The Earth is warming.

IPCC 2006 study:

90- 99% probable that the measured temperature rise is caused by humans.

Significant climate change could lead to:

- Increased damage from storms, floods, wildfires
- Property losses and population displacement from sea-level rise
- Productivity of farms, forests, & fisheries
- Increased species extinction
- Spread of disease (malaria, cholera, dengue fever, …)
- **Water Shortage**

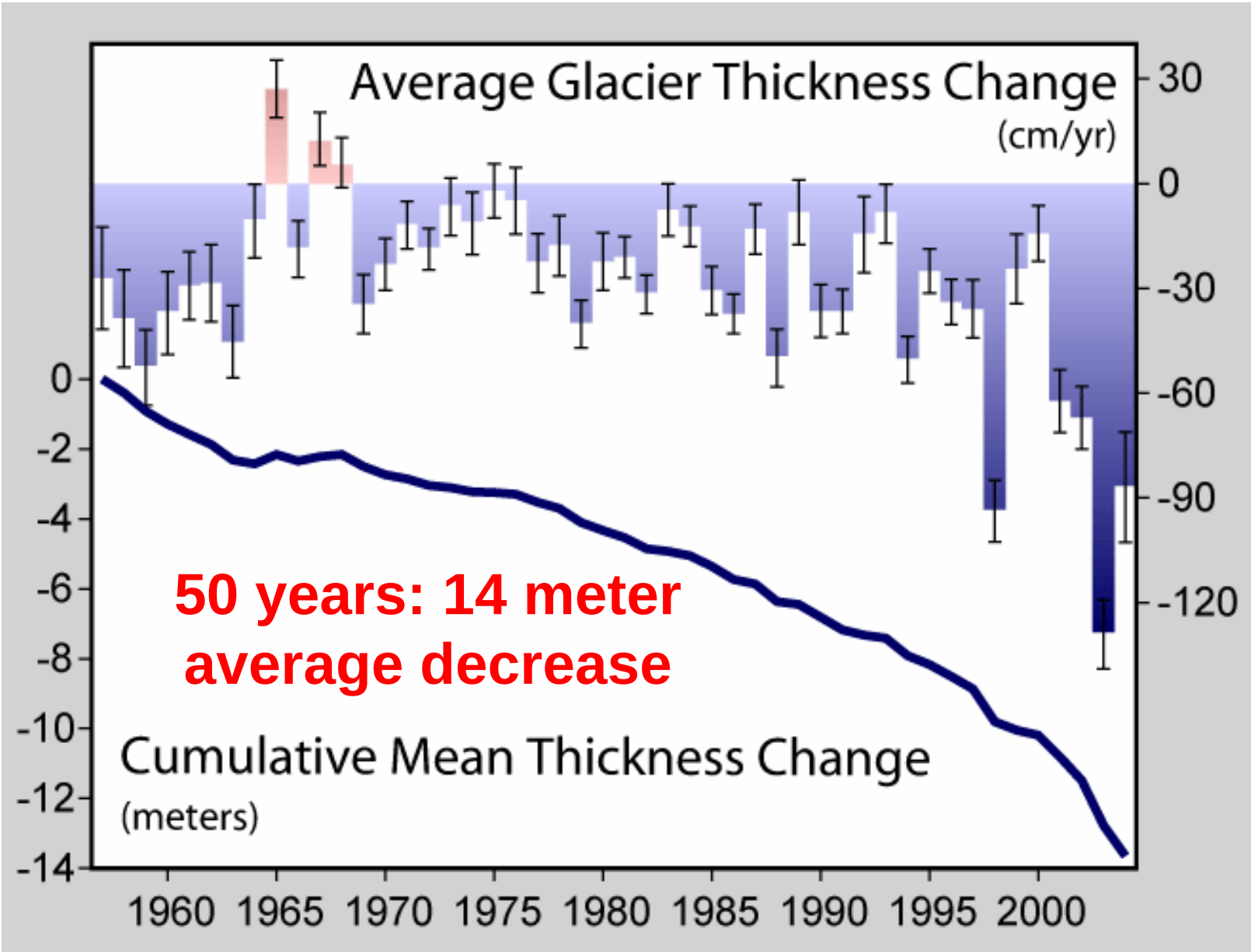
Emissions pathways, climate change, and impacts on California

K. Hayhoea, et al., PNAS **101**, 12422 (2004)

Using two climate models that bracket most of the IPCC emissions scenarios:

	B1	A1 fi
Heat wave mortality:	**2-3x**	**5-7x**
Alpine/subalpine forests	**50–75%**	**75–90%**
Sierra snowpack	**30–70%**	**73–90%**

Snowpack in major glacier water sources all over the world will be affected.


Average Glacier Thickness Change
(cm/yr)
30
0
-30
-60
-90
-120
0
-2
-4
-6
-8
-10
-12
-14
50 years: 14 meter
average decrease
Cumulative Mean Thickness Change
(meters)
1960 1965 1970 1975 1980 1985 1990 1995 2000

Frequently asked questions:

Bio-fuels can not solve the energy and climate change problem.

Why aren't you working on the most important problem: energy conservation and efficiency?

A dual strategy is needed to solve the energy problem:

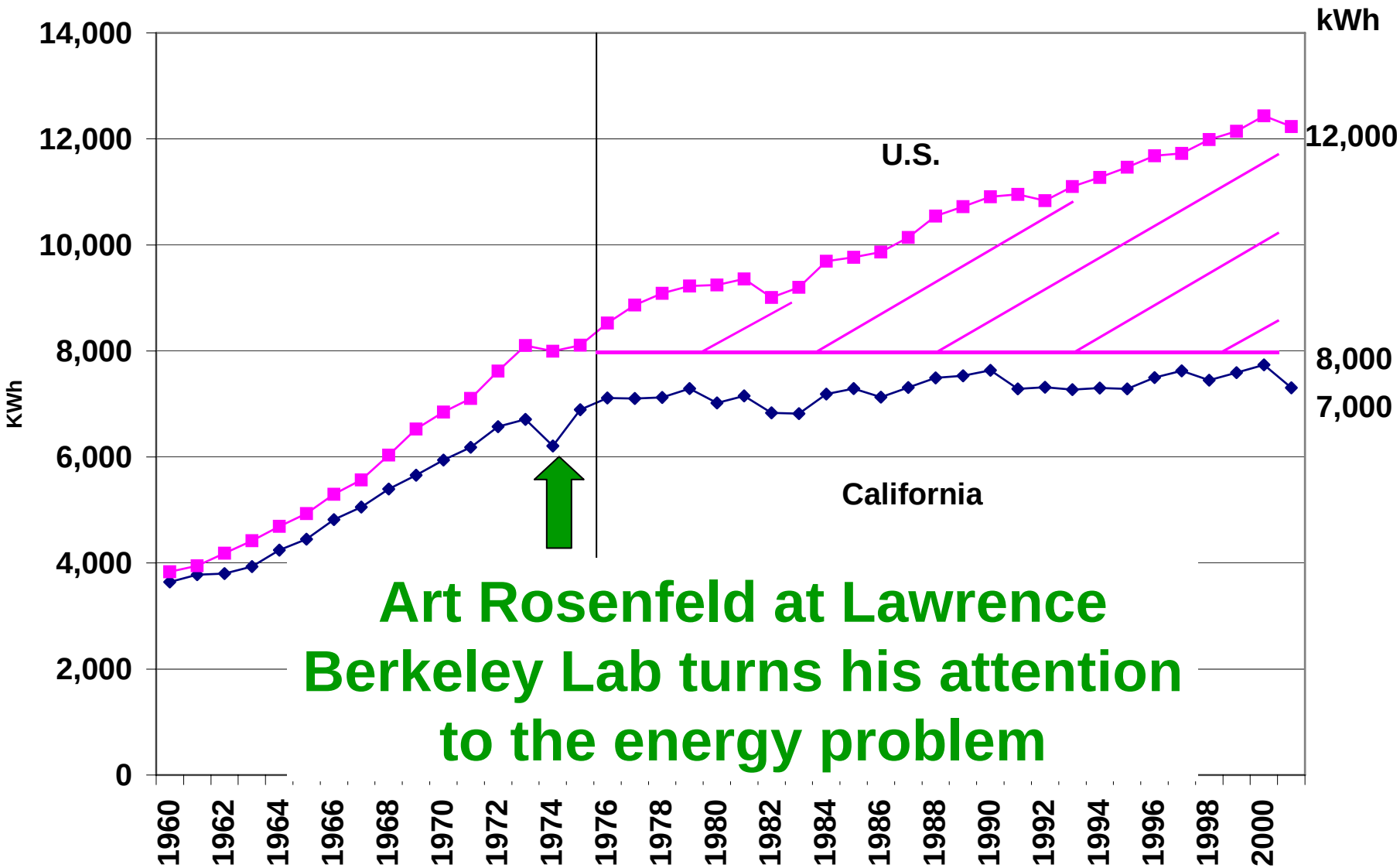
1) Maximize energy efficiency and minimize energy use

   Steve Selkowitz (Energy and Environ. Tech. Div., LBNL)

2) Develop new sources of clean energy

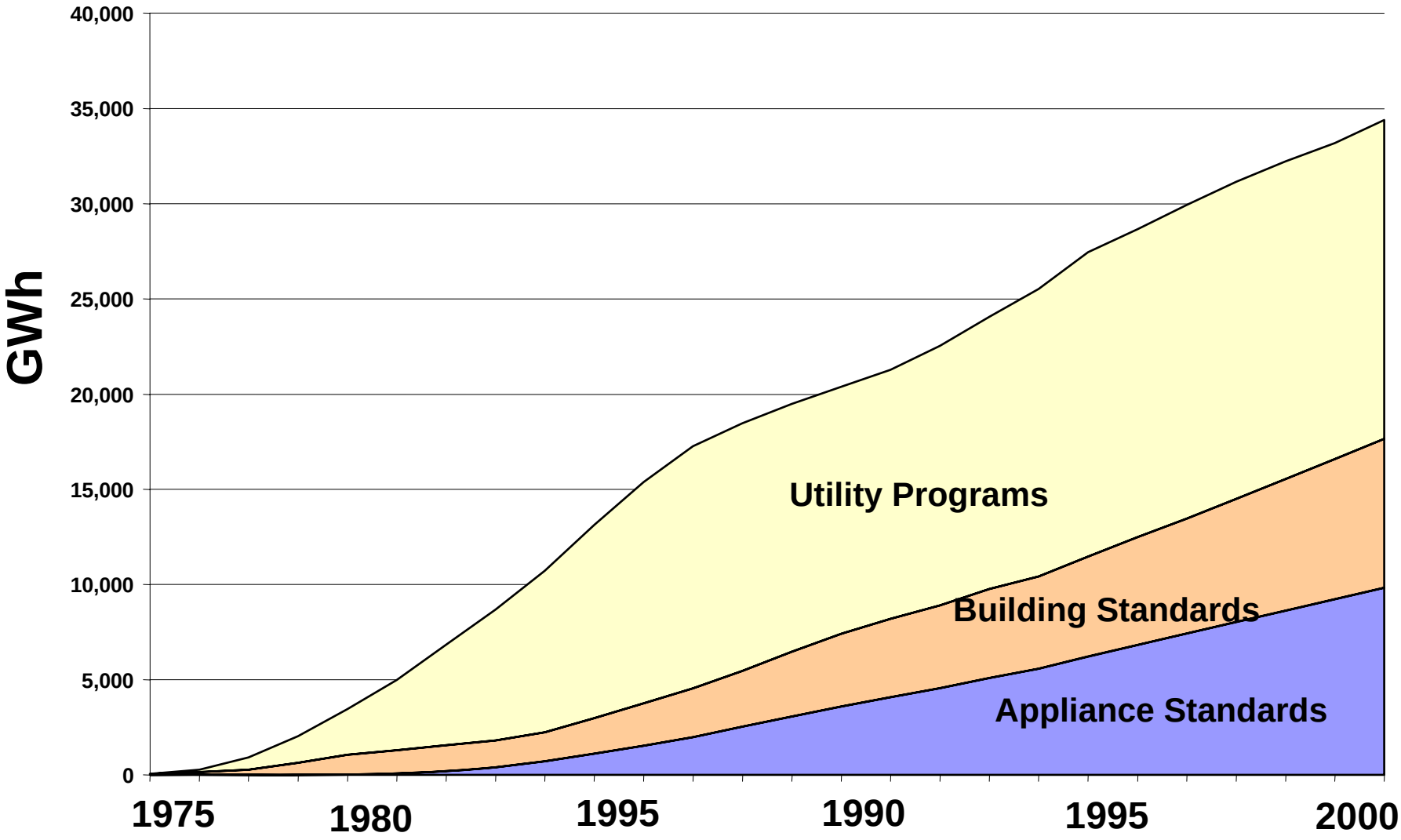
   Bio-fuels (Chris Somerville, Stanford and LBNL)

Electricity Consumption/person in the US and California



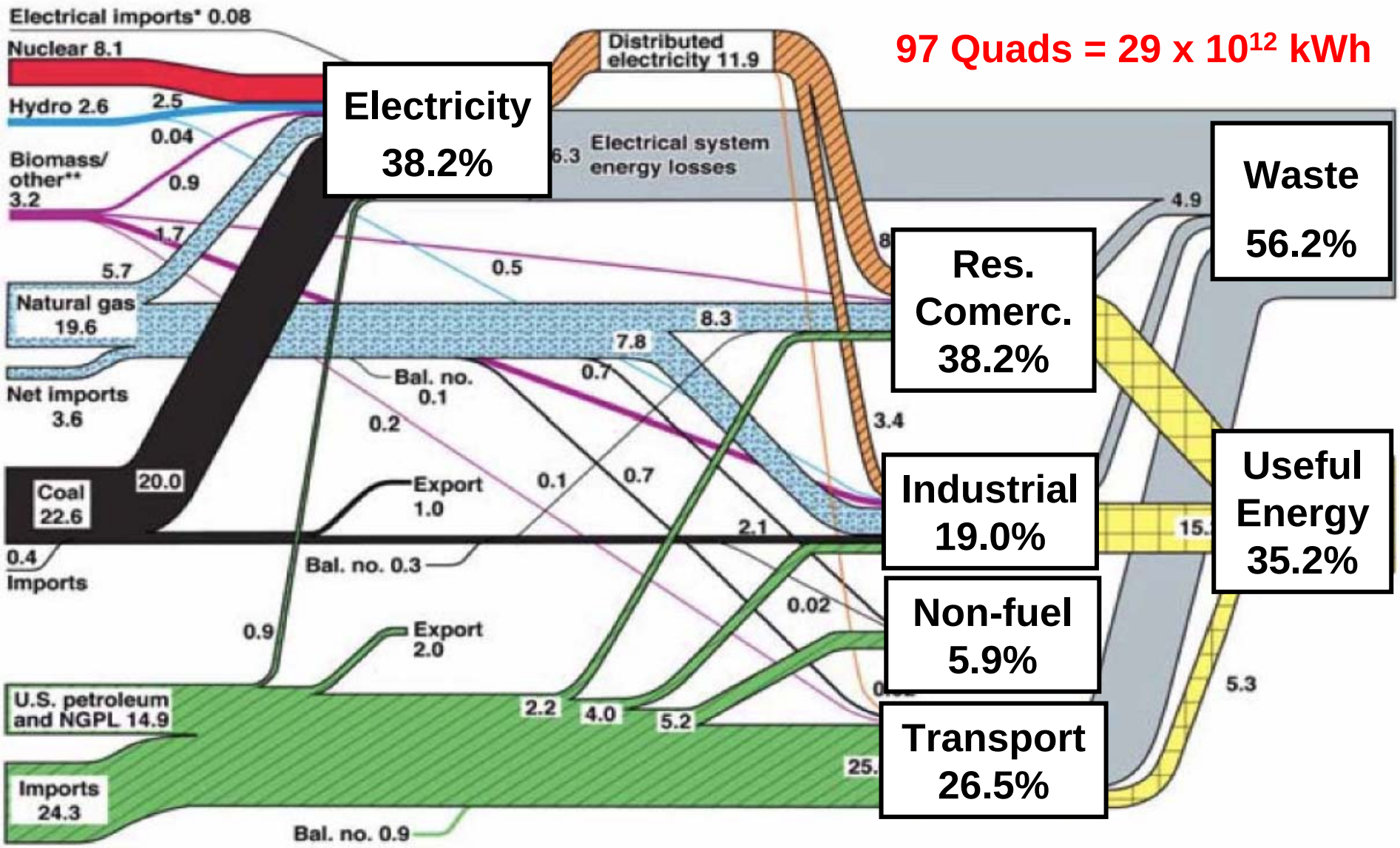
Art Rosenfeld at Lawrence Berkeley Lab turns his attention to the energy problem

Half of the energy savings in California were made by separating utility profits from selling more energy



Source: Mike Messenger, Calif. Energy Commission Staff, April 2003

U.S. Energy Flow Trends – 2002
Net Primary Resource Consumption ~97 Quads



97 Quads = 29 x 10^{12} kWh

International Energy Agency (IEA) forecast

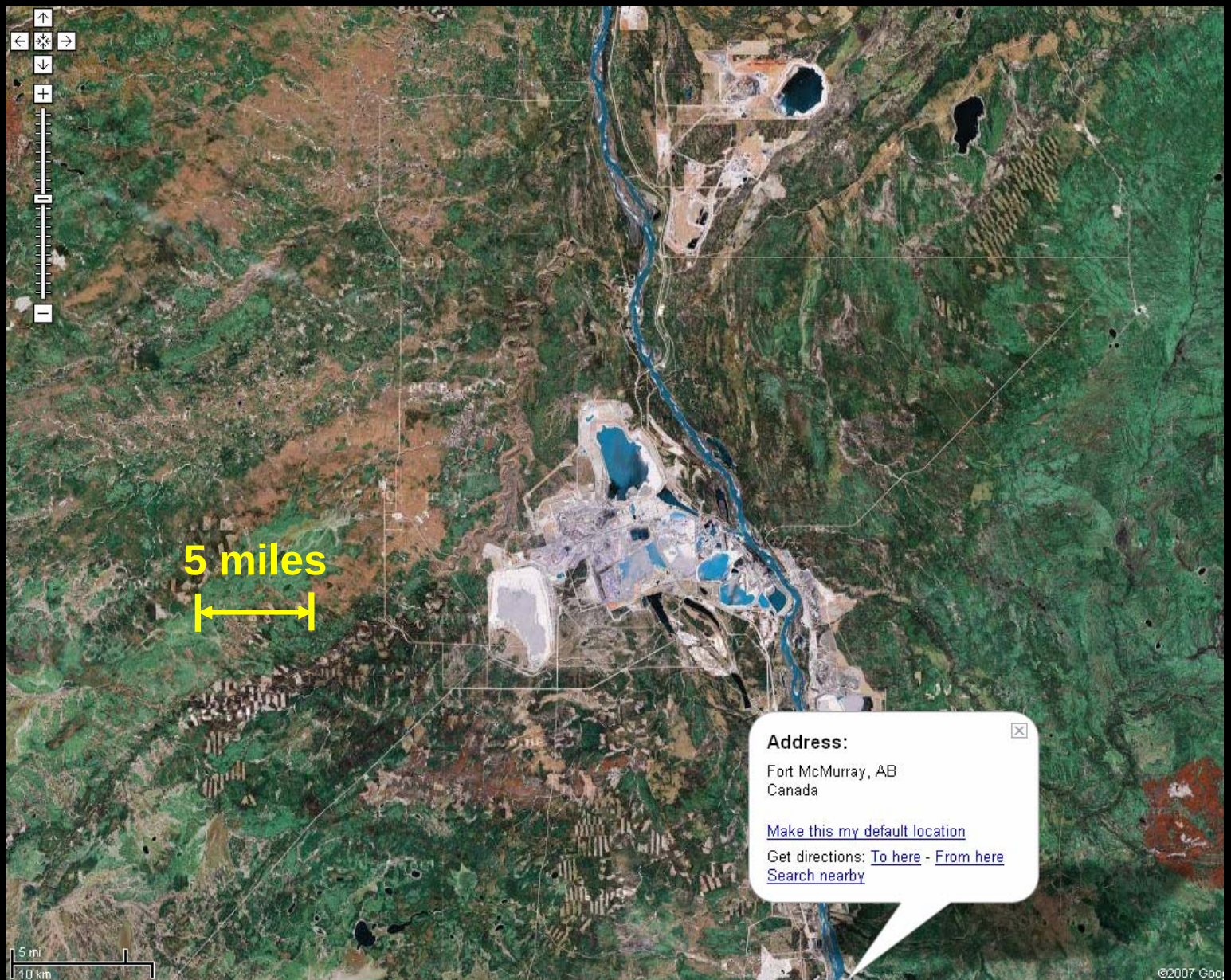
67% of the world supply of coal:

US	27%
Russia	17%
China	13%
India	10%

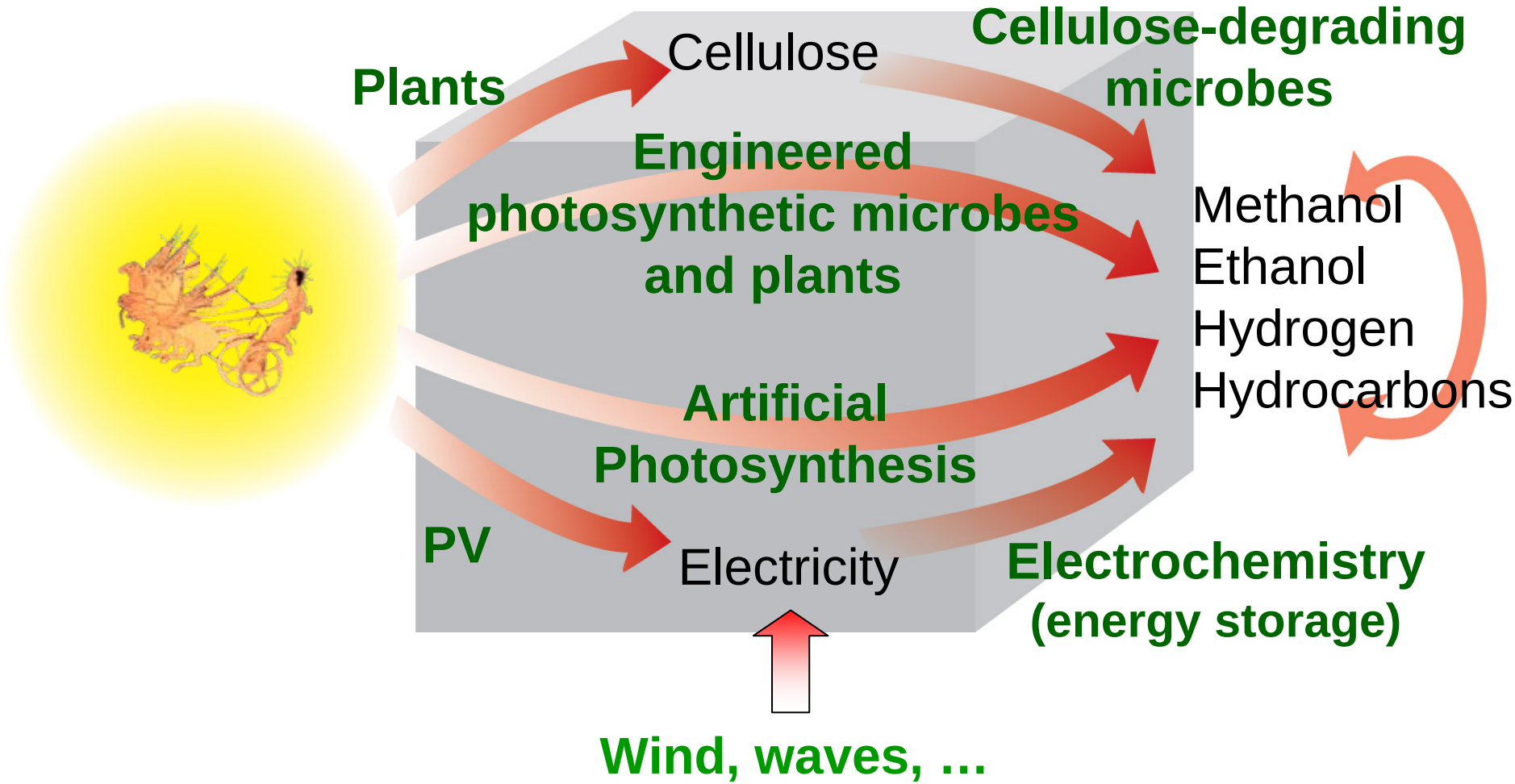
Liquefaction of coal remains a possibility to reduce oil dependency.

China, and India.

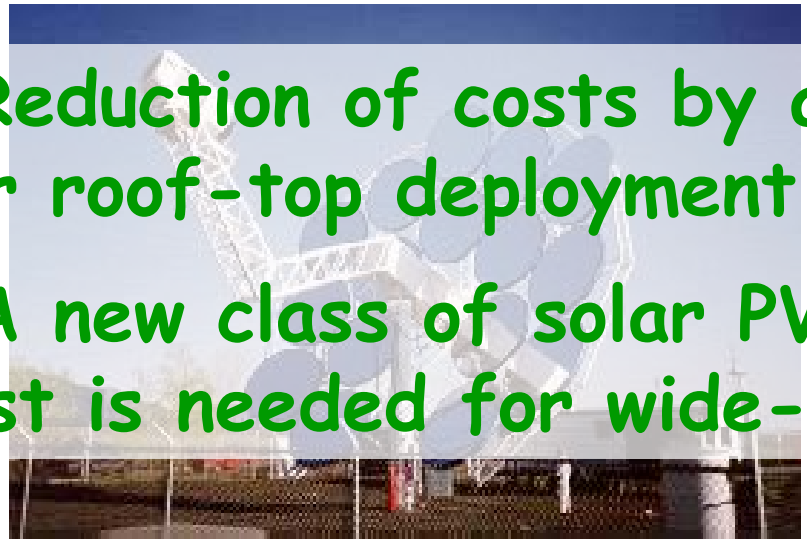
Google satellite image of a tars sands open pit mining facility near Fort McMurray Canada.



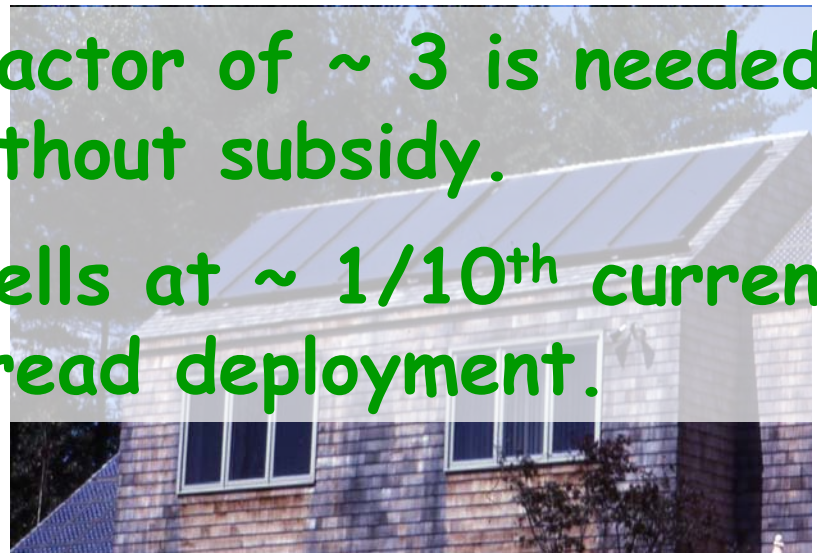
Helios: Lawrence Berkeley Laboratory's attack on the energy problem



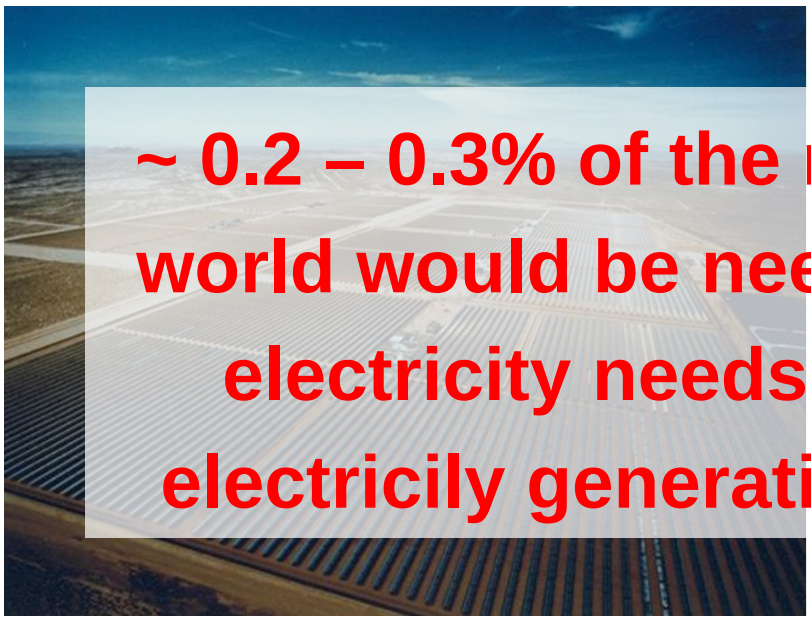
Solar thermal

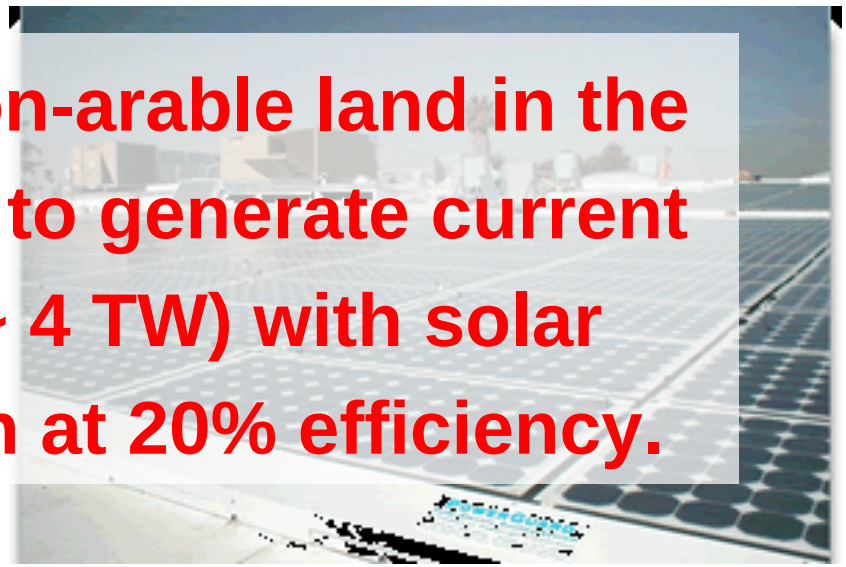


Solar photovoltaic



- Reduction of costs by a factor of ~ 3 is needed for roof-top deployment without subsidy.
- A new class of solar PV cells at ~ 1/10th current cost is needed for wide-spread deployment.





~ 0.2 – 0.3% of the non-arable land in the world would be need to generate current electricity needs (~ 4 TW) with solar electricily generation at 20% efficiency.

Frequently asked questions:

How can there be enough arable land to grow energy and food?

Total Surface Area by Land Cover/Use and Year in Millions of Acres, with Margins of Error

Year	Cropland*	CRP Land*	Pastureland	Rangeland
1982	419.9 ± 2.1	0.0 ± 0.0	131.1 ± 1.4	415.5 ± 3.5
1992	381.3 ± 2.0	34.0 ± 0.2	125.2 ± 1.5	406.8 ± 3.3
1997	376.4 ± 2.0	32.7 ± 0.2	119.5 ± 1.5	404.9 ± 3.3
2001	369.5 ± 2.0	31.8 ± 0.2	119.2 ± 1.8	404.9 ± 3.4
2003	367.9 ± 2.4	31.5 ± 0.3	117.0 ± 1.8	405.1 ± 3.5

In 21 years, Agriculture land use decreased by:

Cropland 52.0 M acres

Pasture land 14.1 M acres

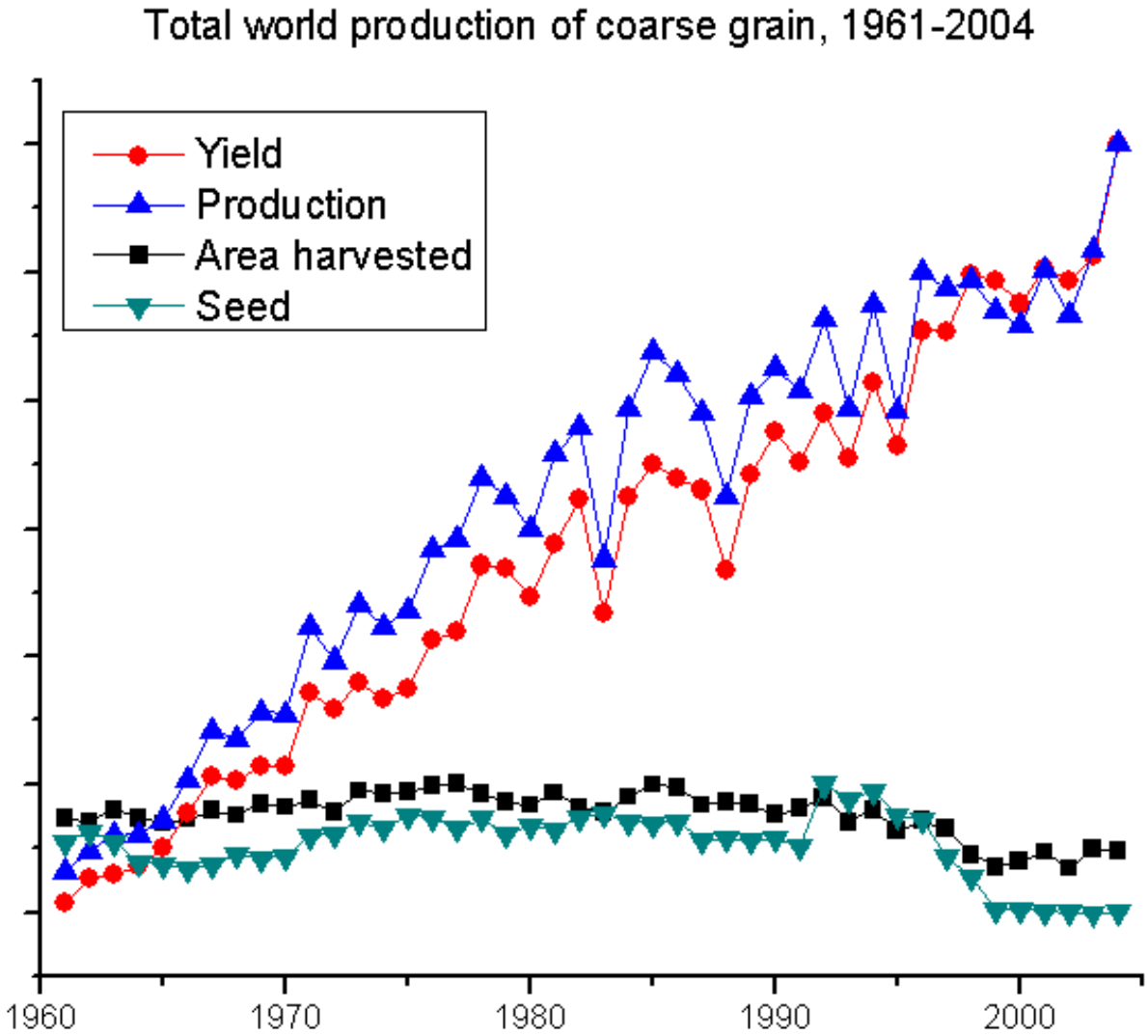
Rangeland 10.4 M acres

Conservation Reserve Program increase:

31.5 M acres

*CRP was not in [illegible] includes cultivate

Source: US Dept of Agriculture



1960:
Population = 3 B

2005:
Population = 6.5 B

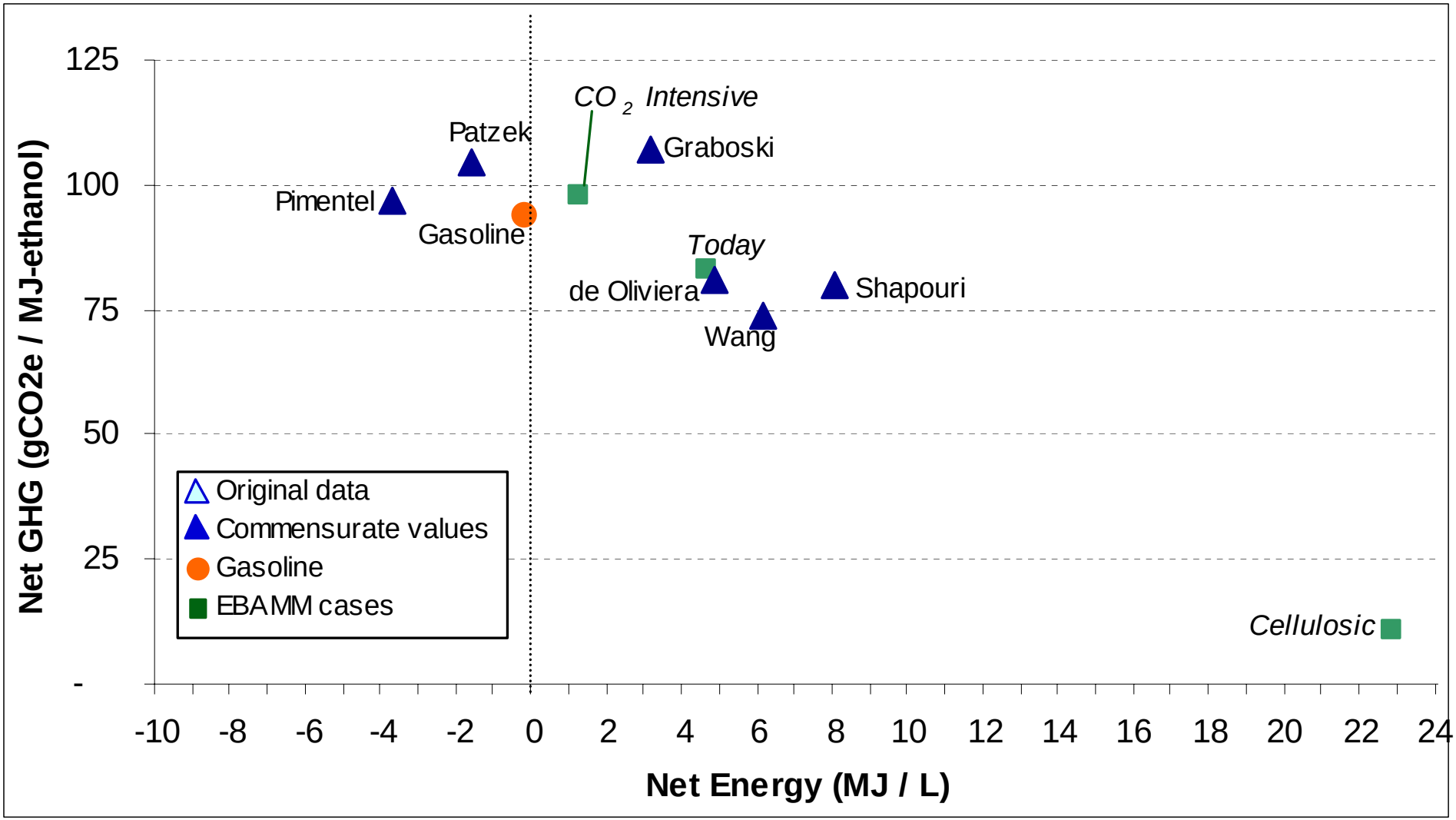
Source: Food and Agriculture Organization (FAO), United Nations

Frequently asked questions:

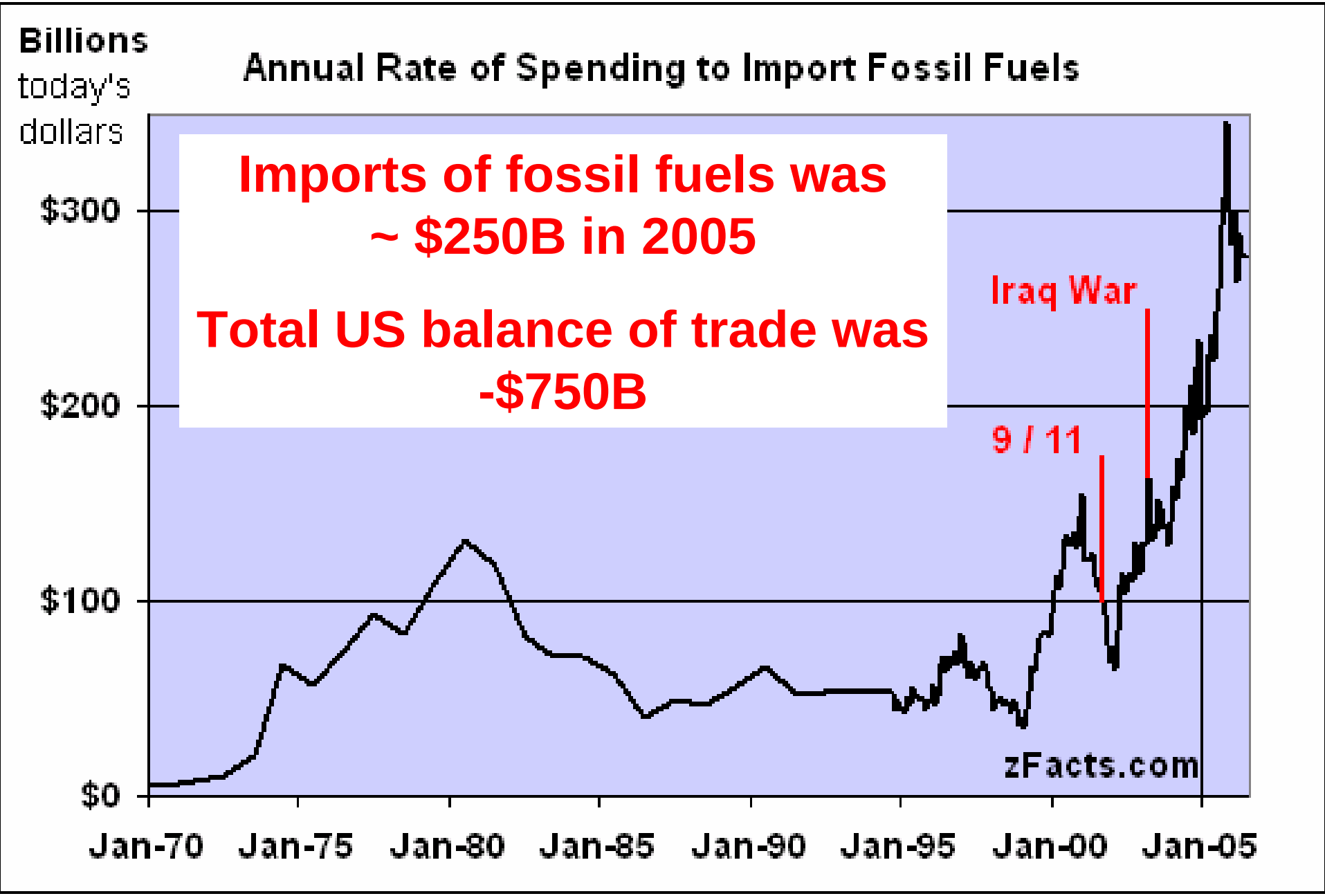
Growing corn for ethanol does not reduce greenhouse emissions and will only be able to replace a small fraction of oil use.

How can any bio-fuel be a significant part of the energy solution?

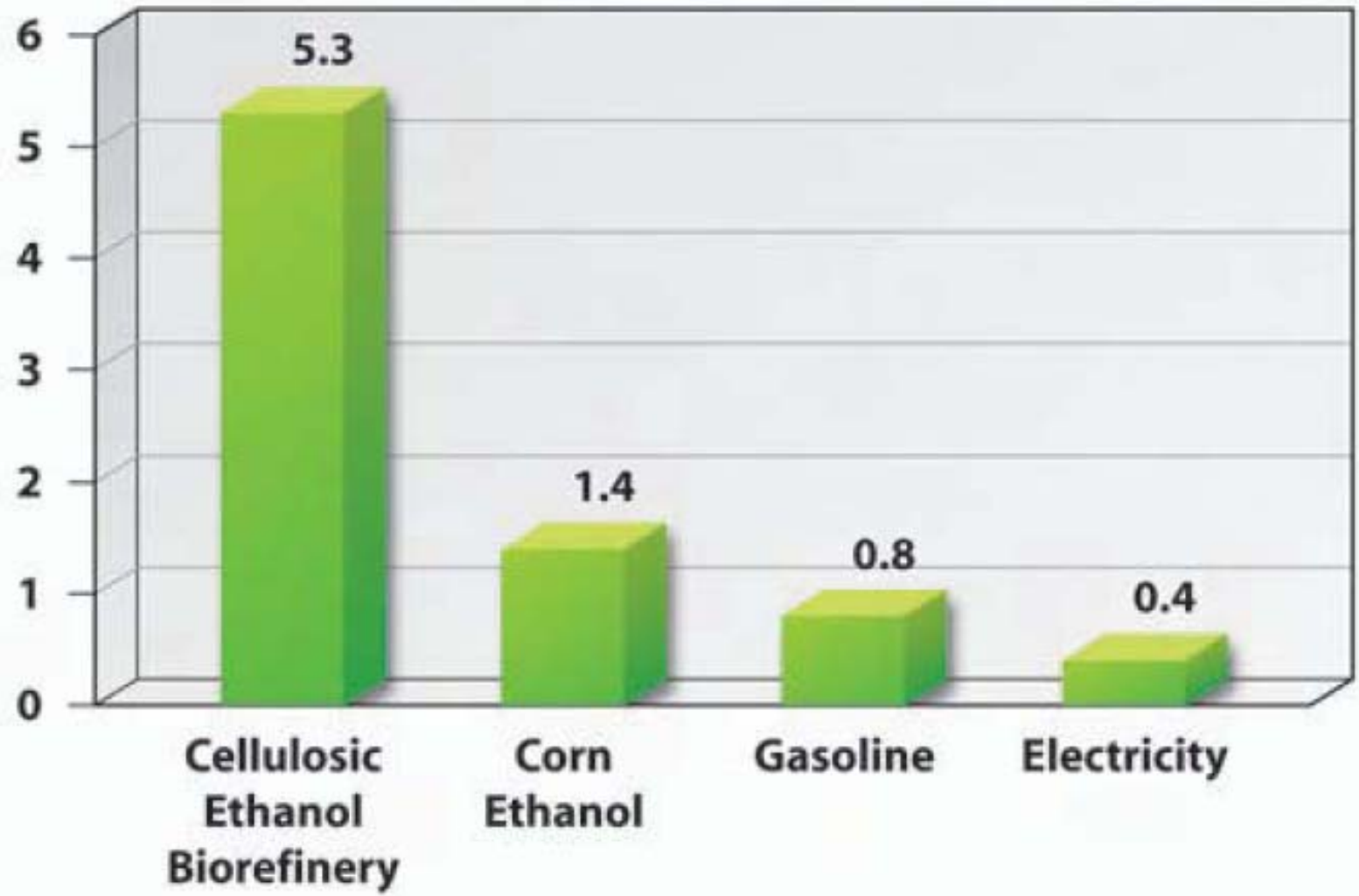
Greenhouse Gases



Alex Farrell, Dan Kammen, et. al.,
"Meta-analysis" of existing literature, Science 2006


Billions
today's
dollars
Annual Rate of Spending to Import Fossil Fuels
Imports of fossil fuels was
~ $250B in 2005
Total US balance of trade was
-$750B
Iraq War
9 / 11
zFacts.com
$300
$200
$100
$0
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05

$$\text{Fossil Energy Ratio (FER)} = \frac{\text{Energy Delivered to Customer}}{\text{Fossil Energy Used}}$$



Feedstock grasses (*Miscanthus)* is a largely unimproved crop. Non-fertilized, non-irrigated test field at U. Illinois can yield a factor of 10 more ethanol / acre than corn.

50 M acres of energy crops plus agricultural wastes (wheat straw, corn stover, wood residues, etc.) can produce ***half*** to ***all*** of current US consumption of gasoline.

Switch grass

Miscanthus

Frequently asked questions:

Current US agriculture practice is not fully sustainable … the water tables are decreasing due to heavy irrigation and becoming polluted due to heavy fertilizer use.

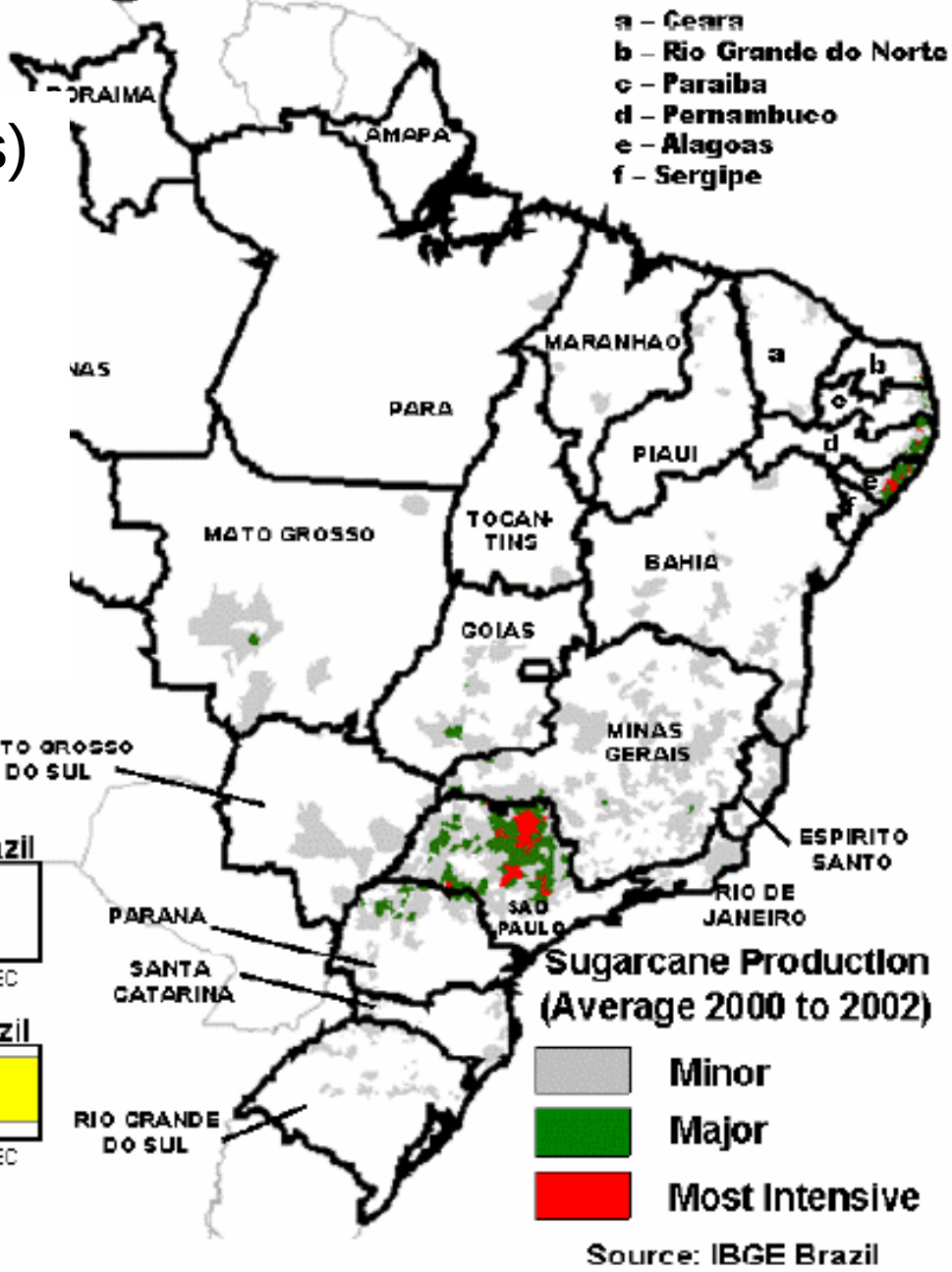
Won't growing crops for energy make this problem worse?

Advantages of perennial plants such as grasses:

- No tillage for ~ 10 years after first planting
- Long-lived roots establish symbiotic interactions with bacteria to acquire nitrogen and mineral nutrients.
- Some perennials withdraw a substantial fraction of mineral nutrients from above-ground portions of the plant before harvest.
- Perennials have lower fertilizer runoff than annuals. (Switchgrass has ~ 1/8 nitrogen runoff and 1/100 the soil erosion of corn.)

Brazil Sugarcane

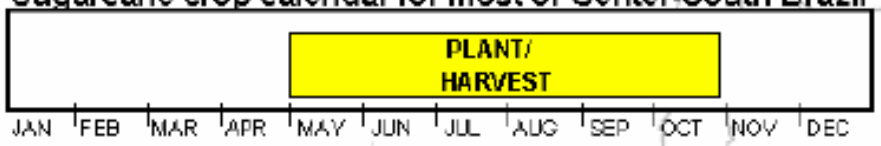
- ~ 60 M hectares (12 M acres) used for agriculture
- ~ 5 M hectares used for sugar cane production
- ~ 2.5 million hectares for ethanol



* State-Level Production

Source: IBGE Brazil

Sugarcane crop calendar for most of Center-South Brazil



Sugarcane crop calendar for most of Northeastern Brazil

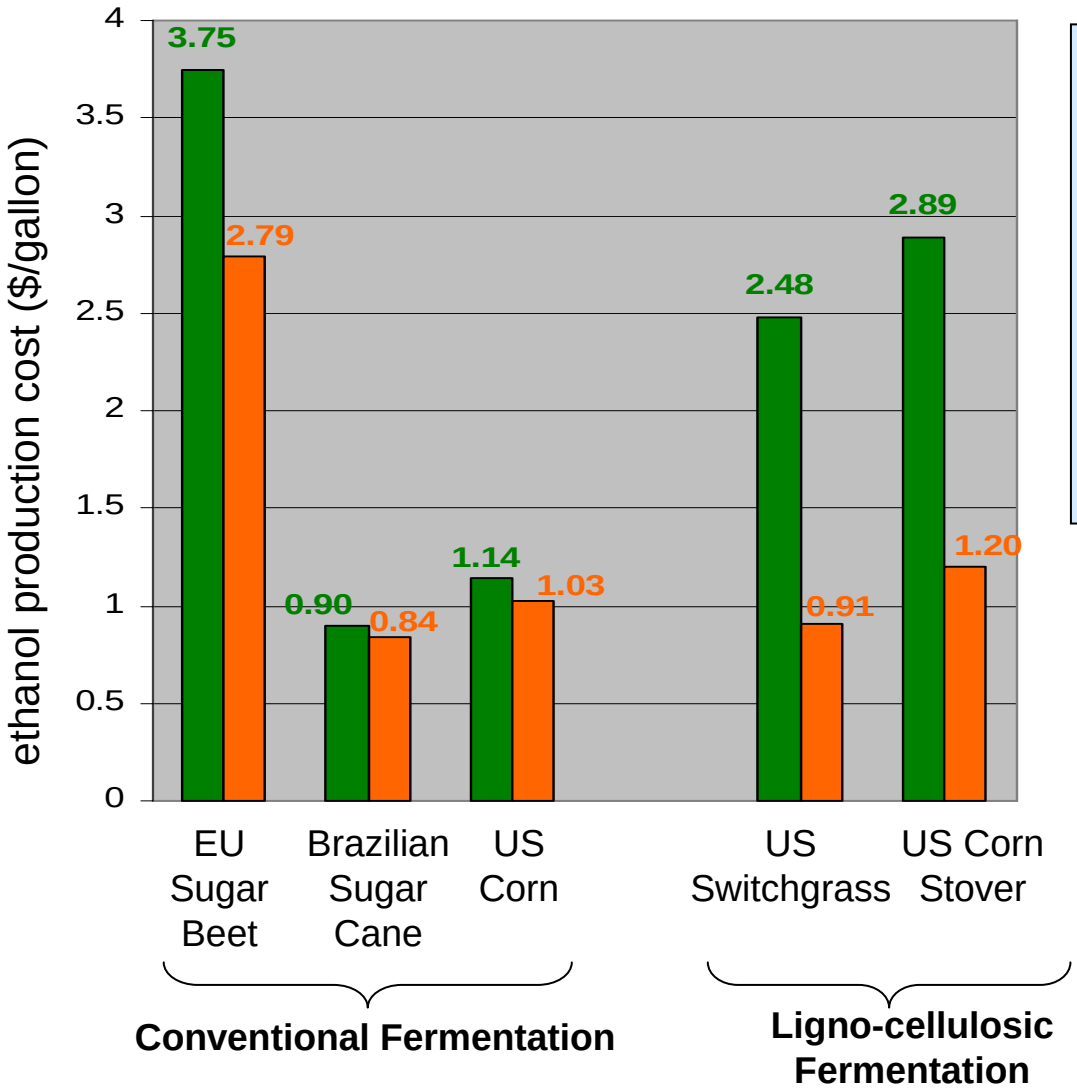
USDA World Agricultural Outlook Board
Joint Agricultural Weather Facility

Frequently asked questions:

If these grasses are so much better than corn or even sugar cane, why aren't they being grown today?

current and projected production costs of bio-gasoline components

Courtesy Steve Koonin, BP Chief Scientist



- Ligno-cellulosic biomass is the key to materiality and sustainability of biofuels in long term
- Currently uneconomic – 1/2 pilot plants operating
- Technology advances will dramatically reduce costs

Key:

- Base case
- 10 year plausible technology stretch

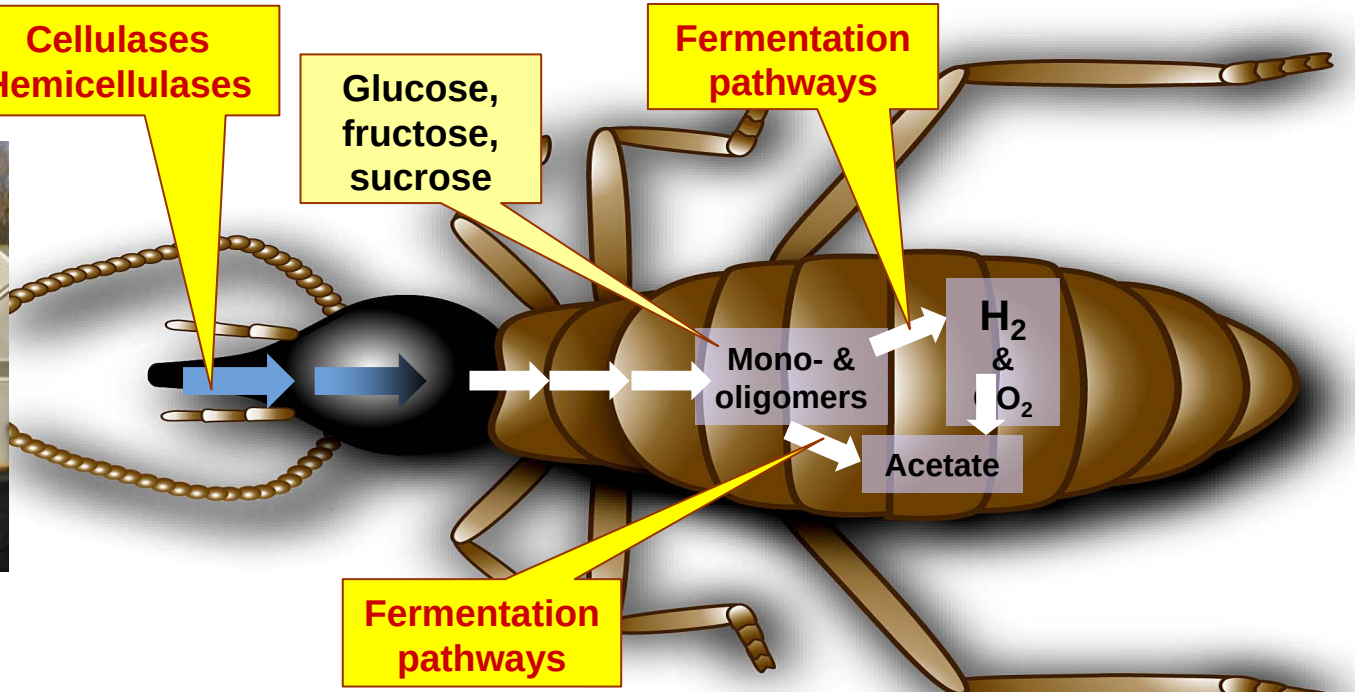
Source: BP Analysis, NREL, CERES, NCGA

Commercial ethanol production from cellulose

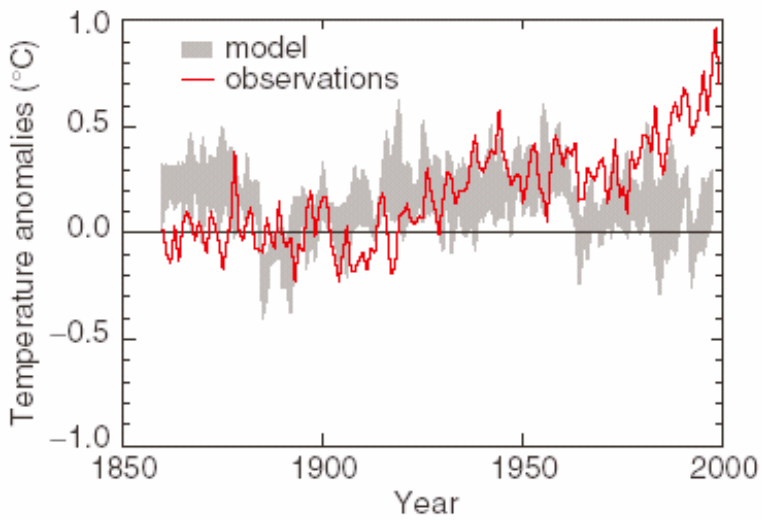
The biggest energy gains will come from improved fuel production from cellulose/lignin

Termites have many specialized enzymes for efficiently digesting lignocellulosic material

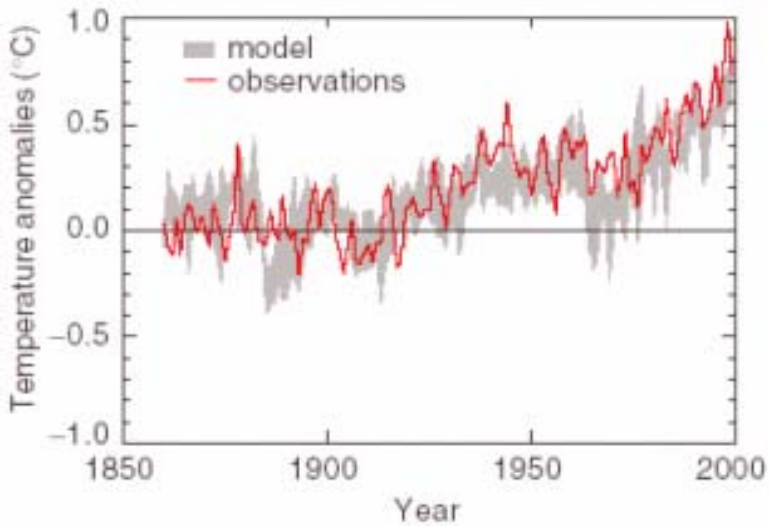
JGI
DOE JOINT GENOME INSTITUTE
US DEPARTMENT OF ENERGY
OFFICE OF SCIENCE



Temperature rise due to human emission of greenhouse gases



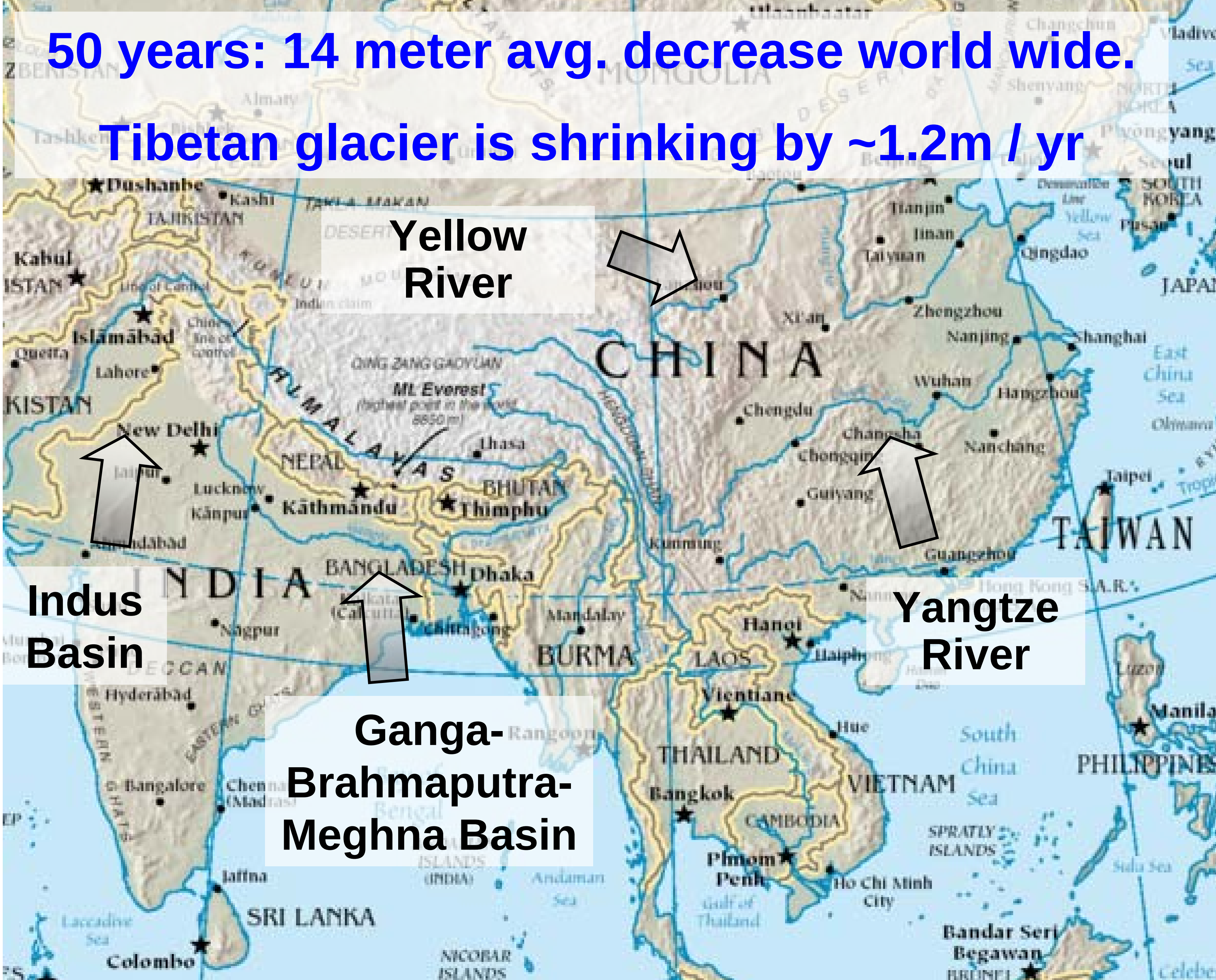
Climate change due to natural causes (solar variations, volcanoes, etc.)



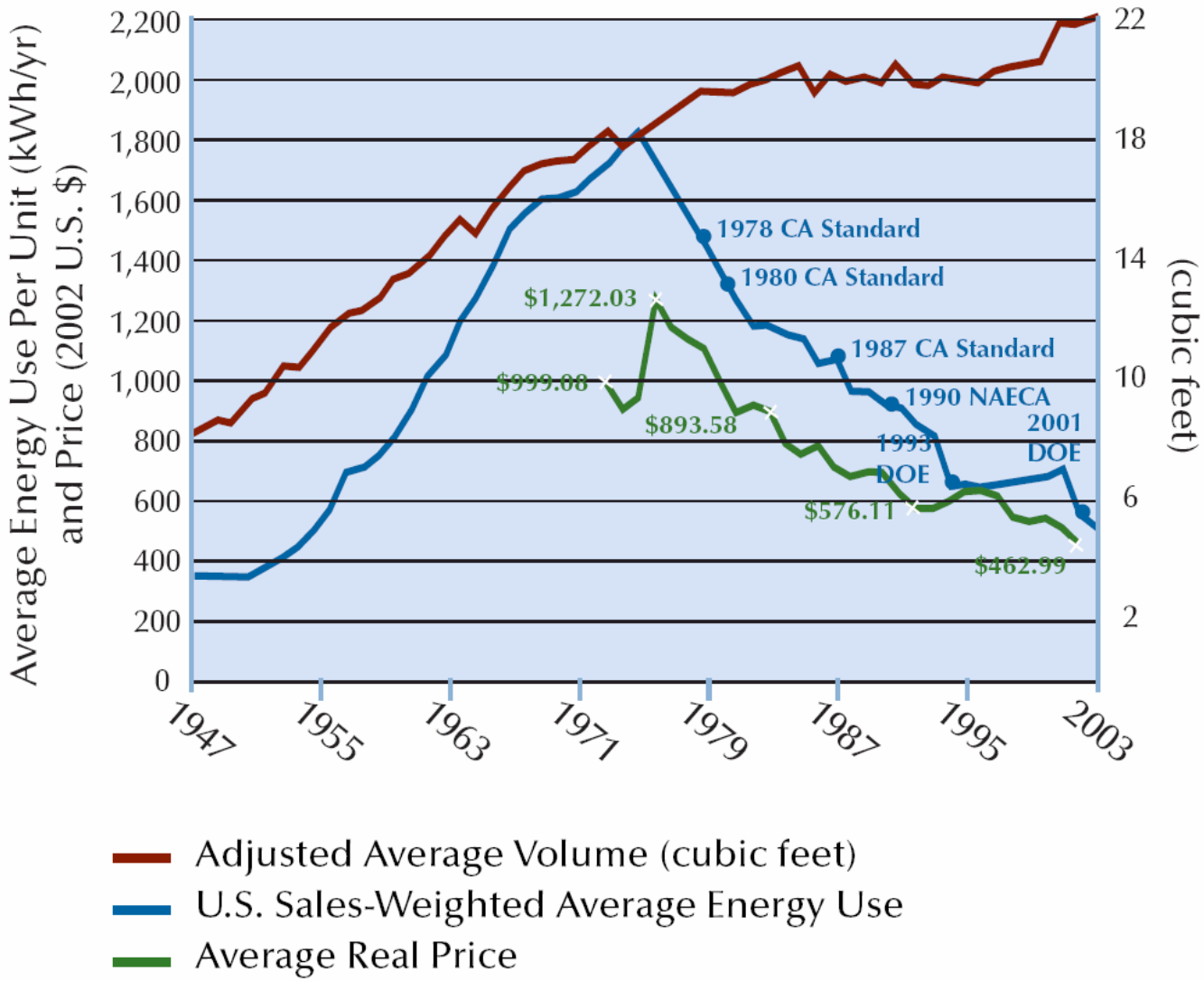
Climate change due to natural causes and human generated greenhouse gases

50 years: 14 meter avg. decrease world wide.

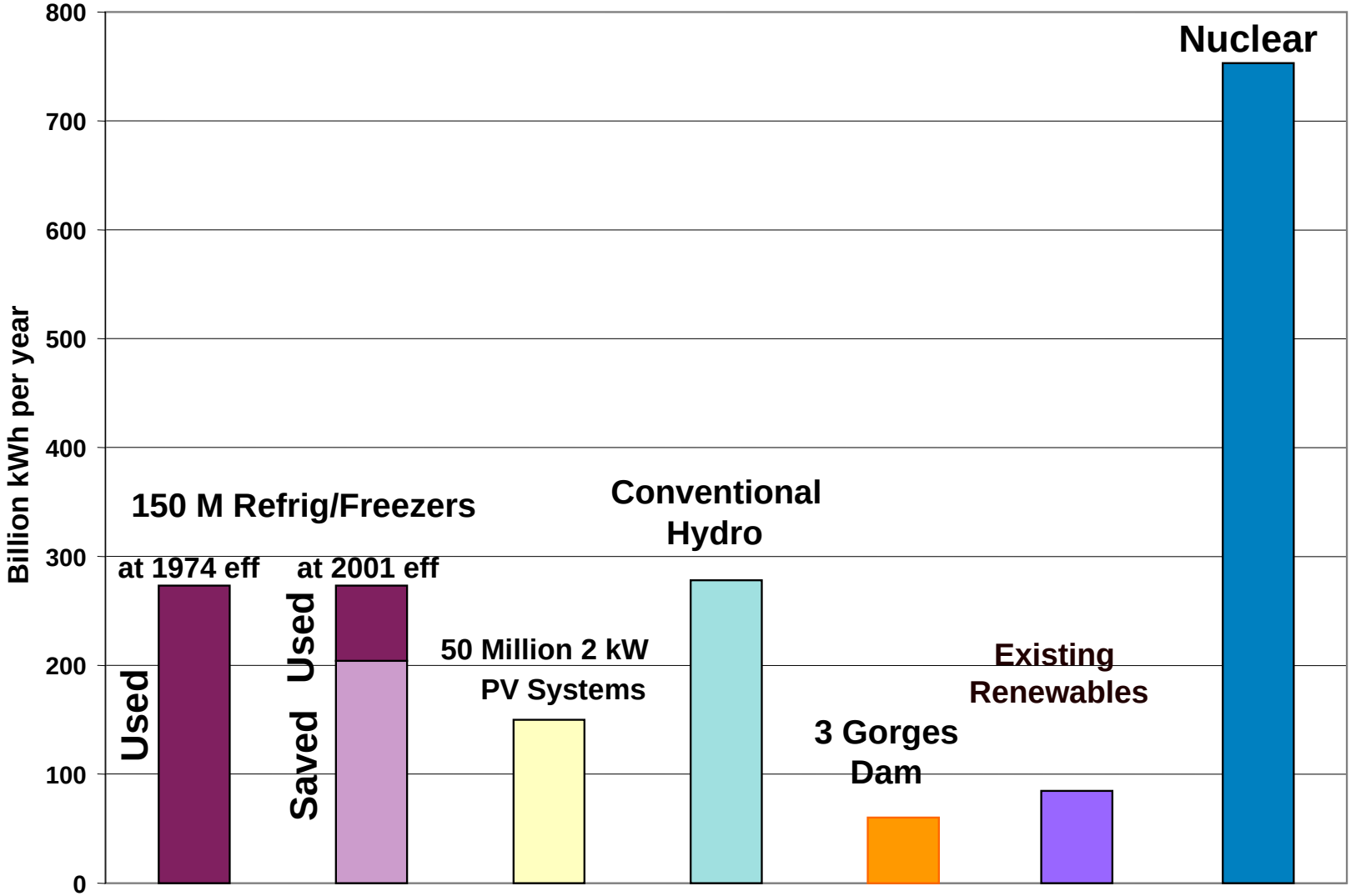
Tibetan glacier is shrinking by ~1.2m / yr



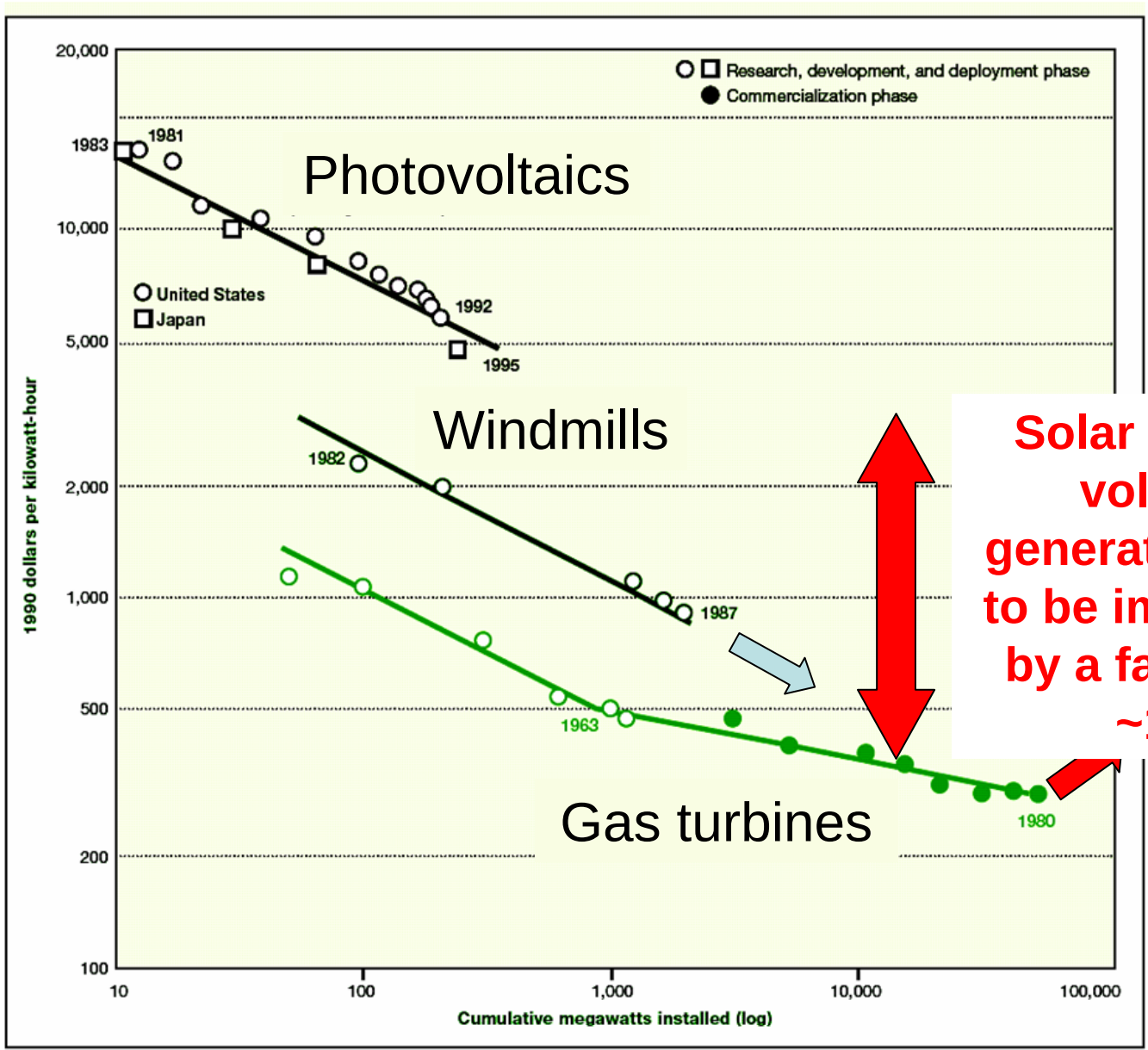
Regulation stimulates technology: Refrigerator efficiency standards and performance. The *expectation* of efficiency standards also stimulated industry innovation



US Electricity Use of Refrigerators and Freezers compared to sources of electricity

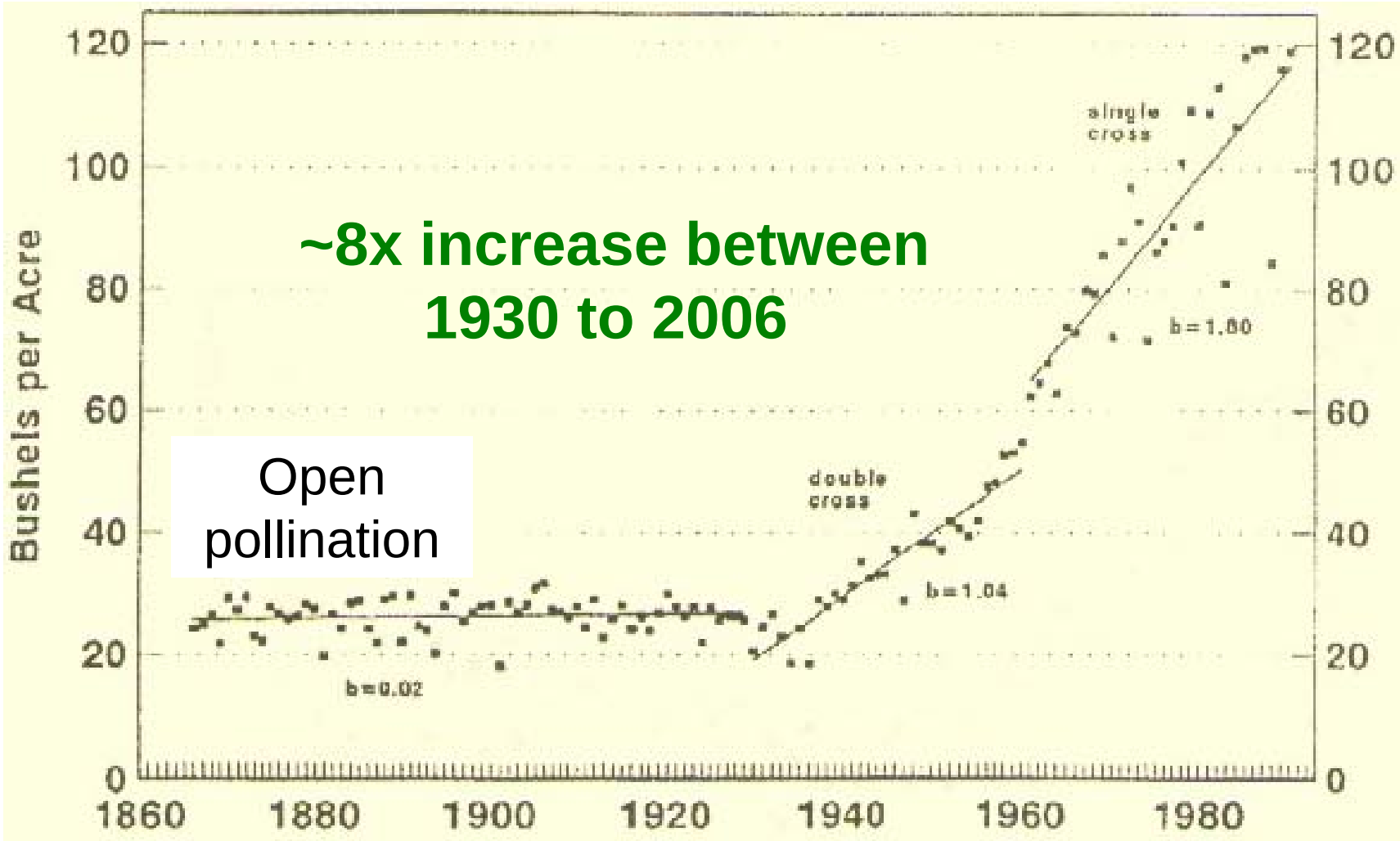


Cost of electricity generation
(1990 dollars/kilowatt hour)



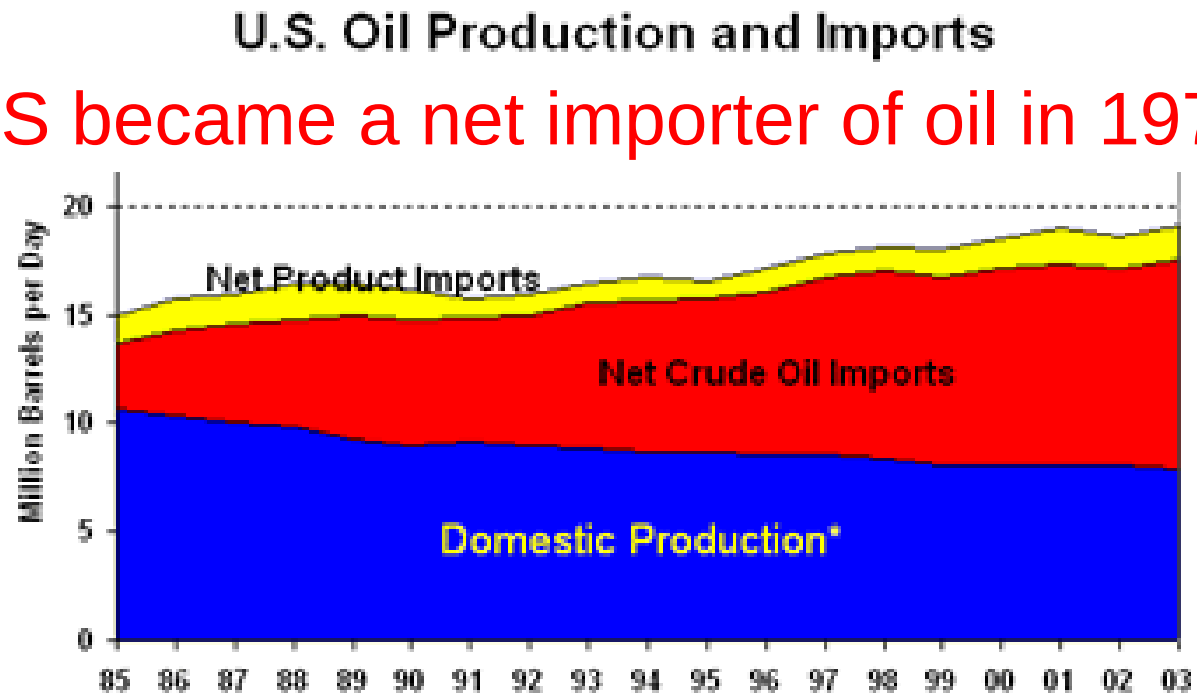
Solar photo-voltaic generation has to be improved by a factor of ~10

Average production of corn per acre in the United States



(Original figure from Tollenaar, as cited by McLaughlin, 2004).

- Materiality
  - Is there sufficient land for food and fuel?
- Environmental sustainability
  - Total CO_2 emissions relative to fossil fuel sources
  - Ecosystem sustainability
- Energy balance
  - Fossil energy in vs. net energy produced
- Costs of bio-fuel production



US became a net importer of oil in 1970

China oil consumption and production 1980 -2005