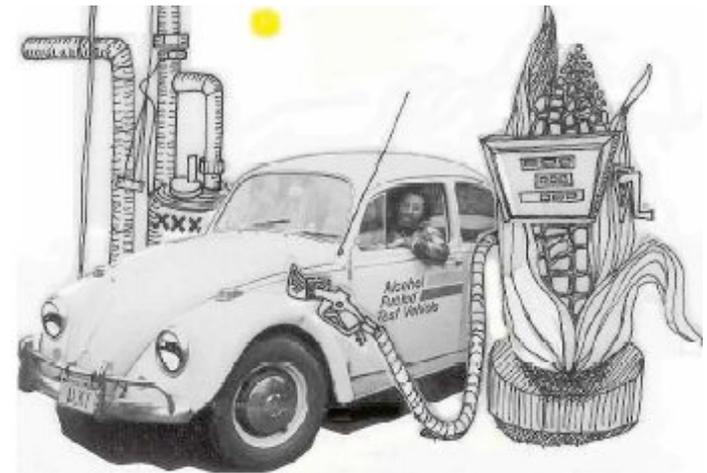


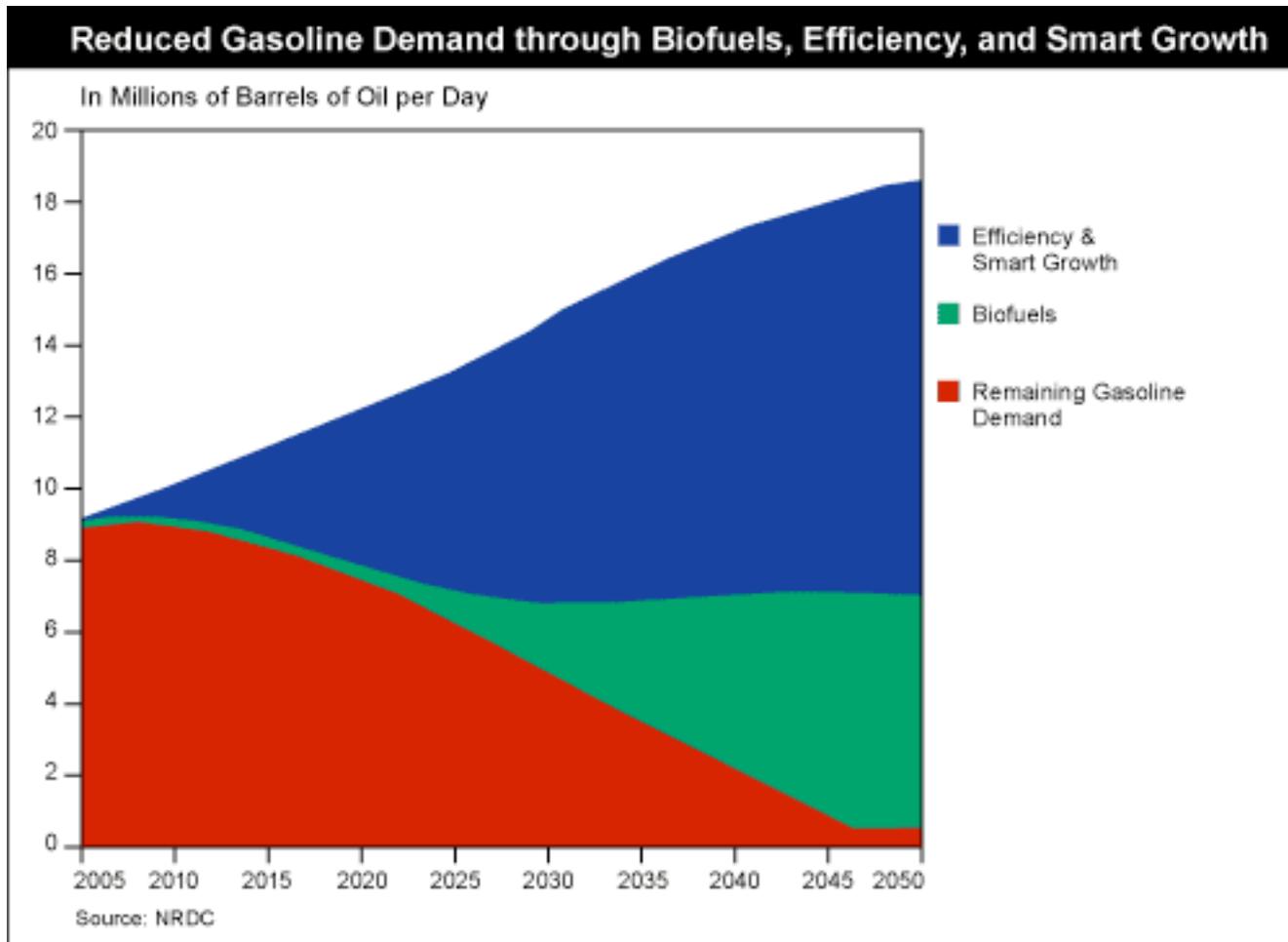
Polymer of glucose (sugar)



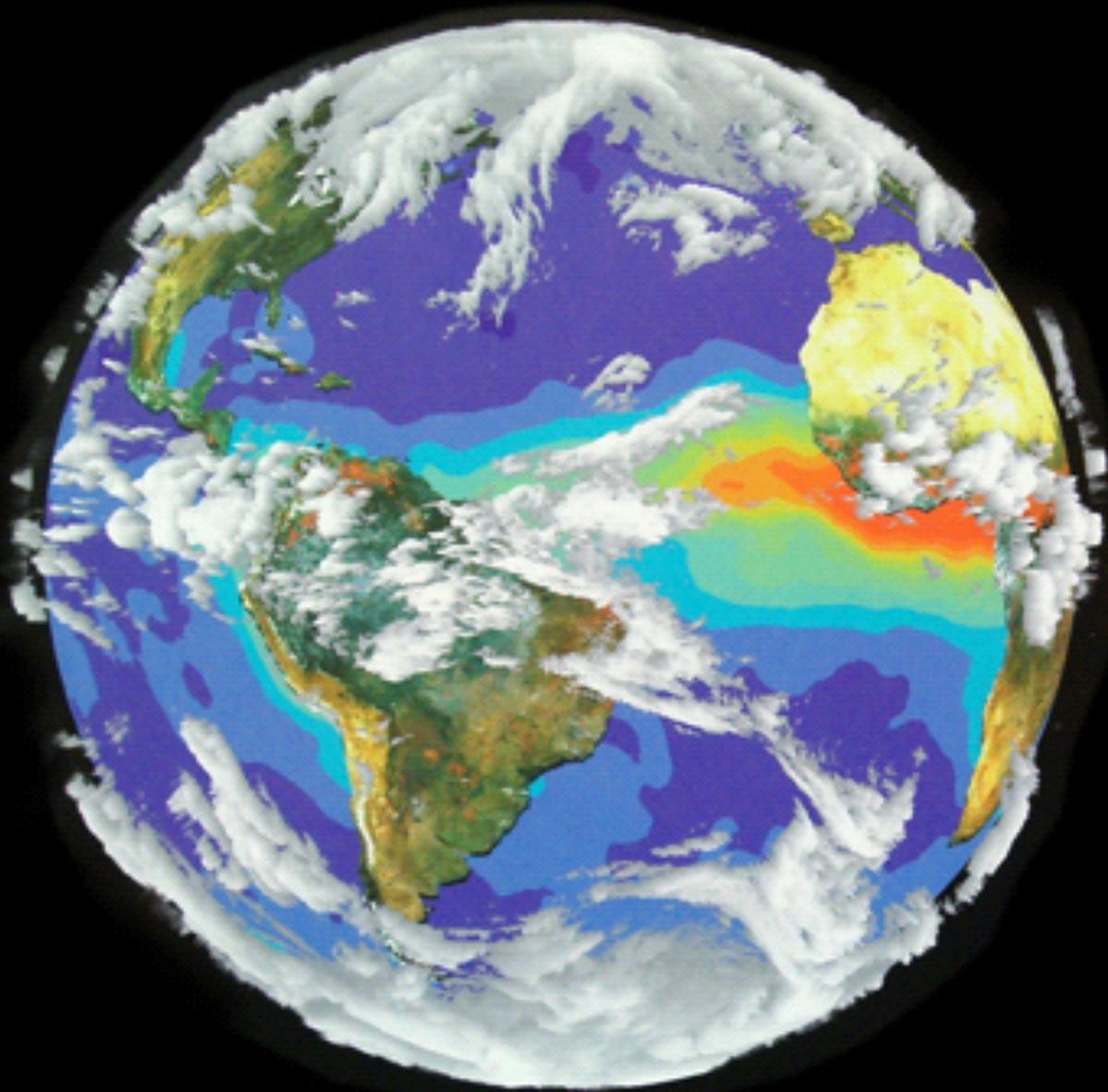
# Biofuels & the Environment

- How sustainable are biofuels grown in row crop agriculture?
  - pesticide use, nutrient runoff, erosion, high water use
- Need perennial cropping system (switchgrass); minimal tillage; soil & nutrients held in place
- At present, we consume 21 million barrels of oil/d.
- If we utilize all 72 million acres of corn for fuel –  
only 10% of demand;  
(what about food, fuel, fiber?)
- **Water footprint – HUGE**
  - 1L EtOH:500-5000 water for feedstock
  - 50 gal H<sub>2</sub>O/ mi driven: **Drink or Drive**





**Combined with better vehicle efficiency and smart-growth urban planning, biofuels could virtually eliminate our demand for gasoline by 2050.**



***What is the impact of our energy use on the Earth system?***

*This Earth image is a compilation of data from several different satellites that remotely sense vegetation, clouds, fires, and aerosols.*

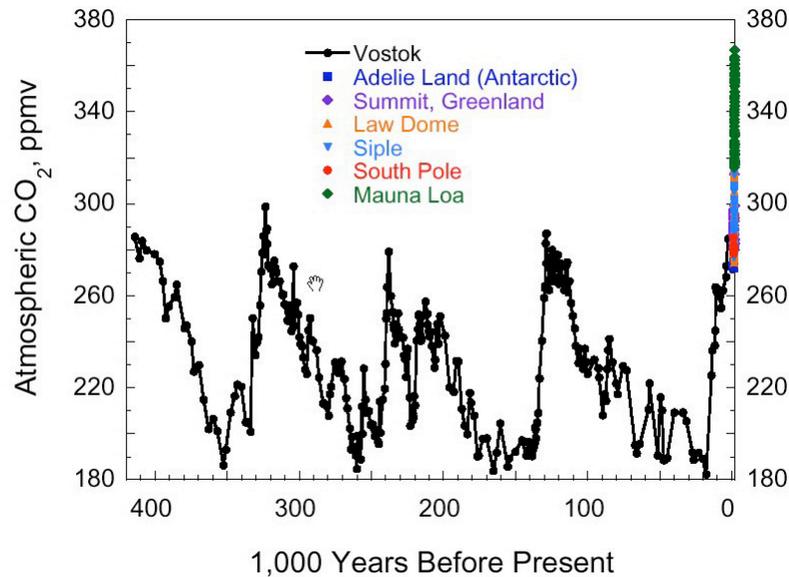
Image Source: NASA, Earth Science Enterprise, *Understanding Our Changing Planet*

URL: <http://departments.weber.edu/sciencecenter/nasa/lithographs/lit26.jpg>

# Climate Change

Atmospheric [CO<sub>2</sub>] : ~~400,000~~ years

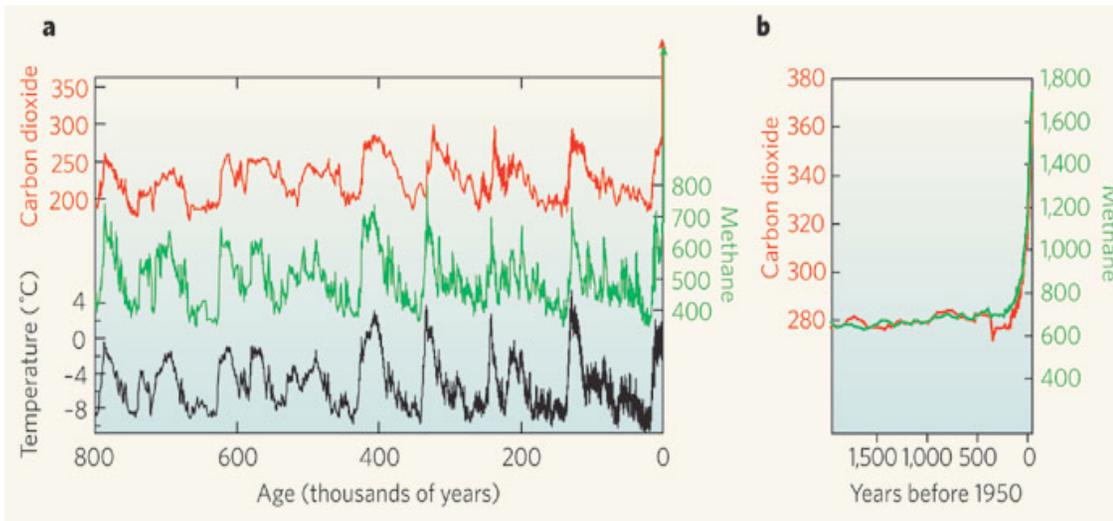
~~650,000~~  
800,000



CO<sub>2</sub> levels are rising faster than IPCC worse case (2.7%);

2006-2007 - 3.5%

1990s - 0.9%



**Palaeoclimate: Windows on the greenhouse Ed Brook *Nature* 453, 291-292(15 May 2008)**

# Global Warning

World leaders neglected early warnings about global warming. Now, without an all-out assault on carbon emissions, we'll soon see a

**"totally different planet."**

By Bill McKibben

- IPCC - Remarkably Conservative Document (AR4)
- Very High **Procrastination Penalty**
- NYT - U.S. predicting steady increase for emissions (3/3/07)



salon.com

*Editor's note:* This piece will appear in the March 15, 2007, issue of the [New York Review of Books](#).

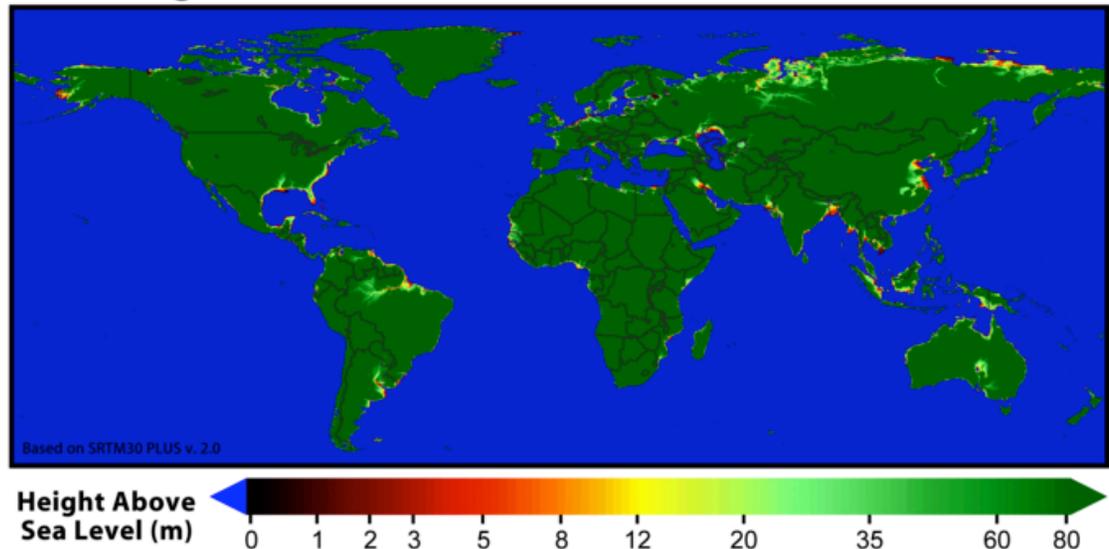
*It has appeared on [TomDispatch.com](#).*

# Glacial Melt & Sea Level Rise

Latest analysis (Pfeffer et al. Science, 2008) – Melting of fresh water ice sheets of Greenland + Antarctica will result in seal level rise between 2.5' – 6' by 2100.



Regions Vulnerable to Sea Level Rise



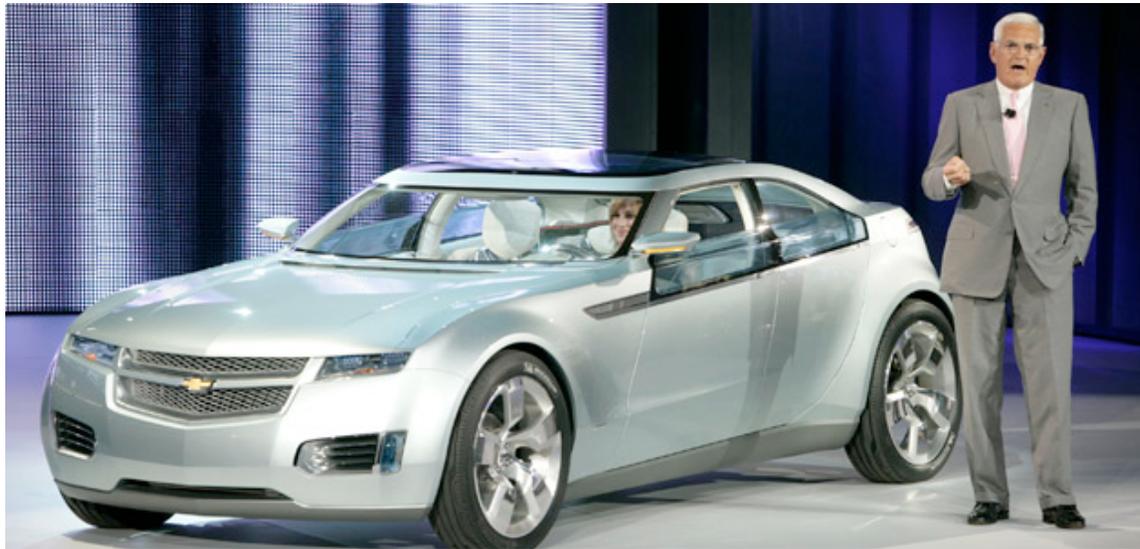
- **Energy R & D has fallen in all industrialized countries except Japan**
  - In US - peak spending was in 1980
  - World-wide - \$15 Billion
  - US - < 2% of total R & D spending
  - National Science Budget for Renewable/Efficiency (\$1B) compared to NIH (\$29B).
  - Total private R&D funding for the entire energy sector is less than that of a single large biotech company (e.g., Amgen, \$2.3B in 2005)
  - Ecomagination (GE) - \$700M R&D (2005) - \$1.5B R&D (2010)



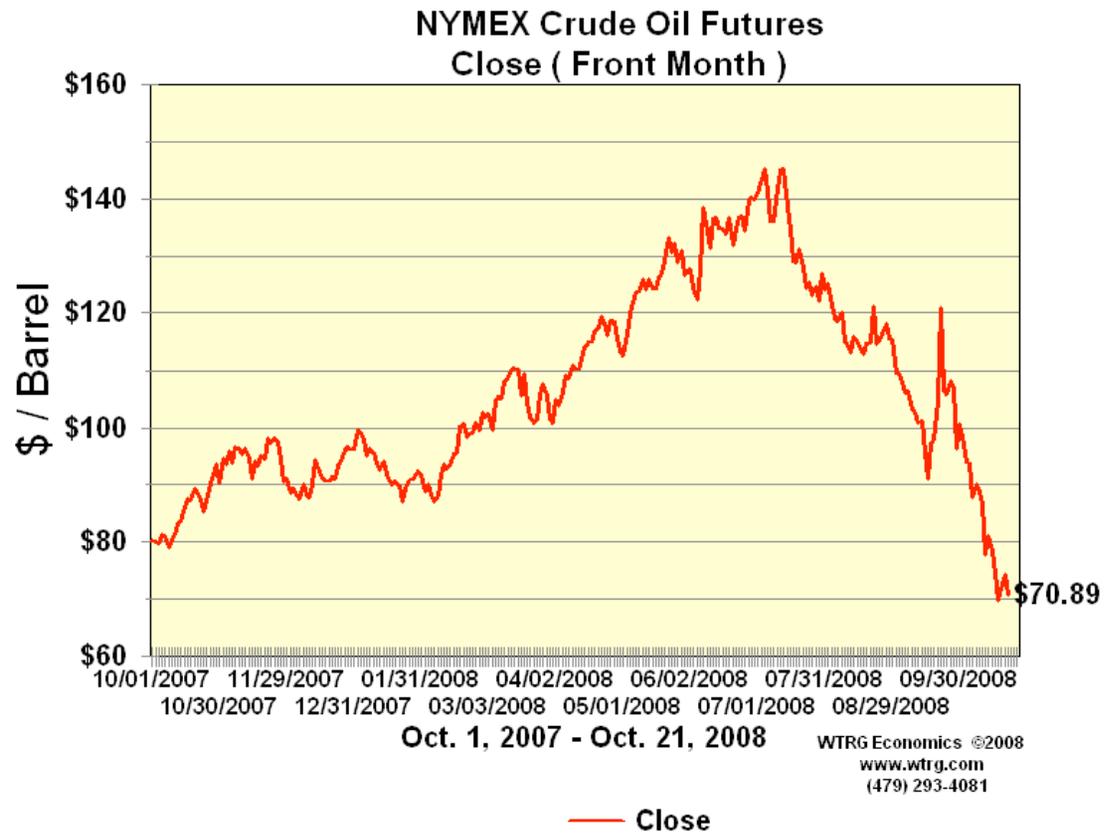
THINK - All-electric, Norwegian, 110 mile range, top speed 65 mpg, 95% recyclable materials, 2-seater



## Bob Lutz: Volt Is U.S. Car Industry's Moon Shot



Unlike traditional electric cars, Chevy Volt has a revolutionary propulsion system that takes you beyond the power of the battery. It will use a **lithium-ion battery** with a variety of range-extending onboard power sources, including gas and, in some vehicles, E85 ethanol(3) to recharge the battery while you drive beyond the **40-mile battery range**. And when it comes to being plugged in, Chevy Volt will be designed to use a **common household plug**



**Need floor to price of oil & C-tax**

# CONCLUSIONS

- Are we running out of oil?

No, but remaining oil is at ever increasing \$, energy, & environmental cost.

- Does it make sense to continue to rely on oil & other fossil fuels given high costs and impacts?

No, but the shift from fossil fuels will take political will, leadership and large investments in both new technology (R & D + infrastructure) and patterns of behavior. . . C tax?

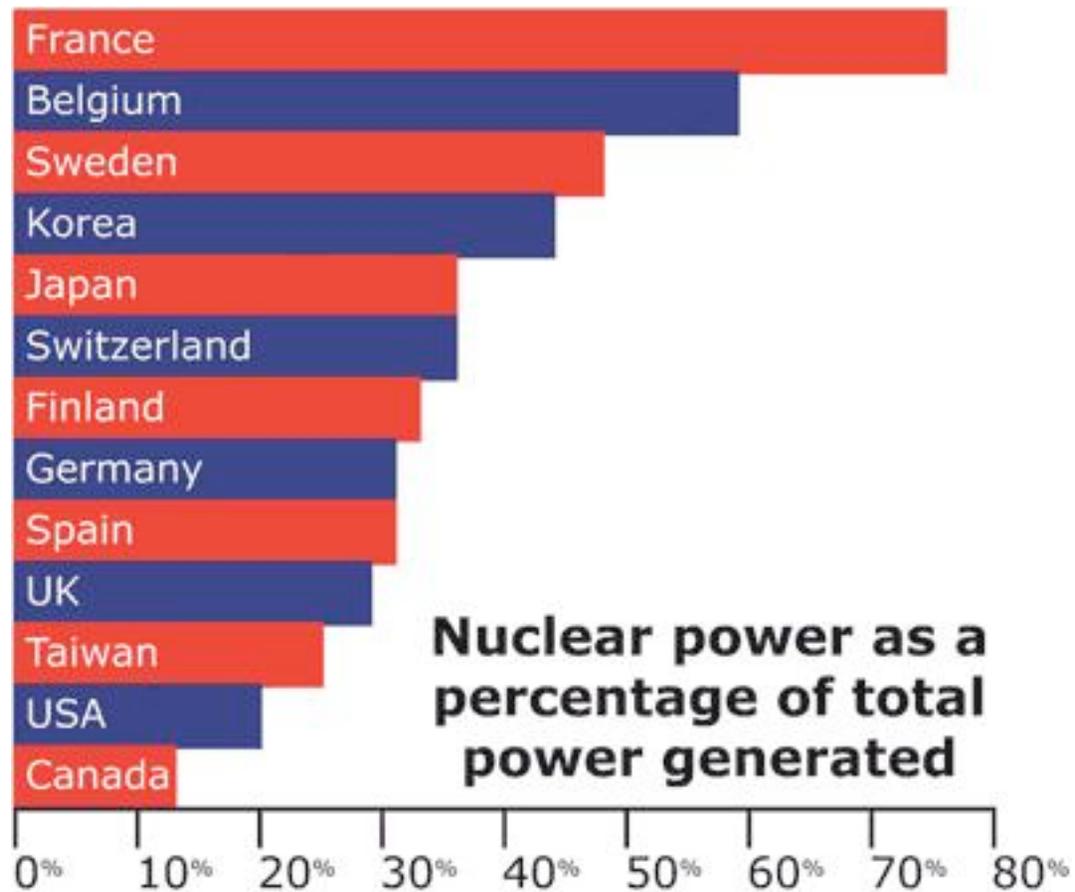
- Need to redesign cities: Buildings, settlement patterns, transportation systems.

- Alternative energy sources, reduced demand & changed uses ALL required. Energy needs to be:

Distributed  
Local  
Renewable  
Mimic Nature



## Follow-up on Nuclear Energy question:



Waste - reprocess, reduce volume, stockpile/store,  
**NOT** bury, in France @ 4 locations;

<http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/french.html>

## NUCLEAR REACTION

WHY DO AMERICANS FEAR NUCLEAR POWER?

Why the French Like Nuclear Energy  
by FRONTLINE producer Jon Palfreman

A popular French riposte to the question of why they have so much nuclear energy is "no oil, no gas, no coal, no choice."



Claude Mandil, the General Director for Energy and Raw Materials at the Ministry of Industry, cites at least three reasons.

**First, he says, the French are an independent people.** The thought of being dependent for energy on a volatile region of the world such as the Middle East disturbed many French people. Citizens quickly accepted that nuclear might be a necessity. A popular French riposte to the question of why they have so much nuclear energy is "no oil, no gas, no coal, no choice."

**Second, Mandil cites cultural factors.** France has a tradition of large, centrally managed technological projects. And, he says, they are popular. "French people like large projects. They like nuclear for the same reasons they like high speed trains and supersonic jets." Part of their popularity comes from the fact that scientists and engineers have a much higher status in France than in America. Many high ranking civil servants and government officials trained as scientists and engineers (rather than lawyers, as in the United States), and, unlike in the U.S. where federal administrators are often looked down upon, these technocrats form a special elite. Many have graduated from a few elite schools such as the Ecole Polytechnic. According to Mandil, respect and trust in technocrats is widespread. "For a long time, in families, the good thing for a child to become was an engineer or a scientist, not a lawyer. We like our engineers and our scientists and we are confident in them."

**Thirdly, he says, the French authorities have worked hard to get people to think of the benefits of nuclear energy as well as the risks.** Glossy television advertising campaigns reinforce the link between nuclear power and the electricity that makes modern life possible. Nuclear plants solicit people to take tours--an offer that six million French people have taken up. Today, nuclear energy is an everyday thing in France.

## Some data about U:

- Uranium has a lot of isotopes (~ 16 or more).. among the naturally occurring there are:  
[U-234](#) ( 0.0055% ) [U-235](#) ( 0.720% ) [U-238](#) ( 99.2745% )
- Uranium needs to be enriched in U-235 to ~ 4% in order to be used in a conventional nuclear power plant - the only ones working today for generating energy.
- There are about 50 years of proved reserves of Uranium if one only uses U-235 as the major combustible and if the demand stays the same as it is today. If there were to be a significant increase in demand for U in conventional nuclear power plants this will decrease... There are estimated additional and potential sources leading to maybe 80 to 120 years of this fuel.
- Now, if one were able to use U-238, as it is used in a fast breeder - only one worked and is maybe still working at the pilot scale in France (?)- then we will have quite a few years ahead of us ...
- Lovelock is suggesting that we move full speed towards using nuclear energy instead of burning fossil fuels. The big problem with a fast breeder is that it generates Pu - plutonium - that then can be burned again OR used to make bombs.. => big security problems!