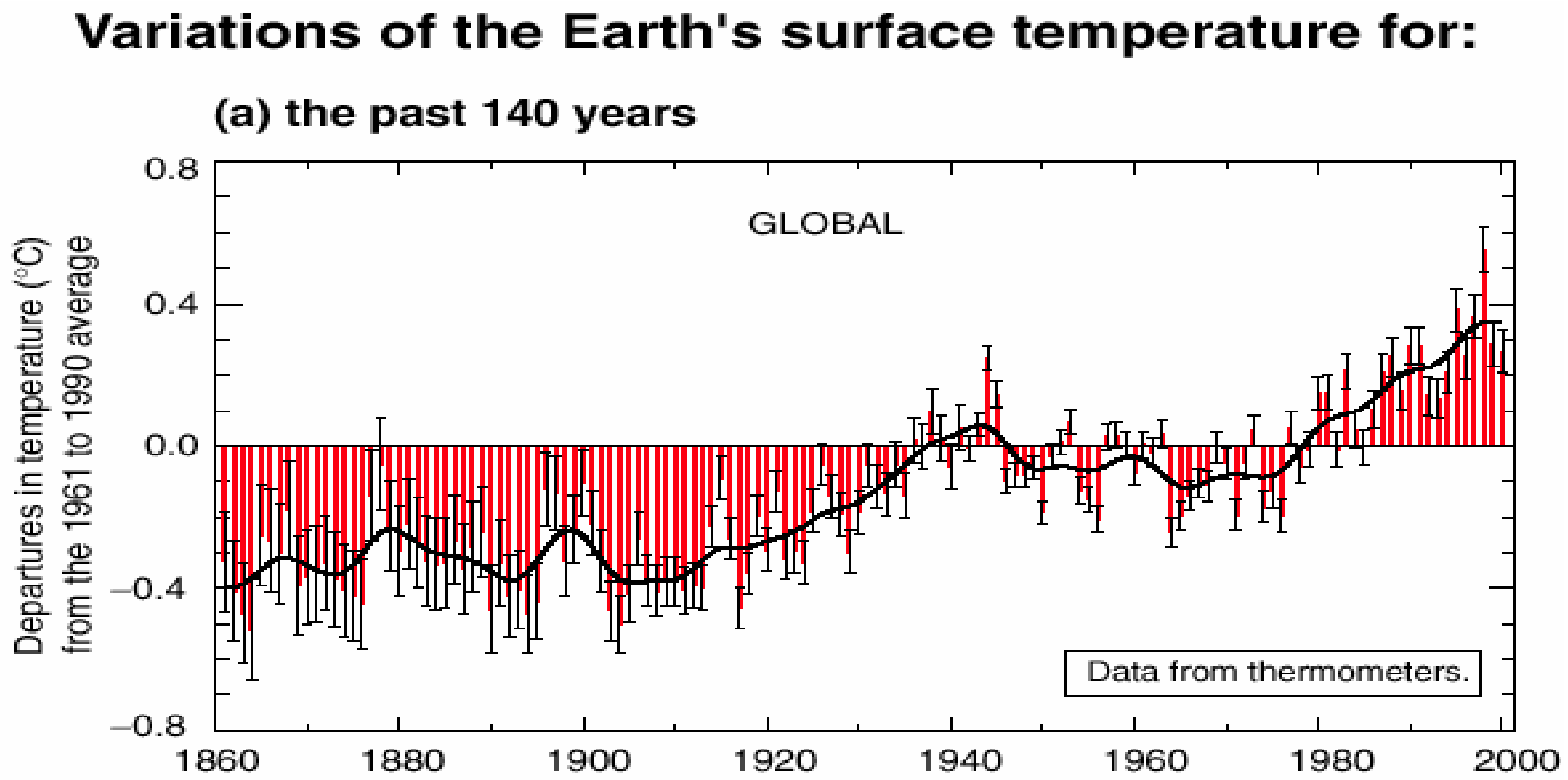
New solutions to the Energy Crisis?

Summer Series Lecture
1 August, 2005

- The possibility (likelihood) of global warming and its consequences

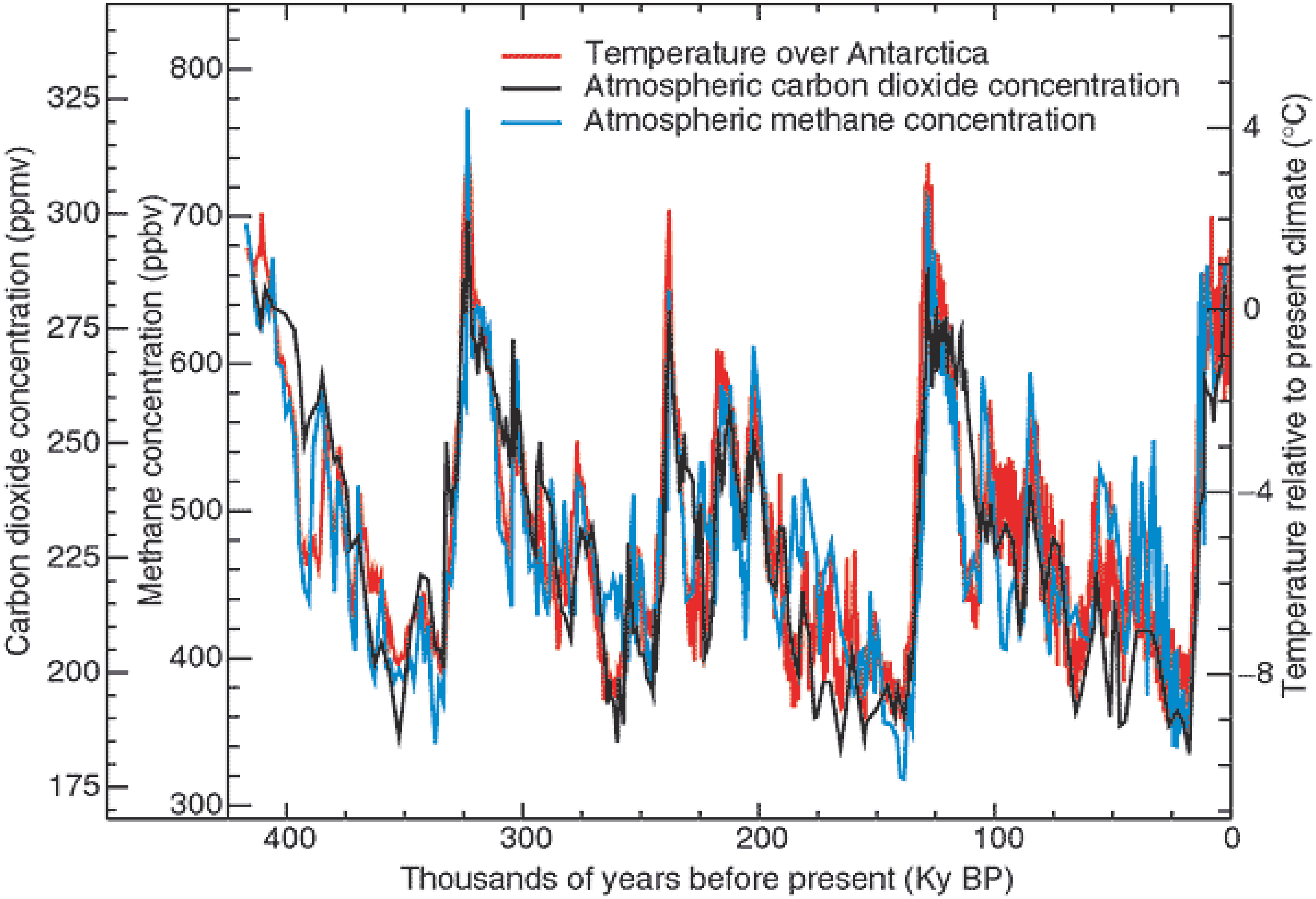
- Possible solutions

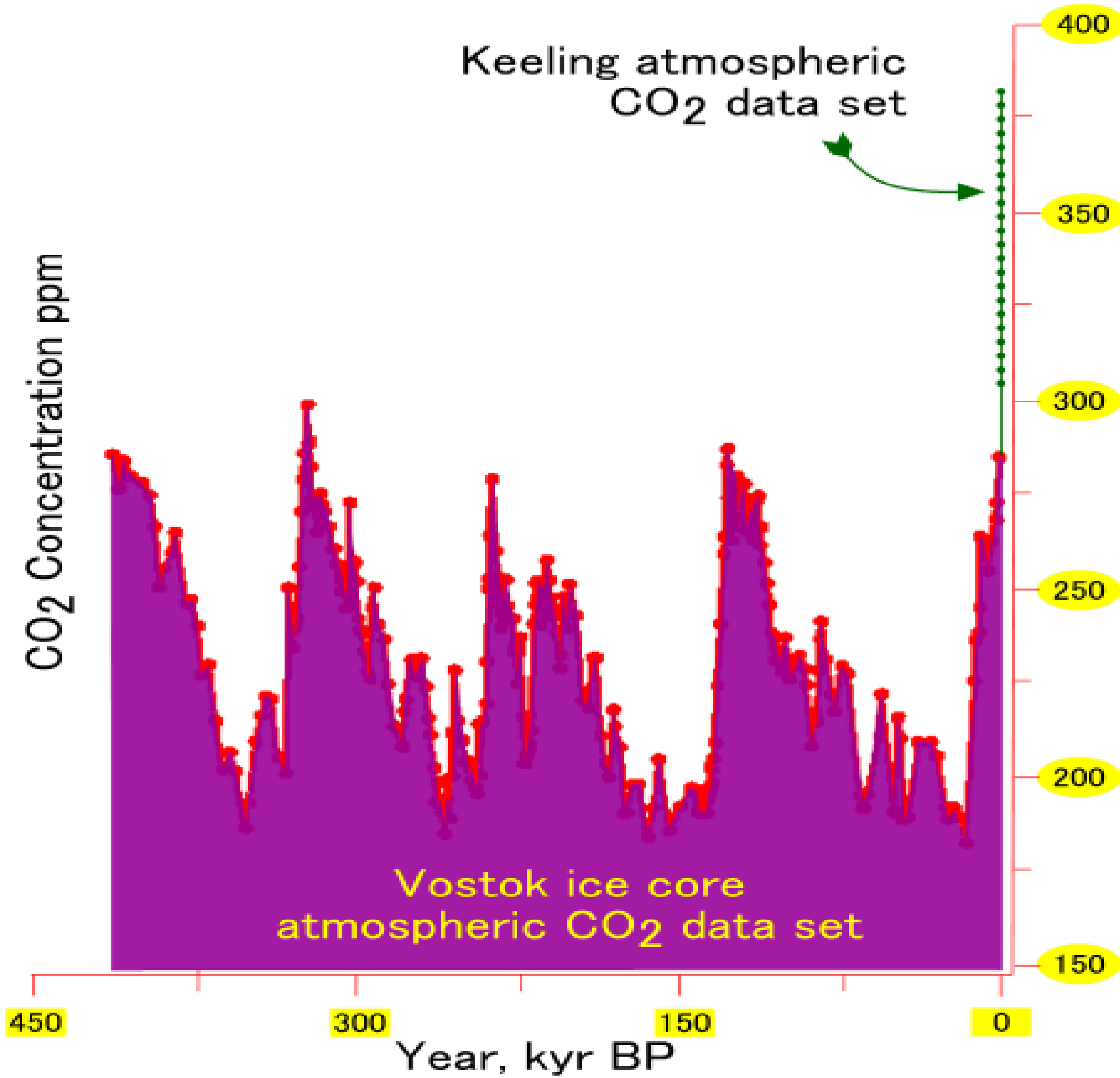


140 years is nothing by geological time scales!

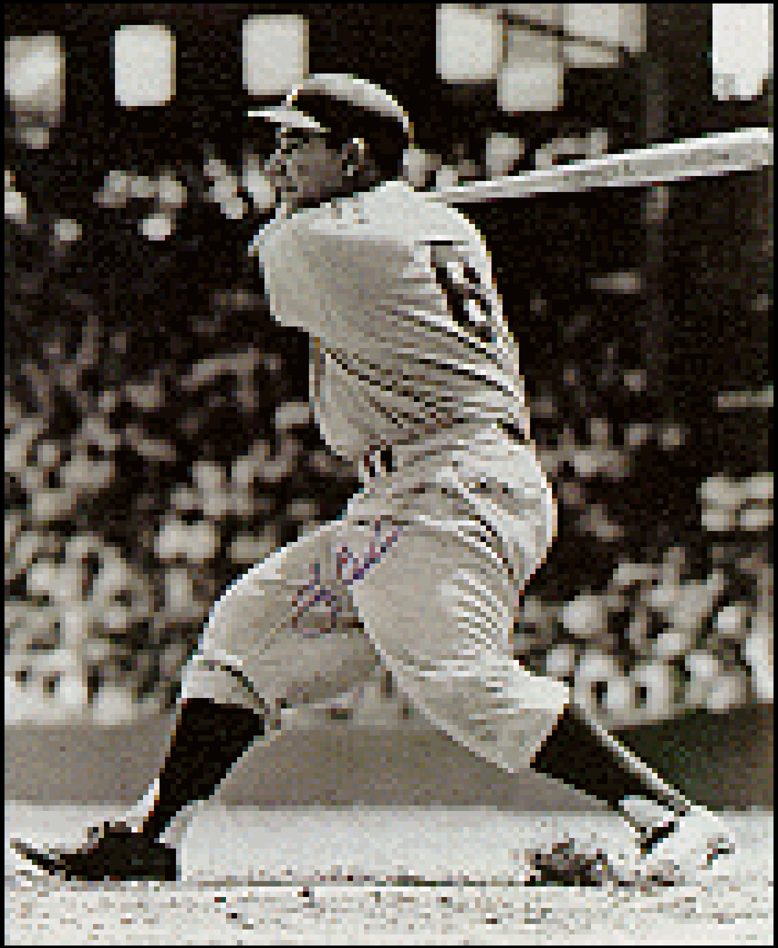
Temperature over the last 420,000 years

Source: Working Group I of the Intergovernmental Panel on Climate Change



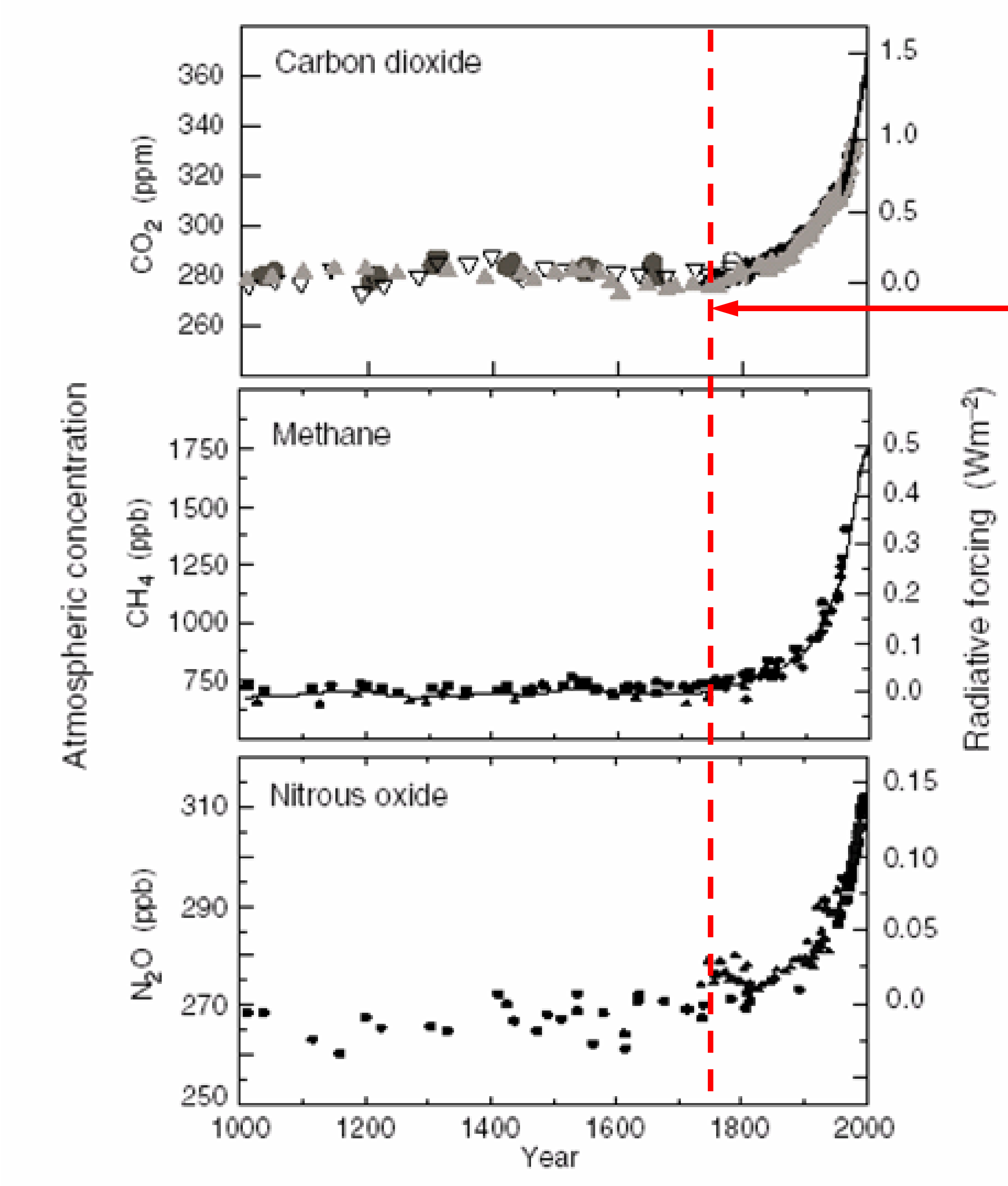

Keeling atmospheric
CO_2 data set
400
350
300
250
200
150
CO_2 Concentration ppm
Vostok ice core
atmospheric CO_2 data set
450
300
150
0
Year, kyr BP

Can we predict climate change due to increased greenhouse gases?



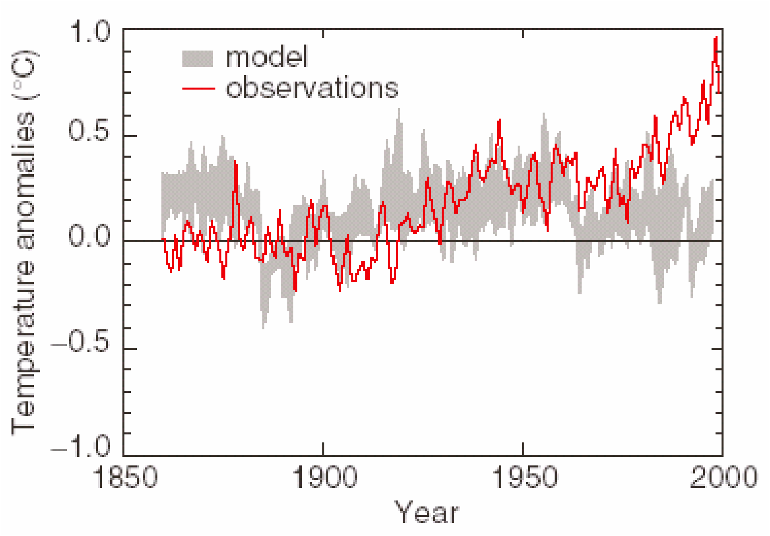
"Predictions are hard to make, especially about the future."

Concentration of Greenhouse gases

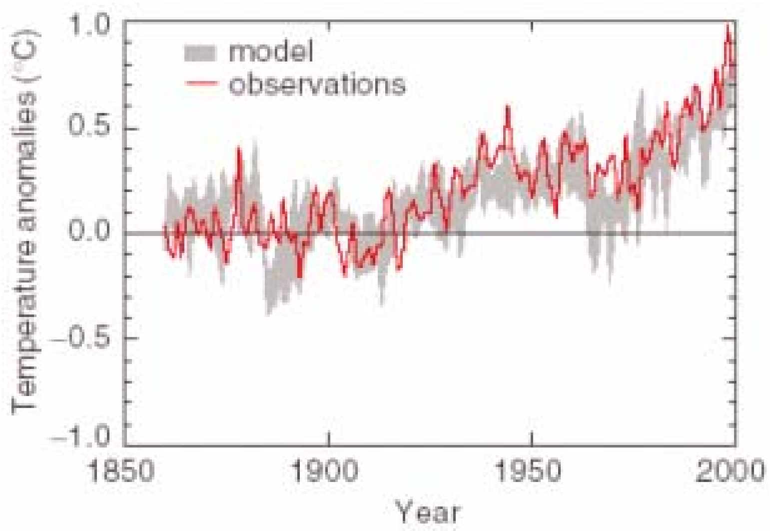


1750, the beginning of the industrial revolution

Can we predict the past?

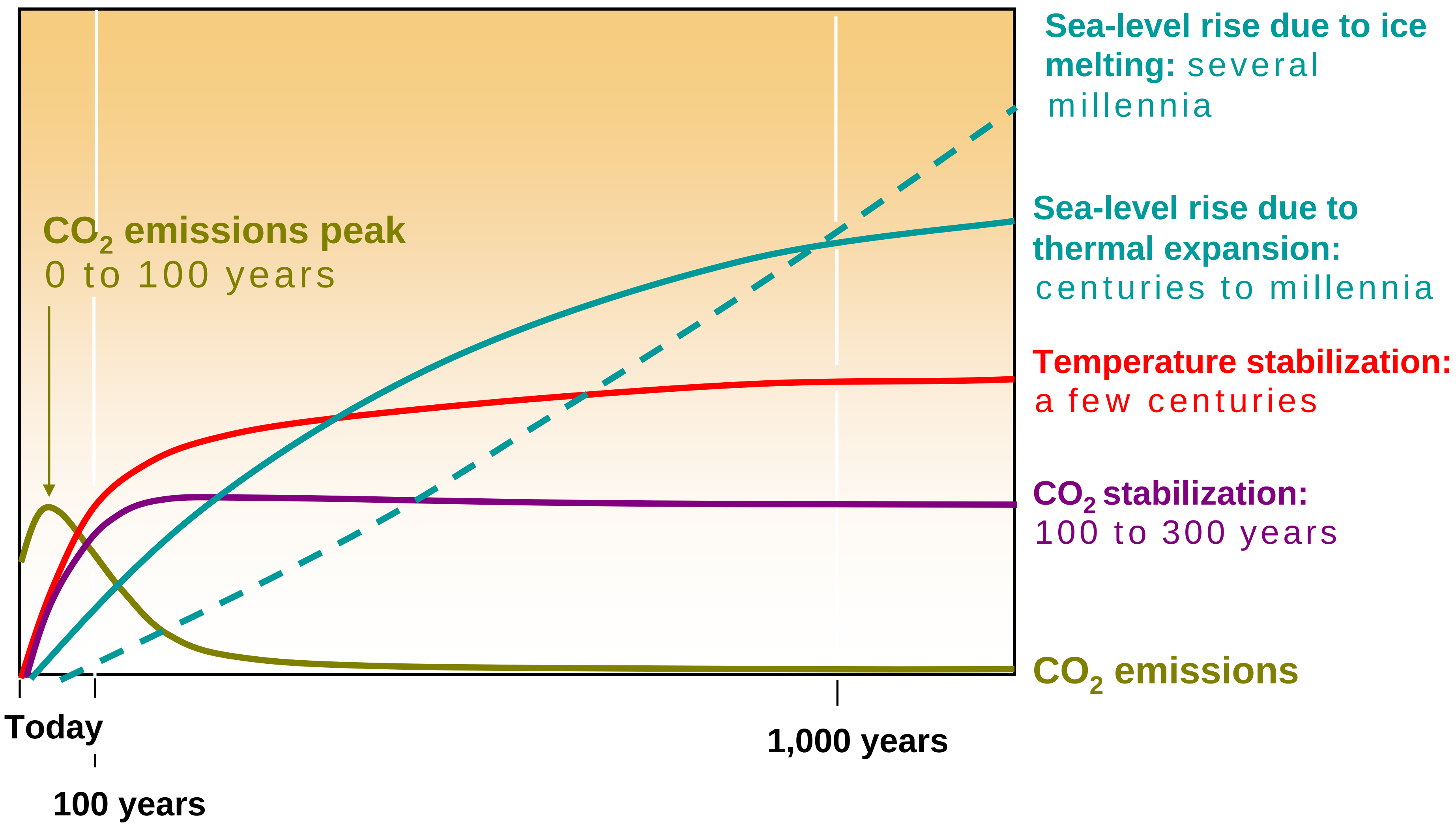


Climate change due to natural causes (solar variations, volcanoes, etc.)



Climate change due to natural causes and human generated greenhouse gases

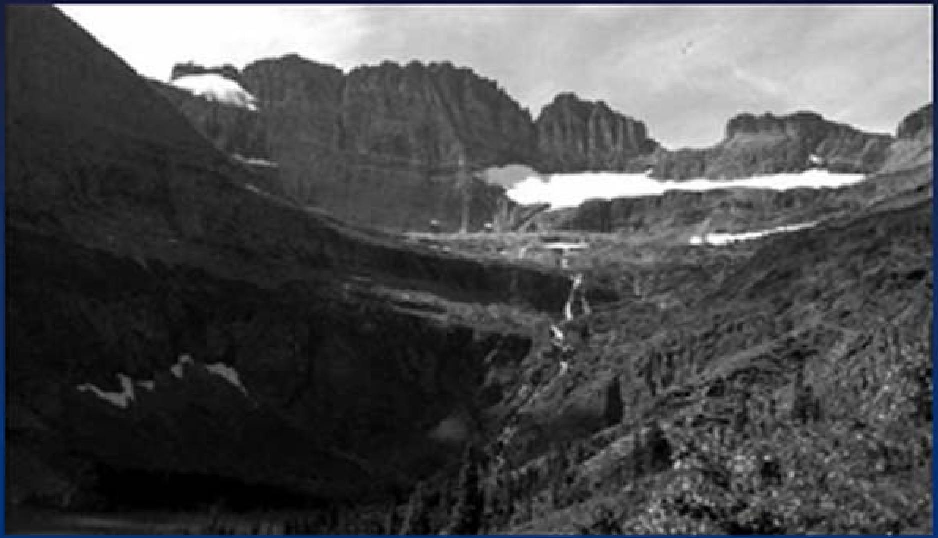
CO_2 Concentration, Temperature, and Sea Level Continue to Rise Long after Emissions are Reduced



Climate governs

- Damage from storms, floods, wildfires
- Property losses from sea-level rise
- Productivity of farms, forests, & fisheries
- Livability of cities in summer
- Distribution & abundance of species
- Geography of disease

Grinell Glacier and Grinnell Lake, Glacier National Park, 1910-1997



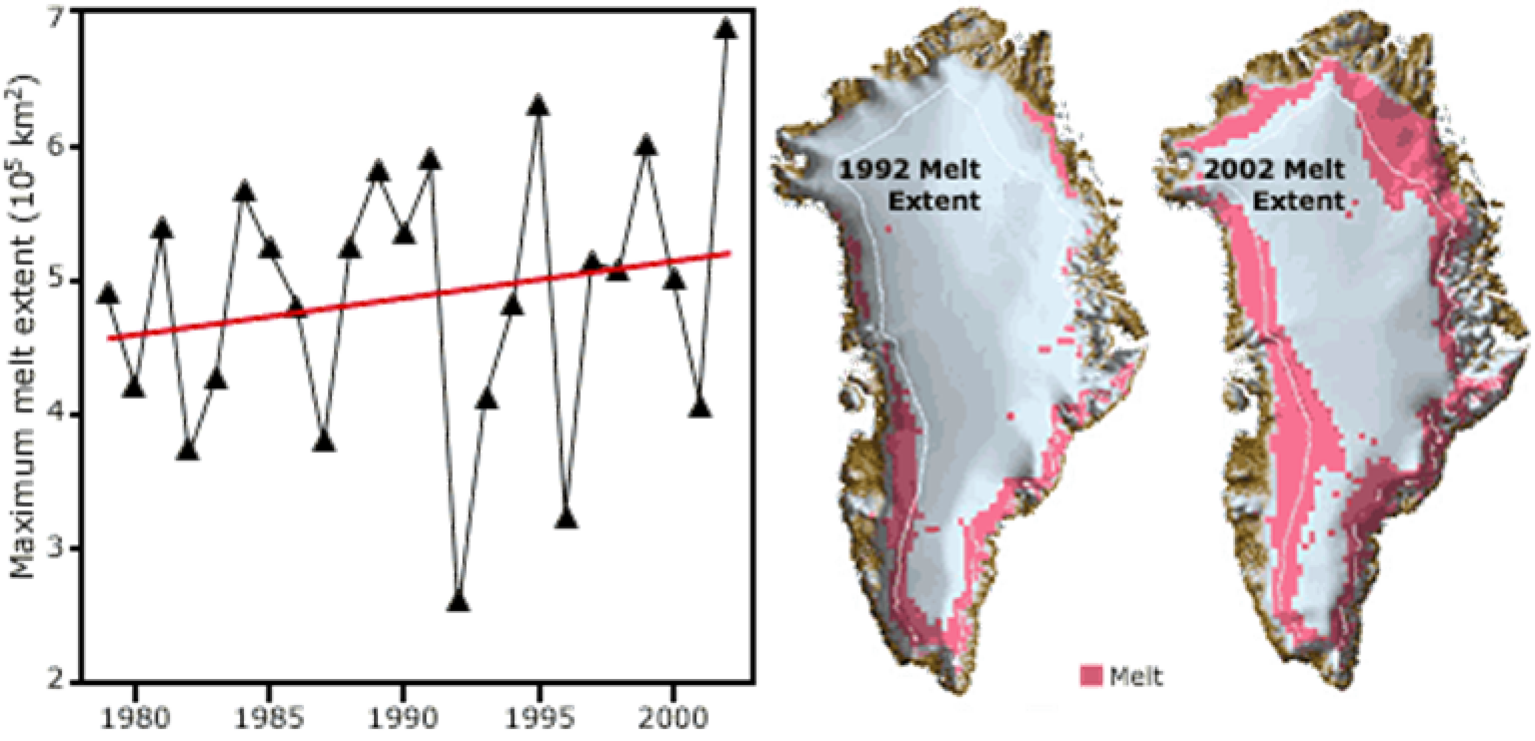
Proposed name change:

Non-Glacier National Park.

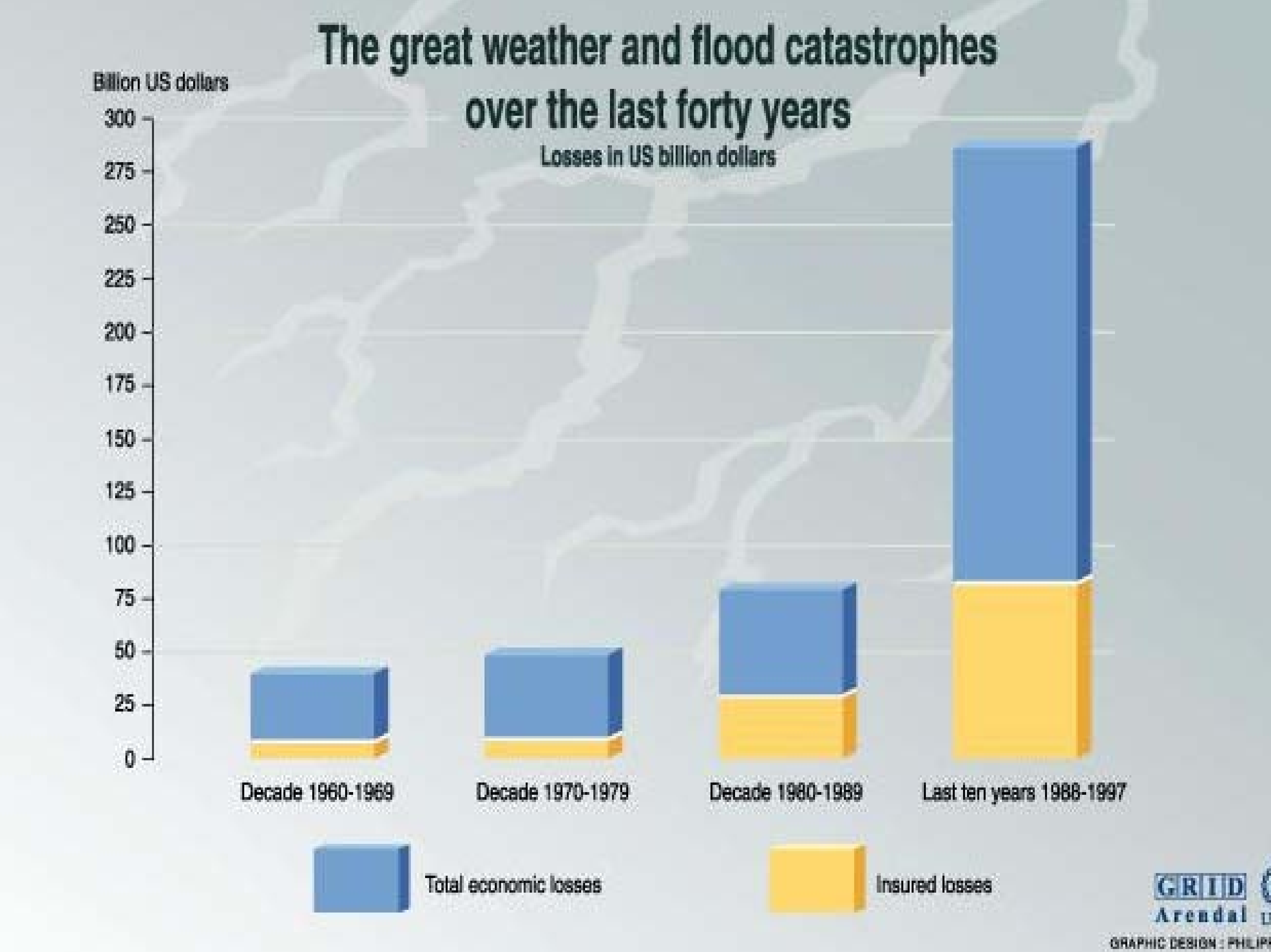
Larson B ice shelf break-up,

Antarctica, 2002

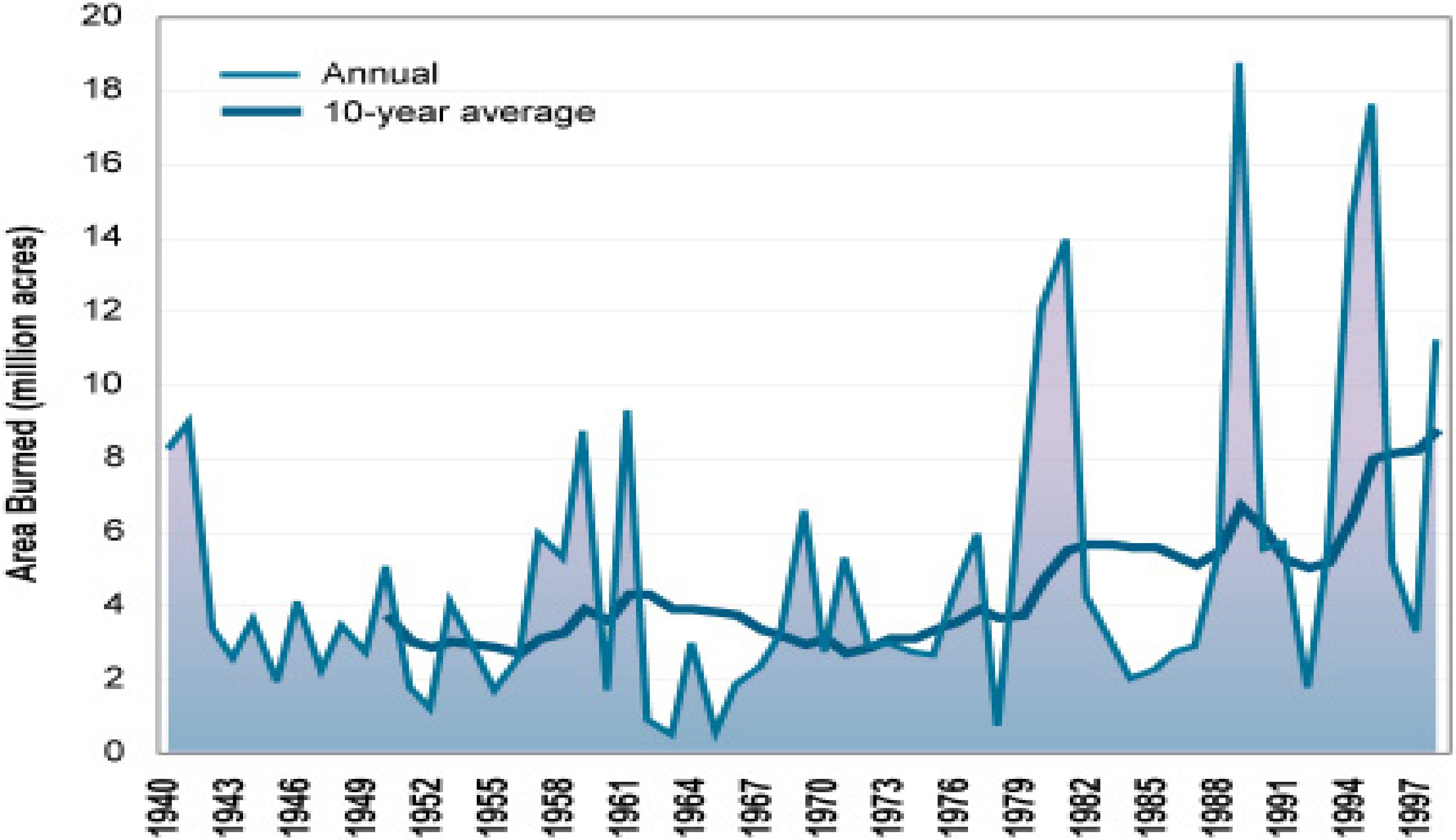
Greenland is melting



Bleached coral head: Bleaching occurs when high water temperature kills the living organisms in the coral, leaving behind only the calcium carbonate skeleton.

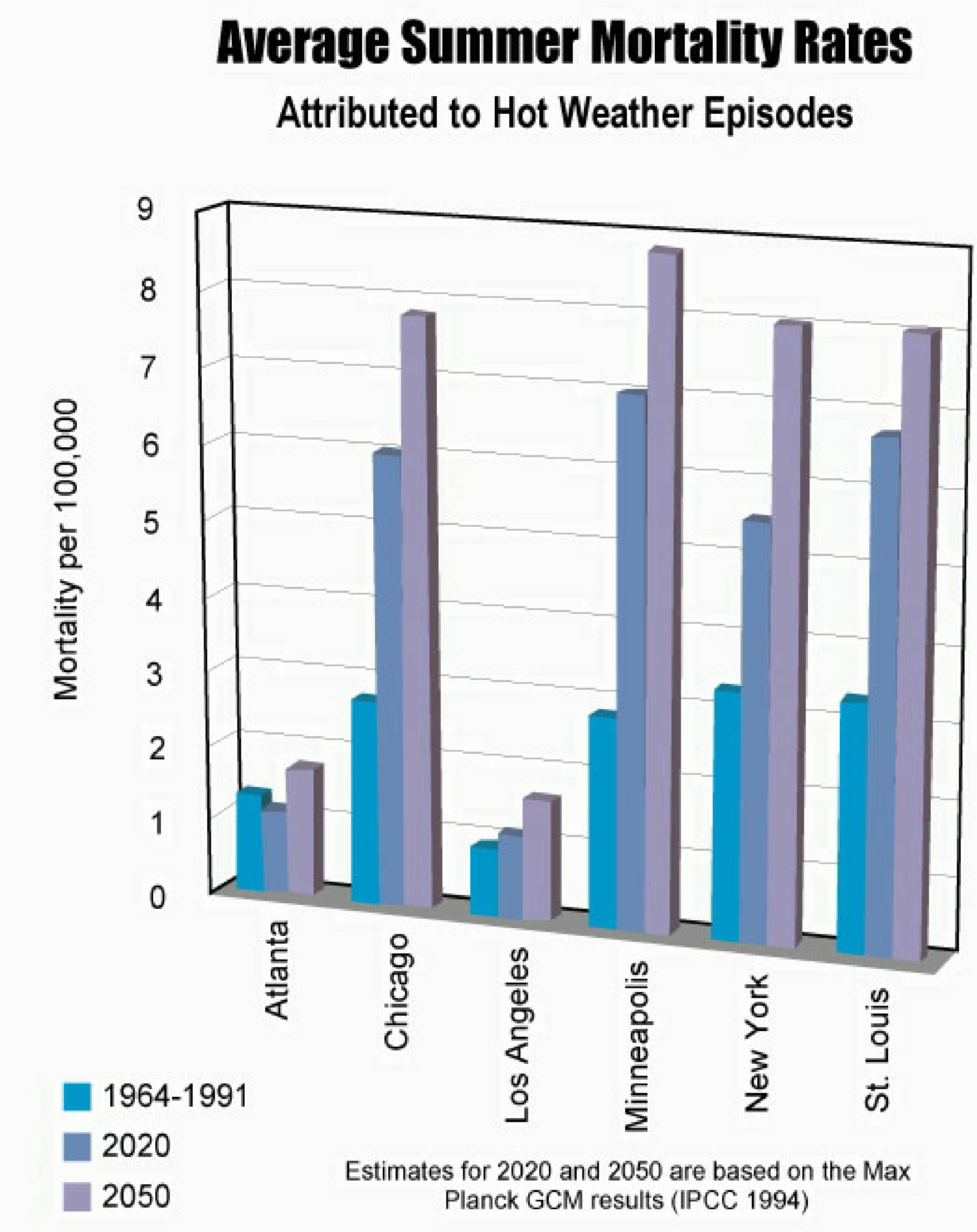

The great weather and flood catastrophes
over the last forty years
Losses in US billion dollars
Billion US dollars
300
275
250
225
200
175
150
125
100
75
50
25
0
Decade 1960-1969
Decade 1970-1979
Decade 1980-1989
Last ten years 1988-1997
Total economic losses
Insured losses
GRID
Arendal
GRAPHIC DESIGN : PHILIP

Annual Area of Northern Boreal Forest Burned in North America



The Alaskan boreal forest is a small part of an enormous forest that extends continuously across the northern part of North America. The average area of this forest burned annually has more than doubled since 1970.

Satellite photo of smoke from S California wildfires, October 2003



In August 2003, France attributed over 3,000 deaths to a two week heat wave.

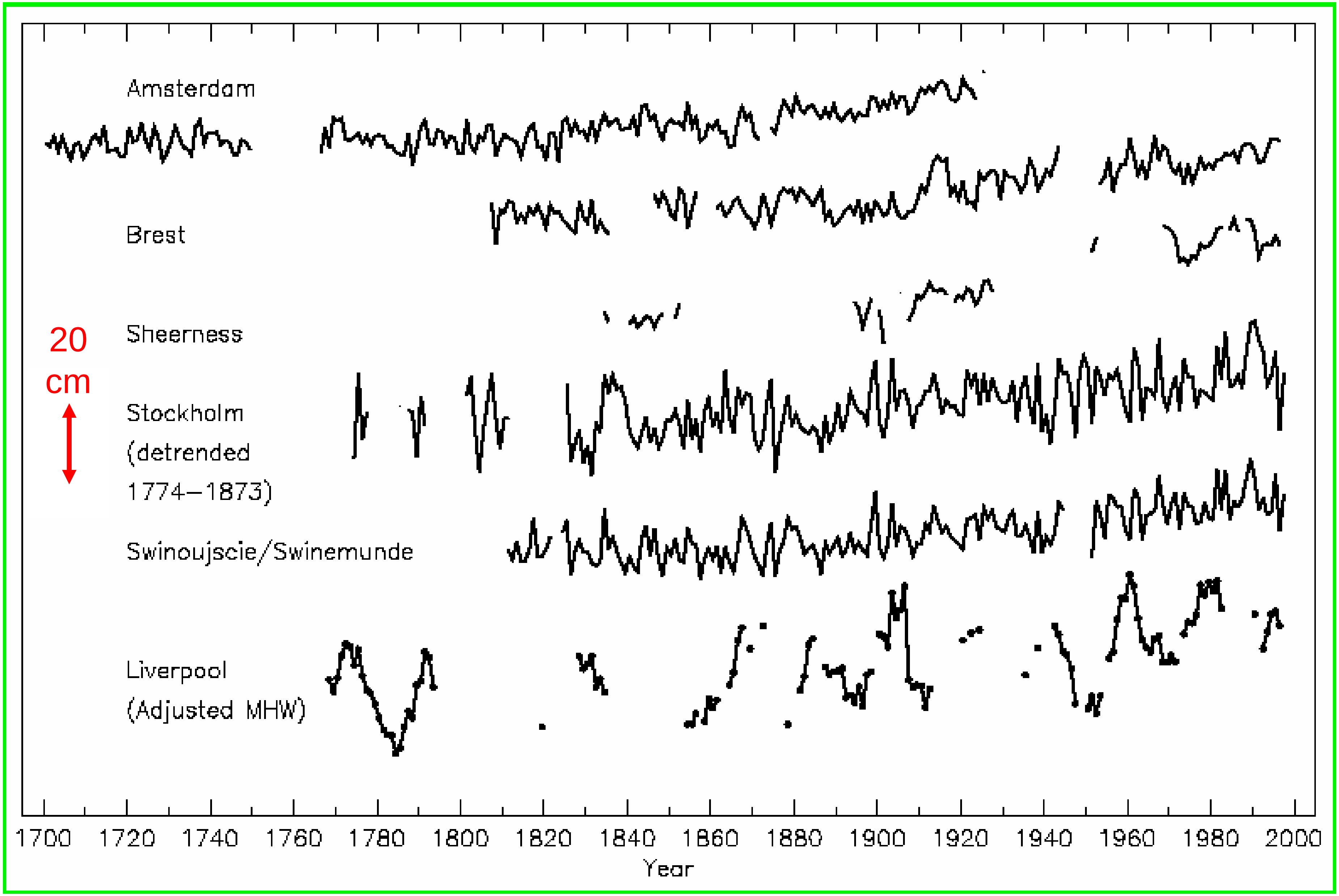
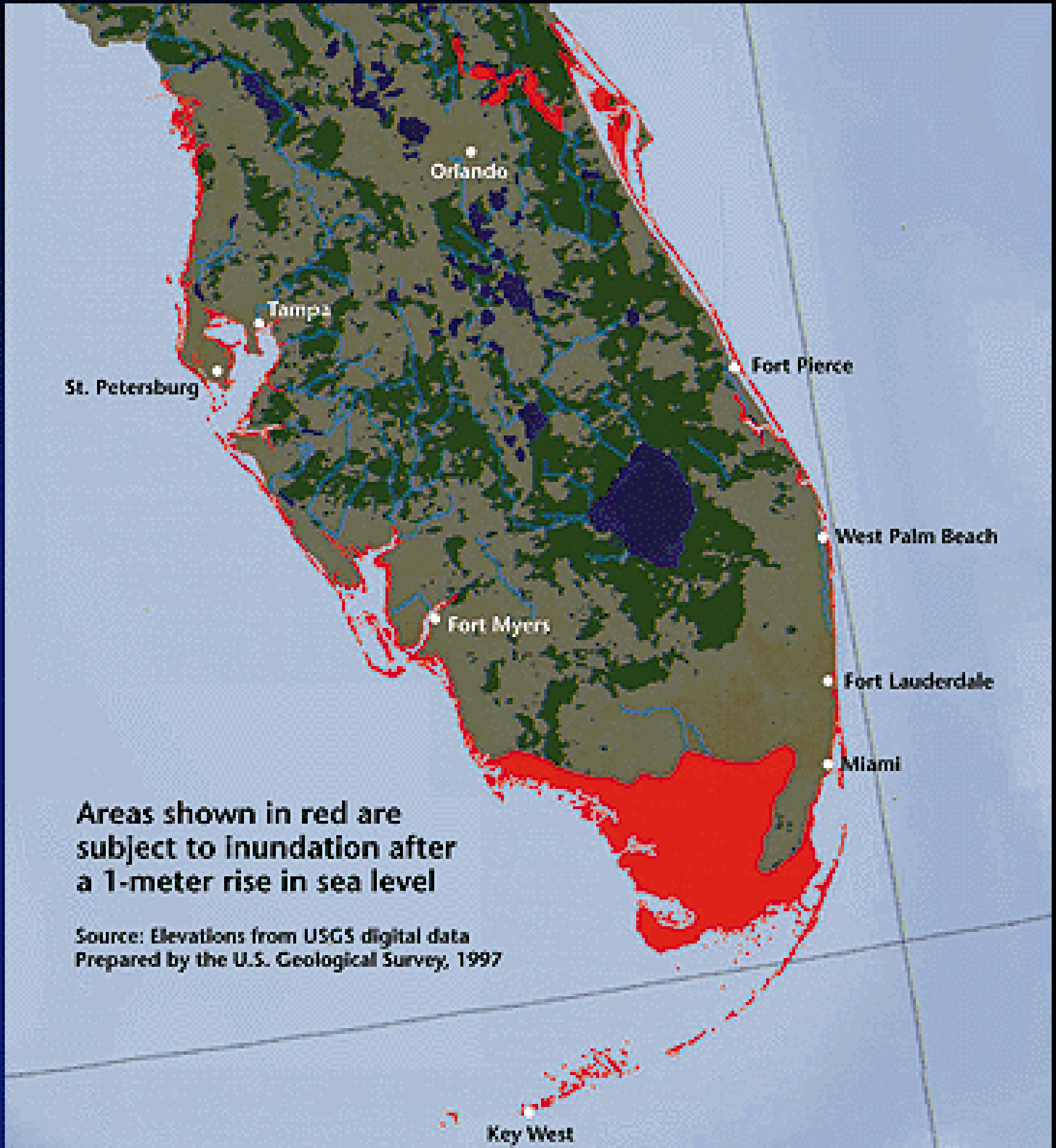
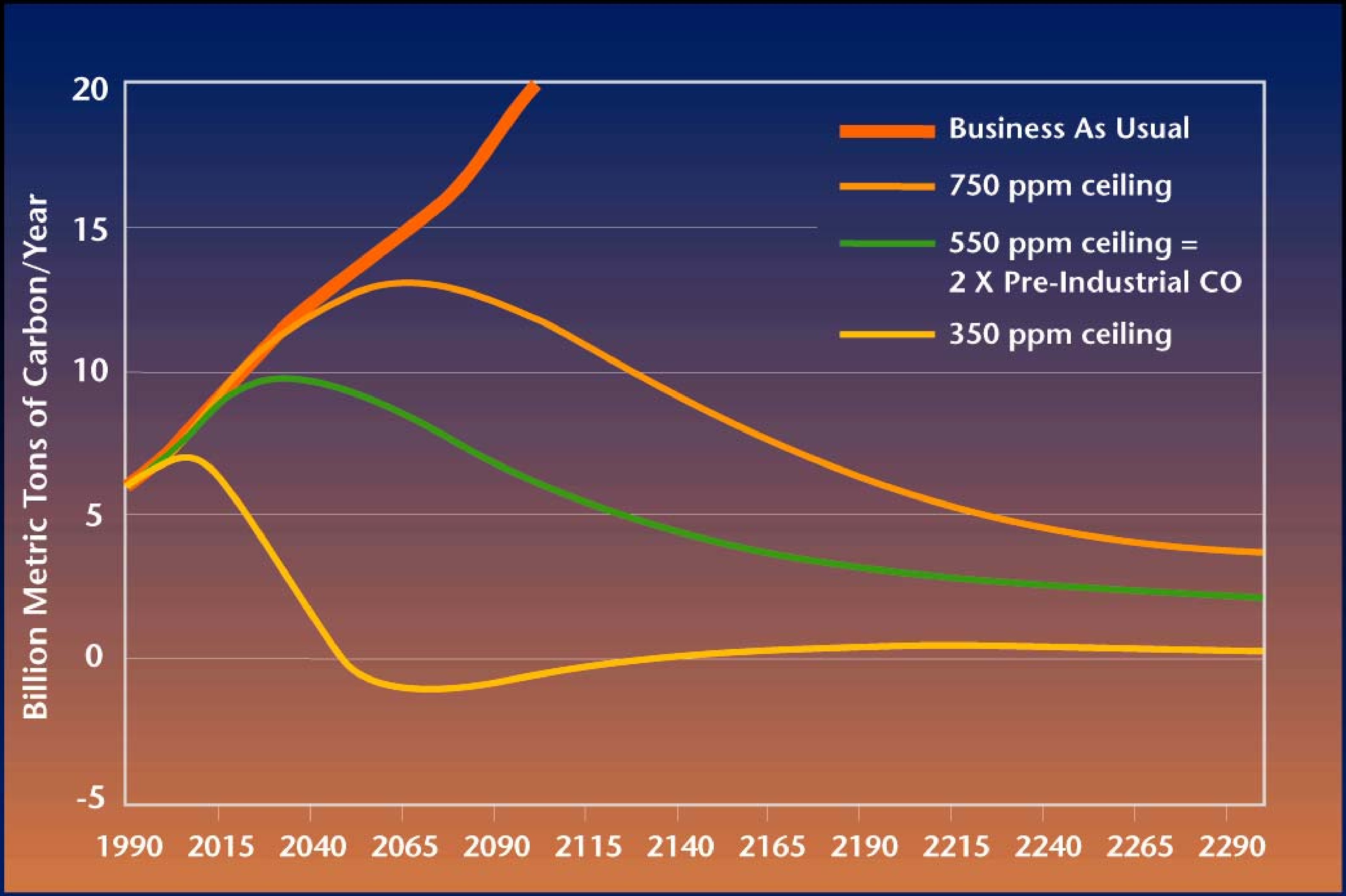


Figure 6: Time-series of relative sea level for the past 300 years from Northern Europe: Amsterdam, Netherlands; Brest, France; Sheerness, UK; *Stockholm, Sweden* (detrended over the period 1774 to 1873 to remove to first order the contribution of post-glacial rebound); Swinoujscie, Poland (formerly *Swinemunde*, Germany); and Liverpool, UK. Data for the latter are of "Adjusted Mean High Water" rather than Mean *Sea* Level and include a nodal (18.6 year) term. The *scale* bar indicates ±100 mm. [Based on Figure 11.7]

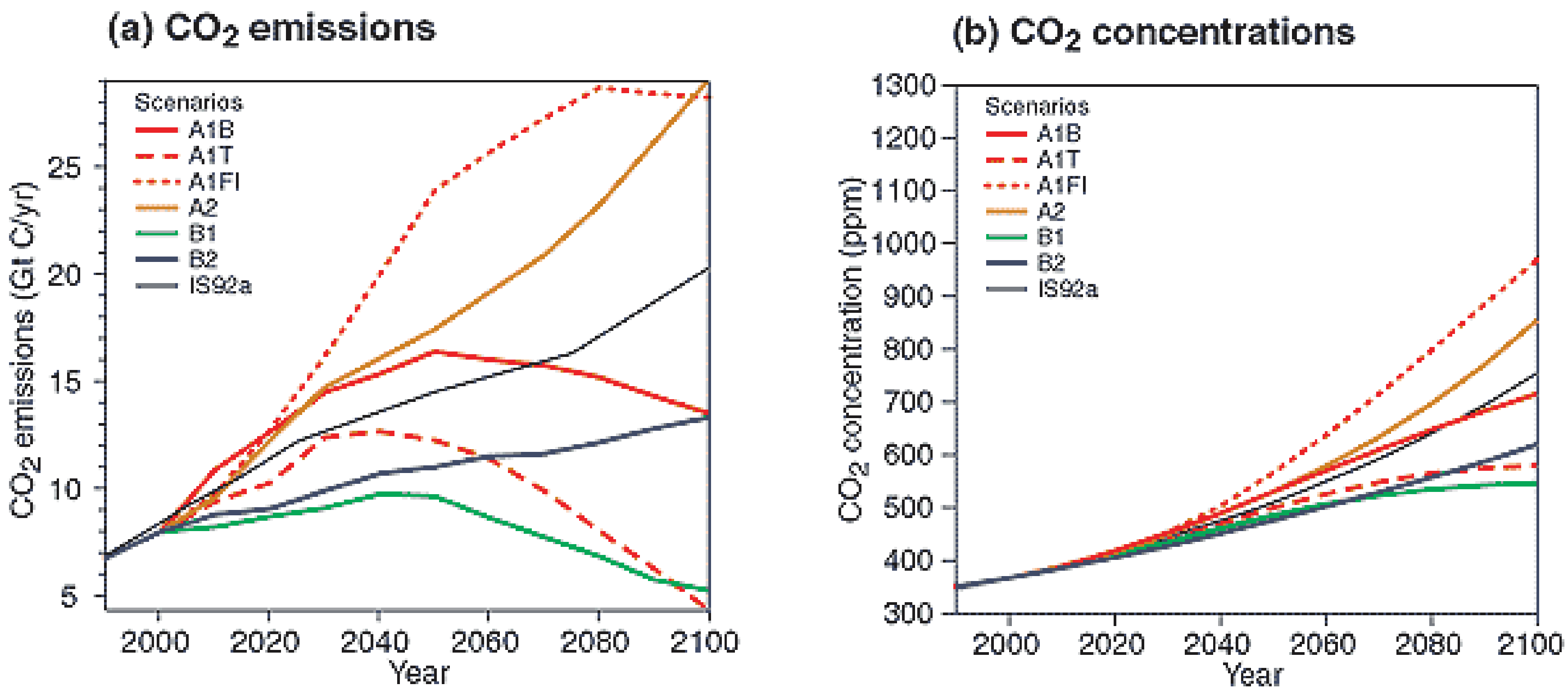
South Florida Shoreline Change after a 1-Meter Rise in Sea Level

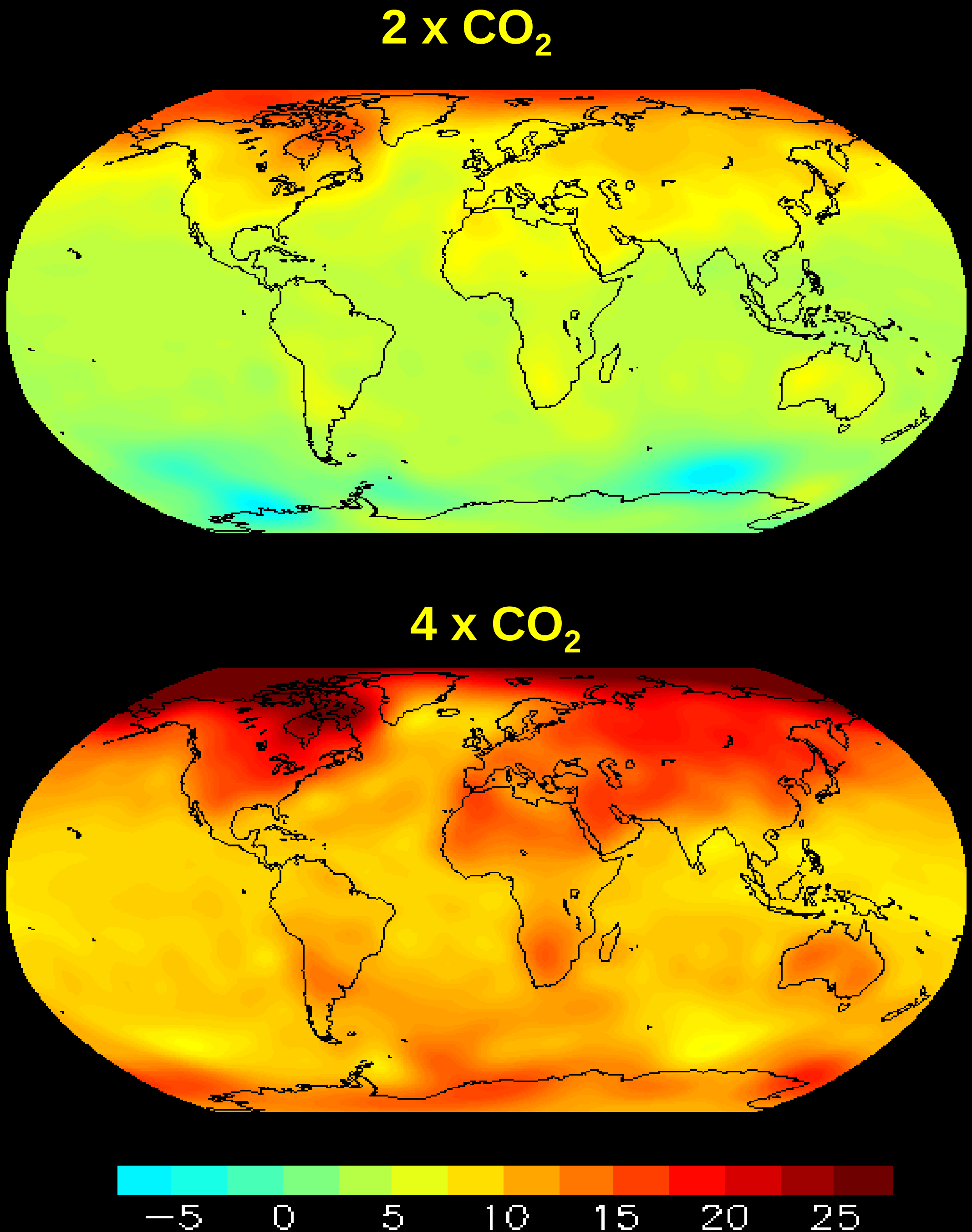


Atmospheric Stabilization Emissions Paths



Kyoto Protocol target (Green line)





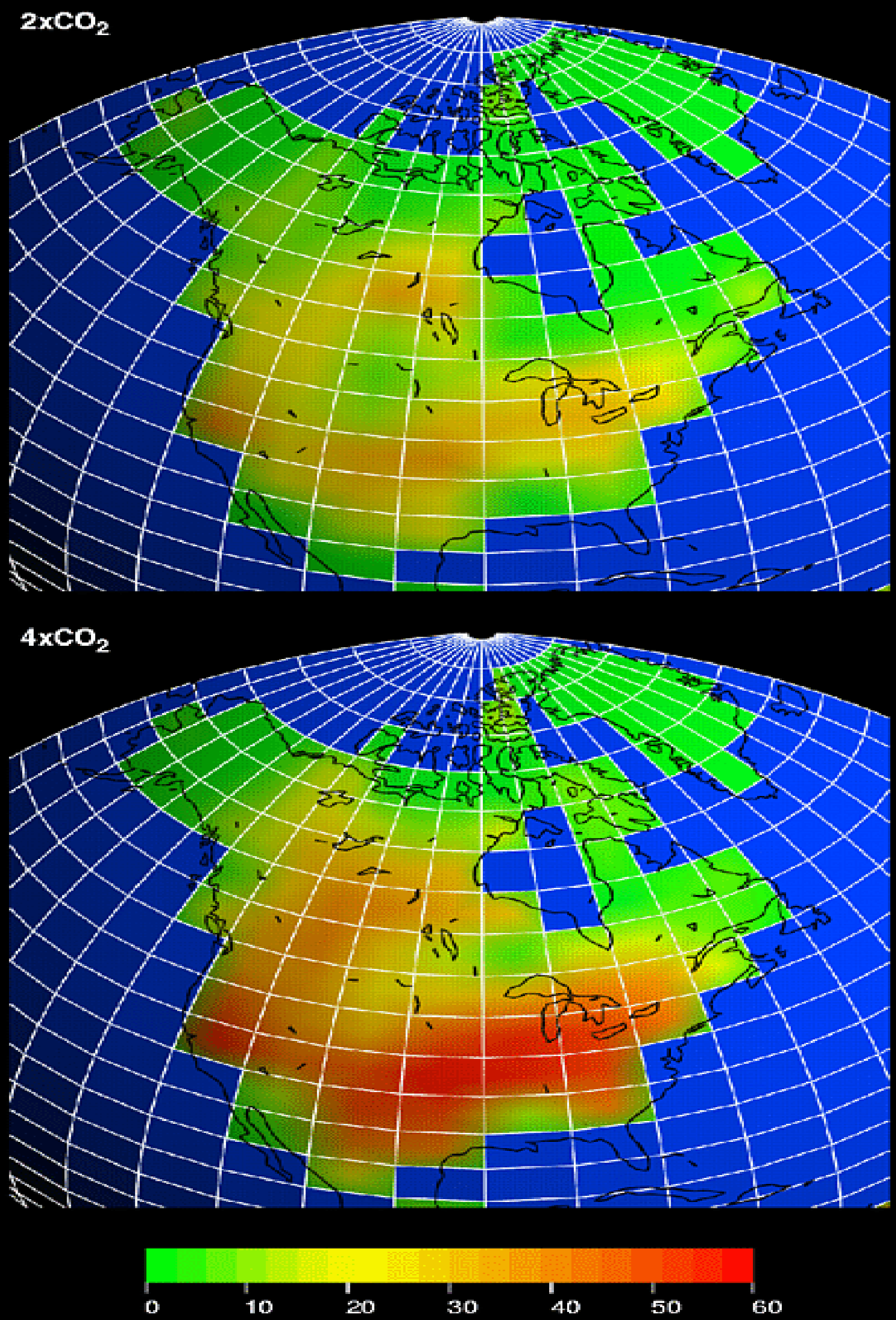
Computer simulations by the Princeton Geophysical Fluid Dynamics Lab for CO2 increases above pre-industrial revolution levels:

2x CO_2 : 5 – 8° F

4x CO_2 : 15-25° F

Pre-industrial:
~275 ppm

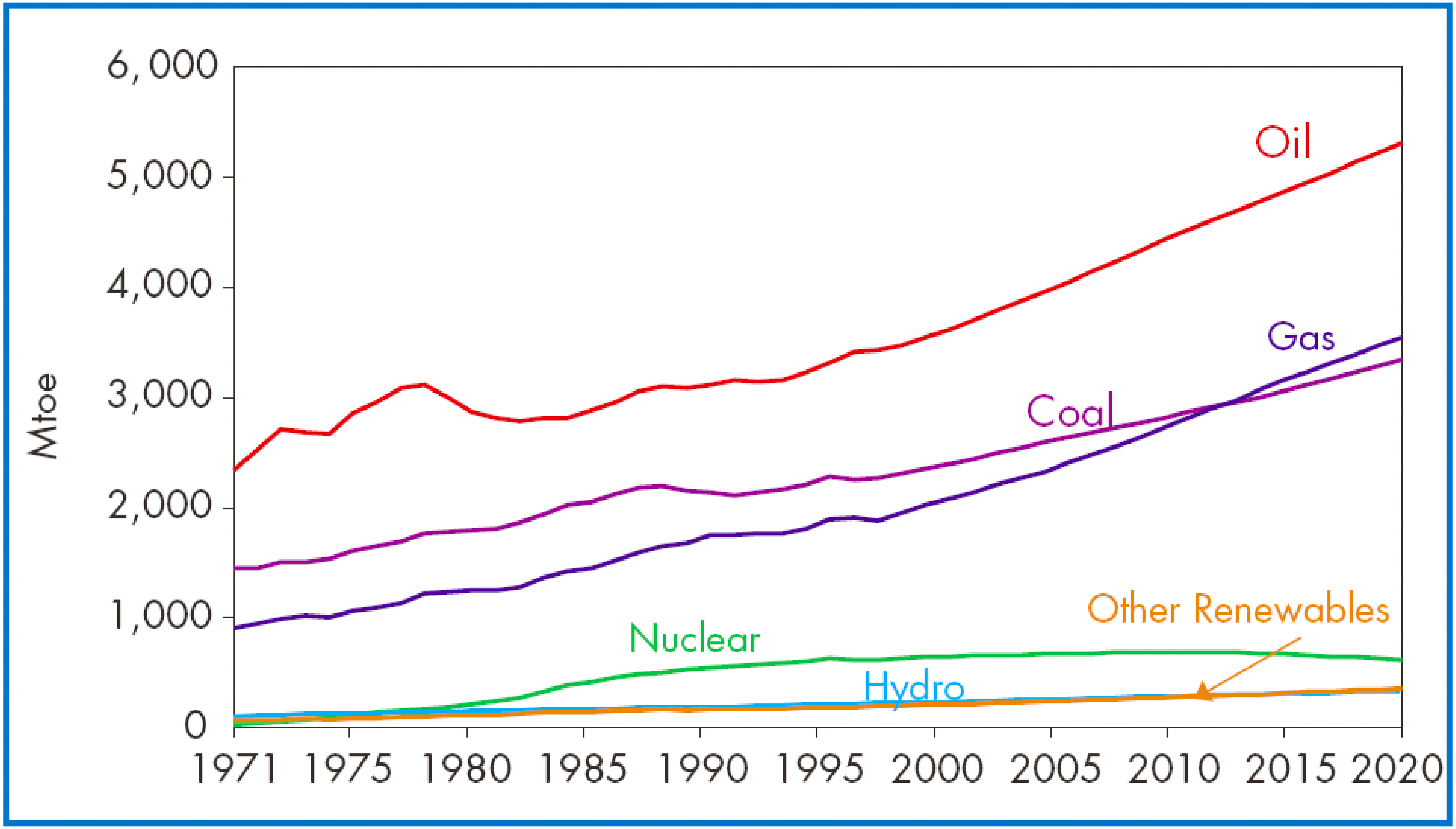
Today:
~380 ppm



Summer soil moisture in N America under doubled & quadrupled CO_2 (from the Princeton GFDL model)

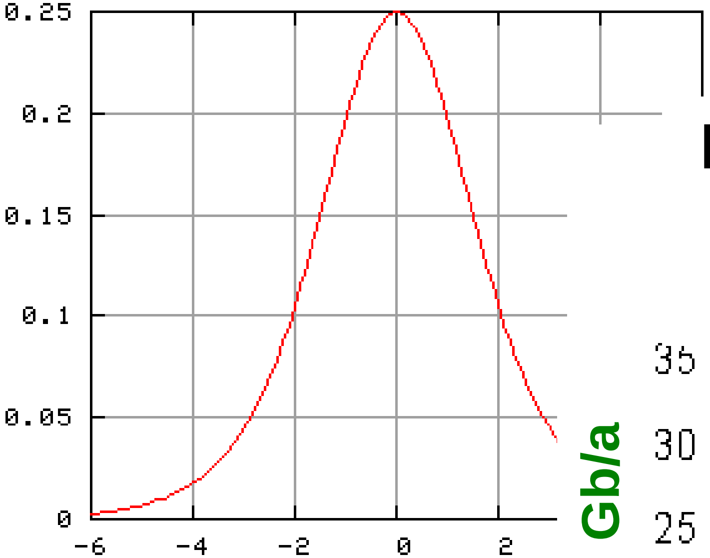
Mid-continent soil-moisture reductions reach 50-60% in the $4xCO_2$ world.

World demand of energy resources



Source: IEA (2000).

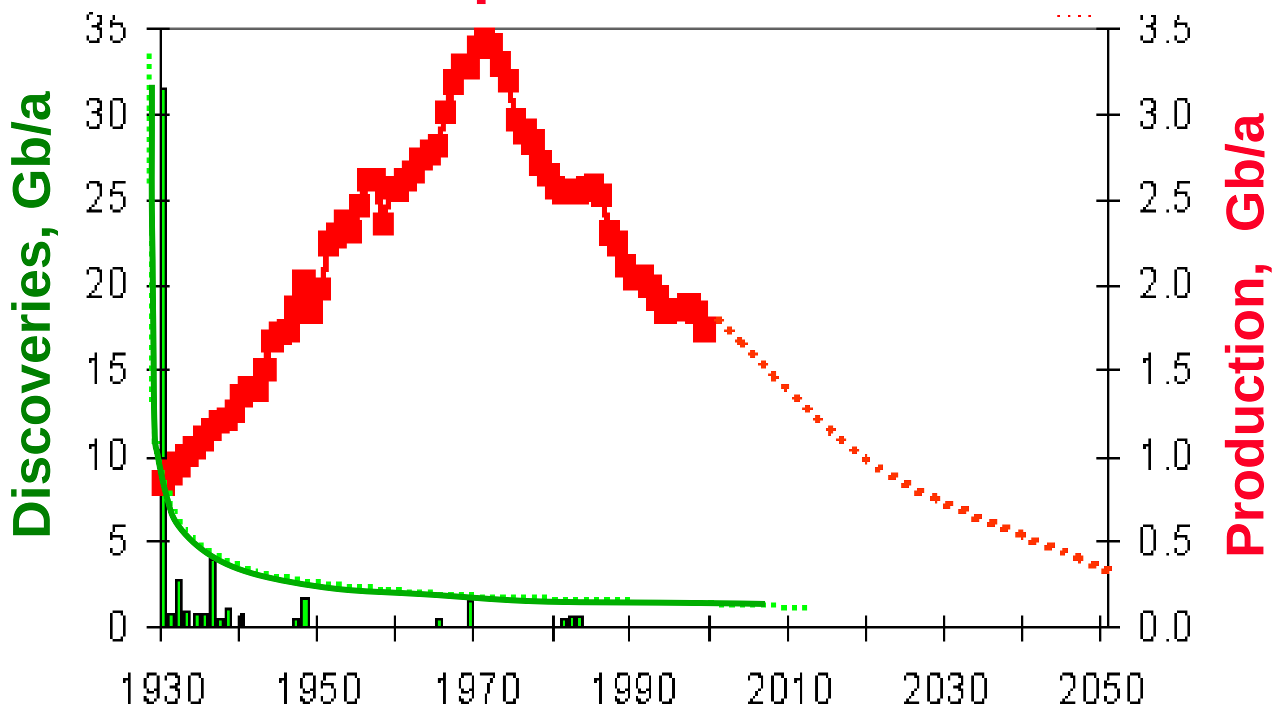
M. King Hubbert Predicted in 1959 that U.S. Domestic Production would Peak in 1970.



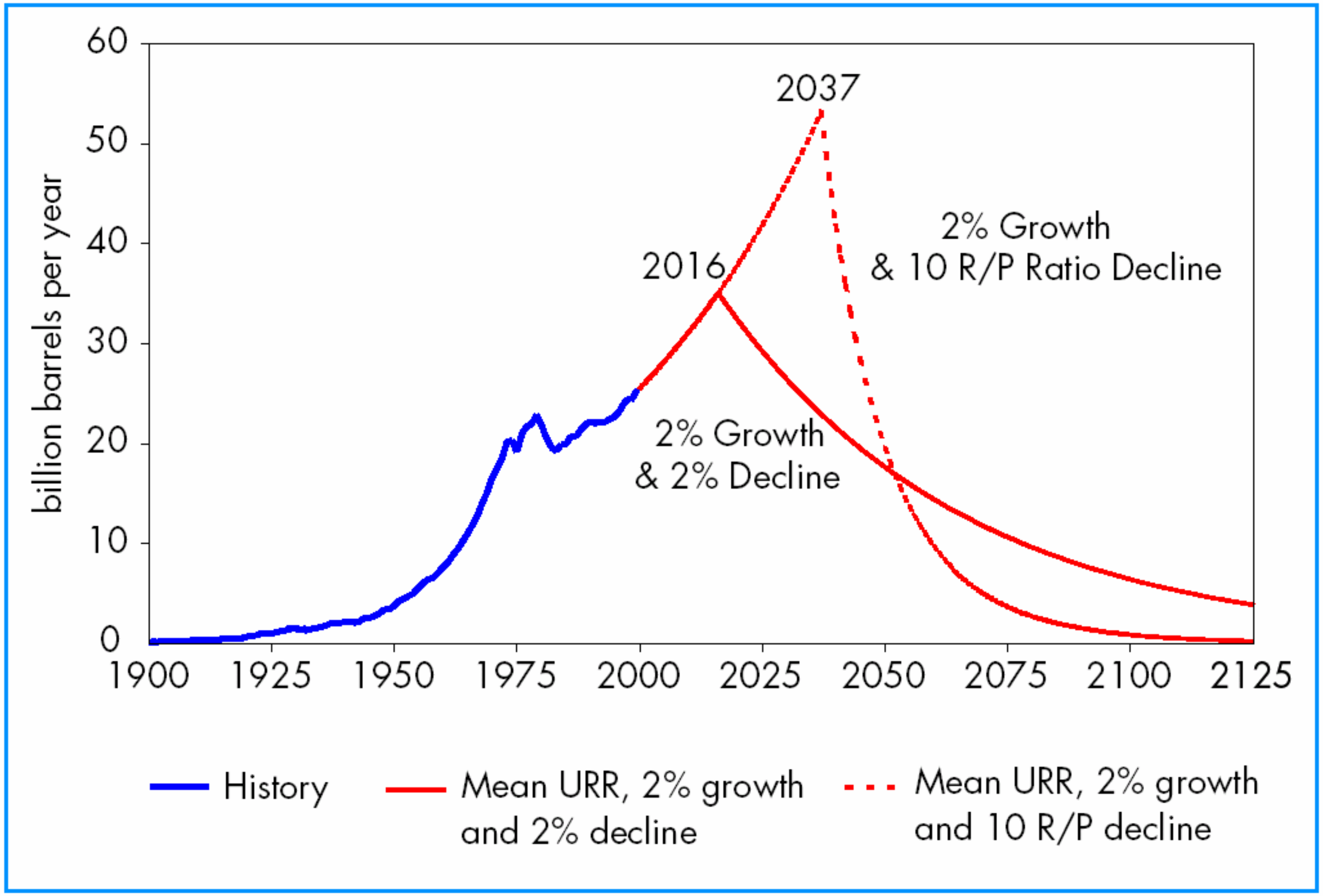
Production in the Lower 48 States

Peak discovery: 1930

Peak production: 1972



Hubbert Curves with different assumptions of rate of decline using GSGS and DOE best estimates of ***total*** discovered and undiscovered global reserves



Source: *World Energy Outlook, 2001* by the International Energy Agency, a body of the Organization for Economic Co-operation and Development (OECD)

International Energy Agency (IEA) Carbon Emission forecast

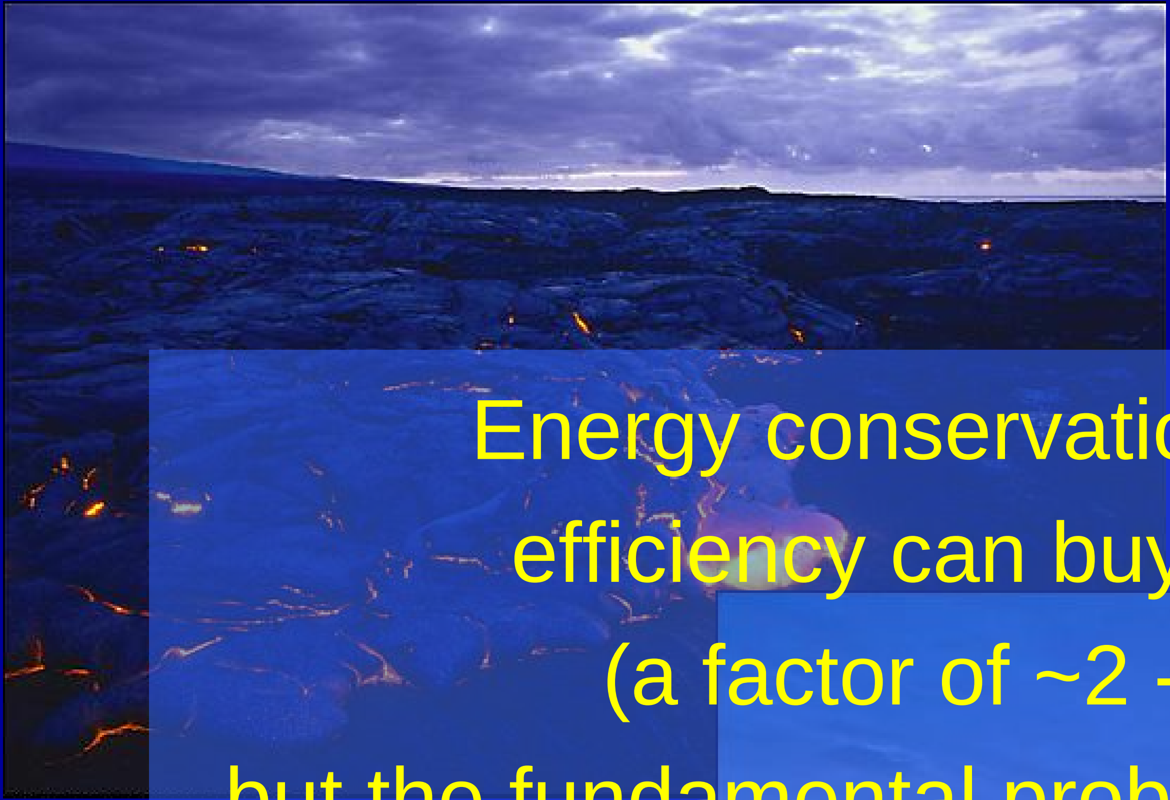
Between 2003-2030:

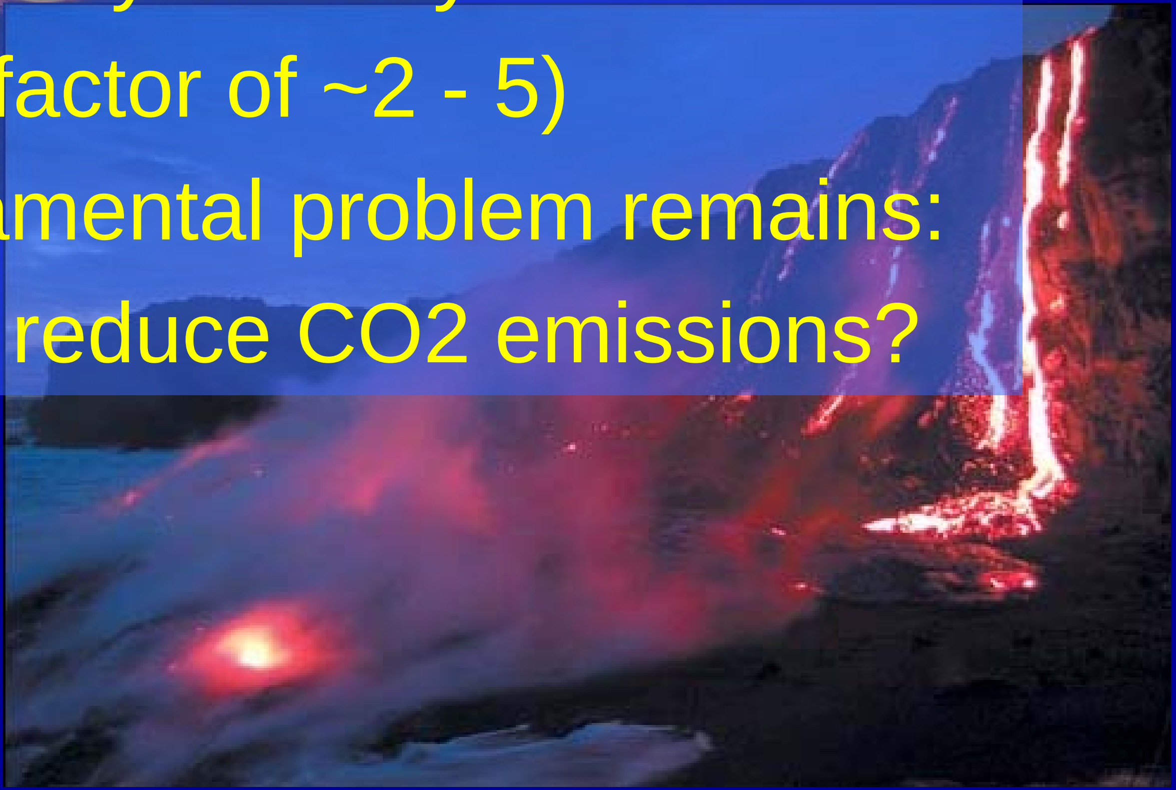
New Coal Plants = 1.4 TW

New Natural Gas Plants = 1.9 TW

The projected carbon emission in the next 30 years we will add 3x more CO_2 emission than the previous 250 years!

Energy from tar sands and shale oil will be as bad for CO_2 emissions as coal .





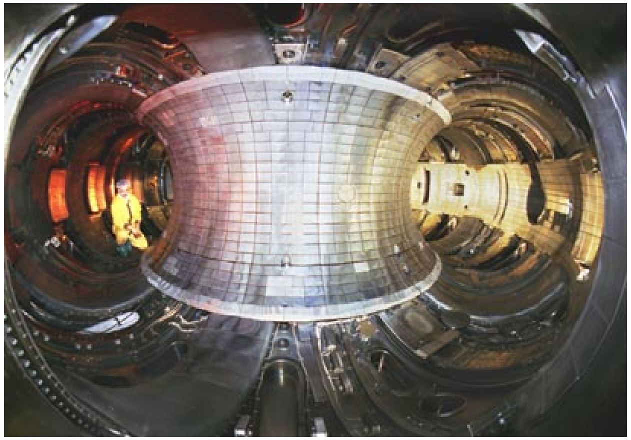
Energy conservation and
efficiency can buy time
(a factor of ~2 - 5)
but the fundamental problem remains:
how can we reduce CO_2 emissions?

- The possibility (likelihood) of global warming and its consequences

- Possible solutions

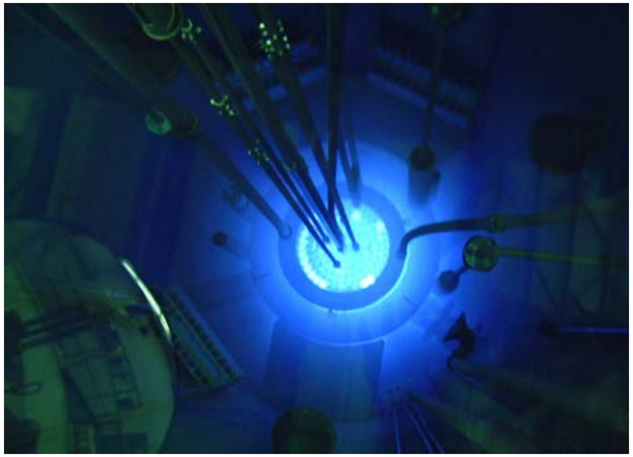
Potential Sources of Energy when Fossil Fuels Run Out

Nuclear Fusion



Magnetic Plasma Confinement, Inertial Fusion

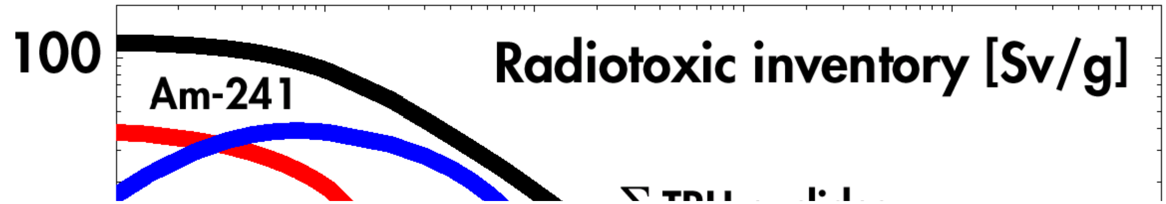
Nuclear Fission



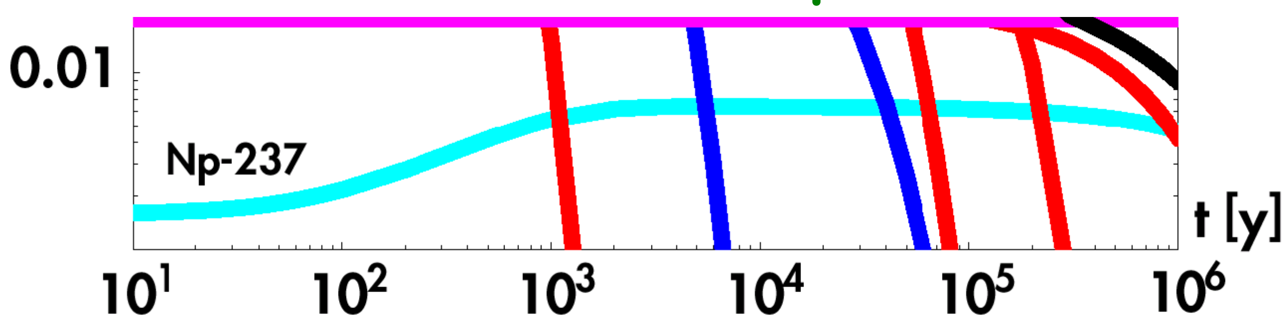
Waste & Nuclear Proliferation

3 TW = One new GW reactor every week for the next 50 years)

Waste production of plutonium, minor actinides, long-lived fission products



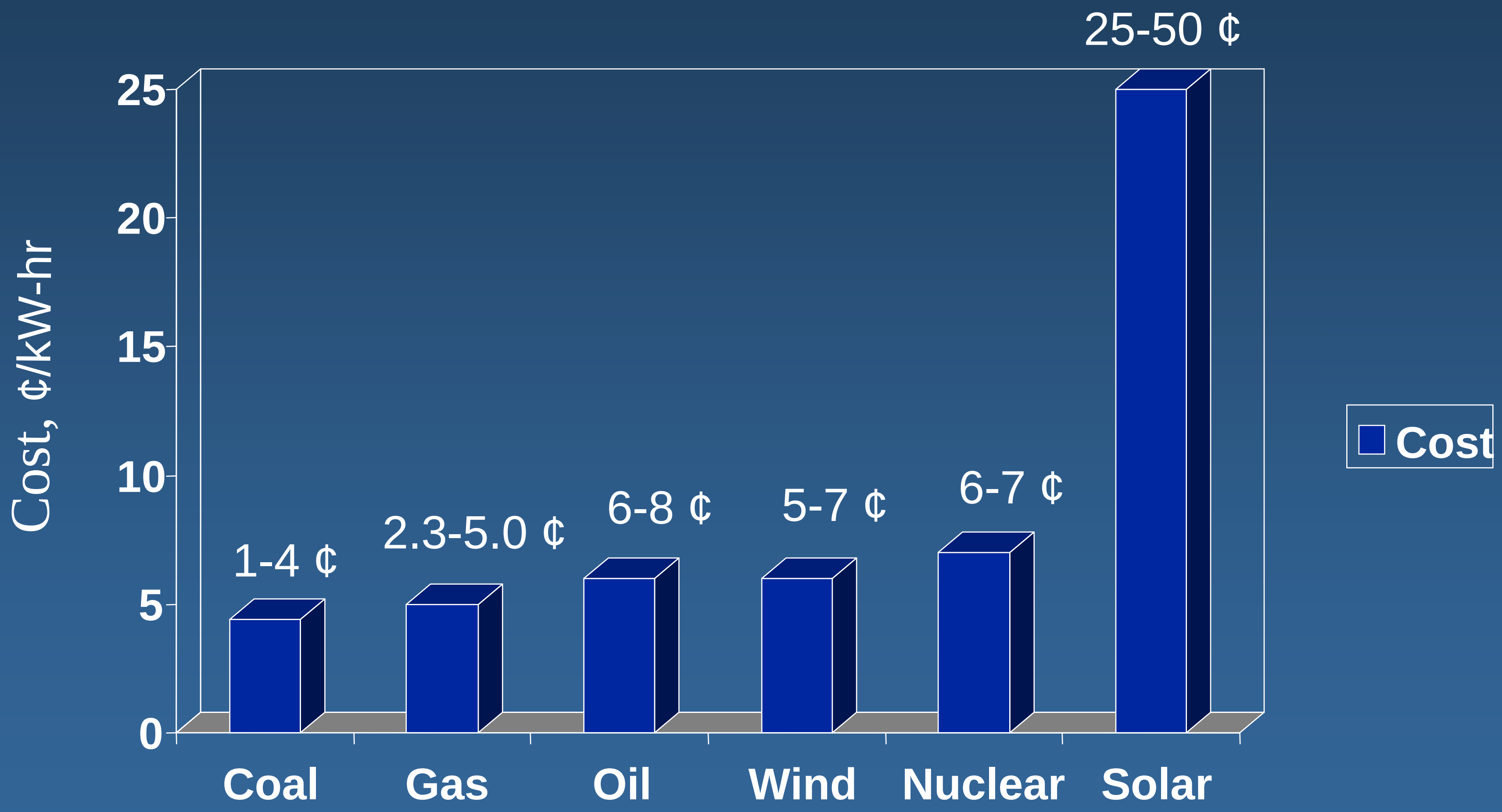
There is hope: re-cycle fuel and research how to efficiently convert (via fission) long-lived nuclear waste into shorter-lived radioactive products



Solar Energy: Photo-voltaic cells

Today: Production Cost of Electricity

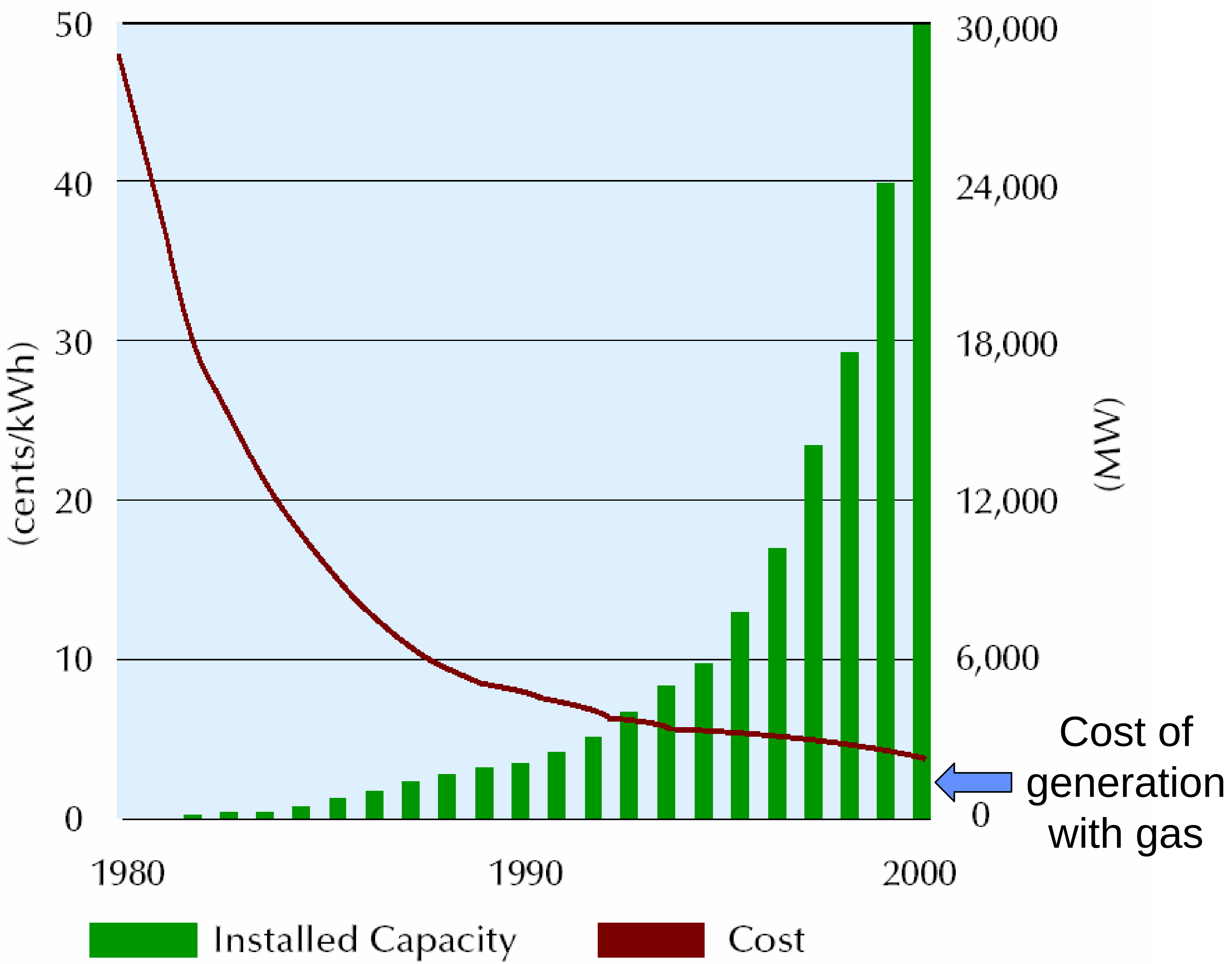
(in the U.S. in 2002)



Courtesy Nate Lewis

Solar Energy: Wind

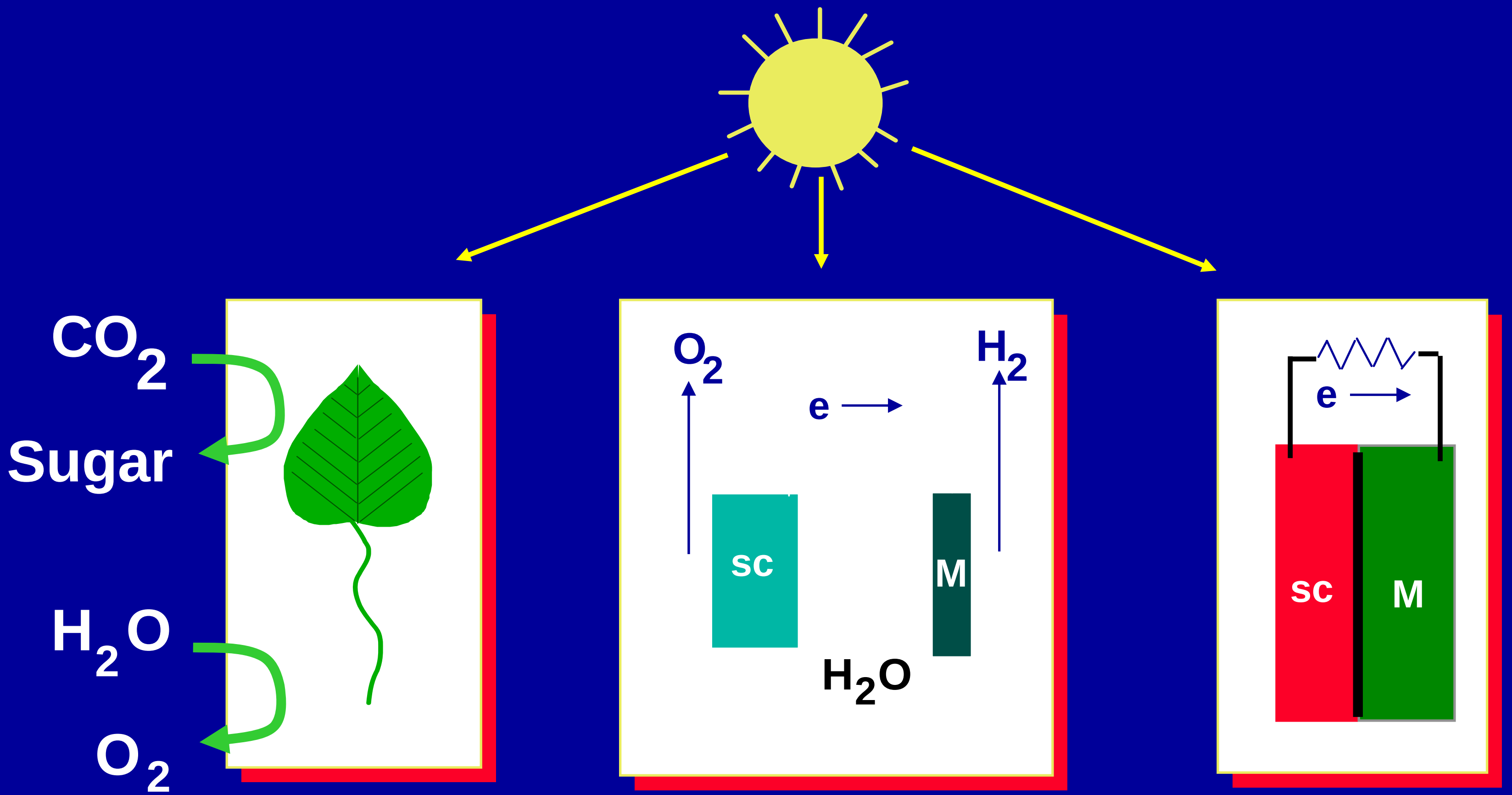
Wind Power Generation



Solar Energy: Hydro-electric as energy storage of electricity?

A possible energy storage

Solar to Chemical Energy

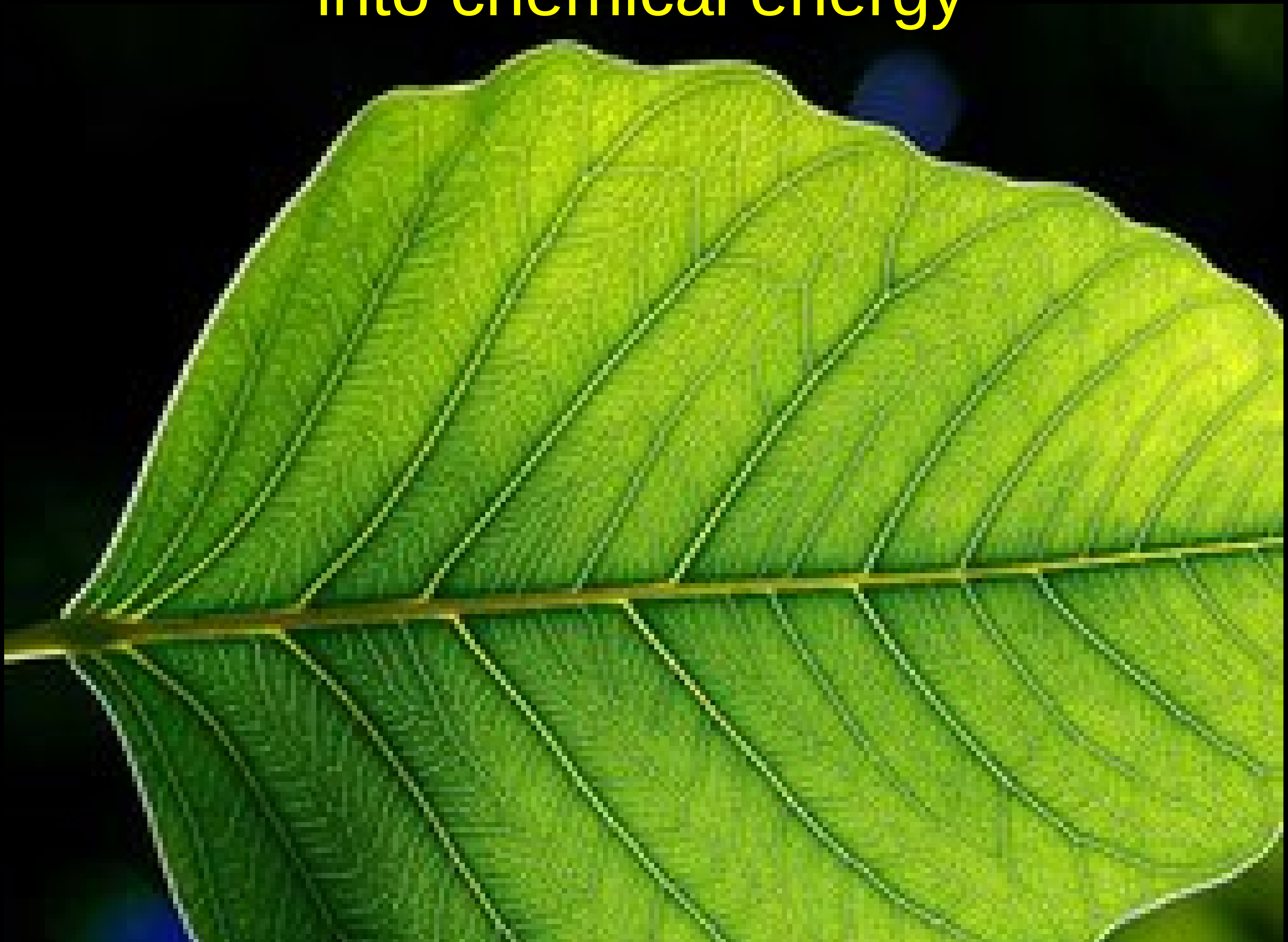


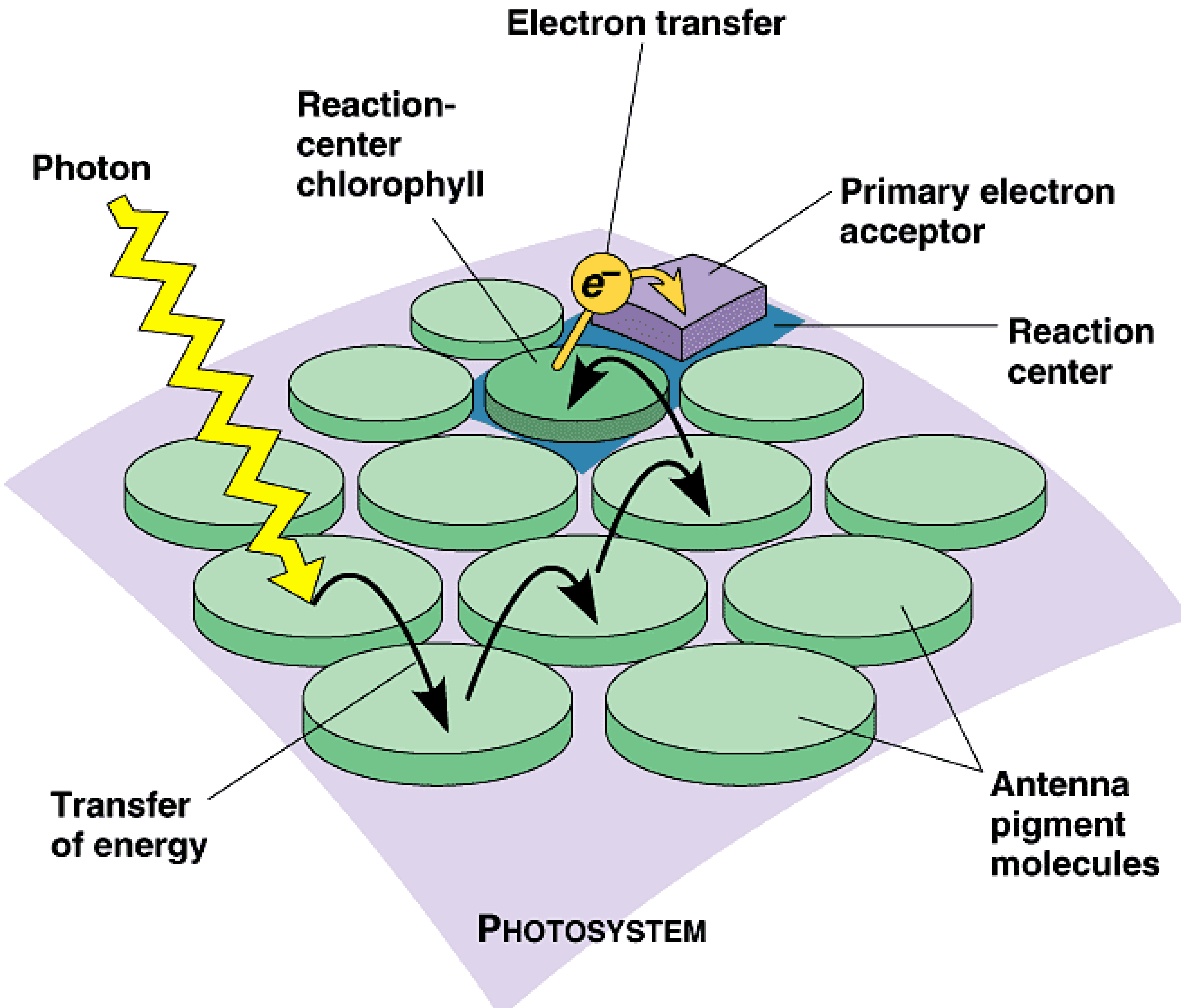
Photosynthesis

Semiconductor/
liquid junctions

Photovoltaic
⇒ electricity
⇒ chemical

Photosynthesis: Nature has found a way to convert sunlight, CO_2, water and nutrients into chemical energy



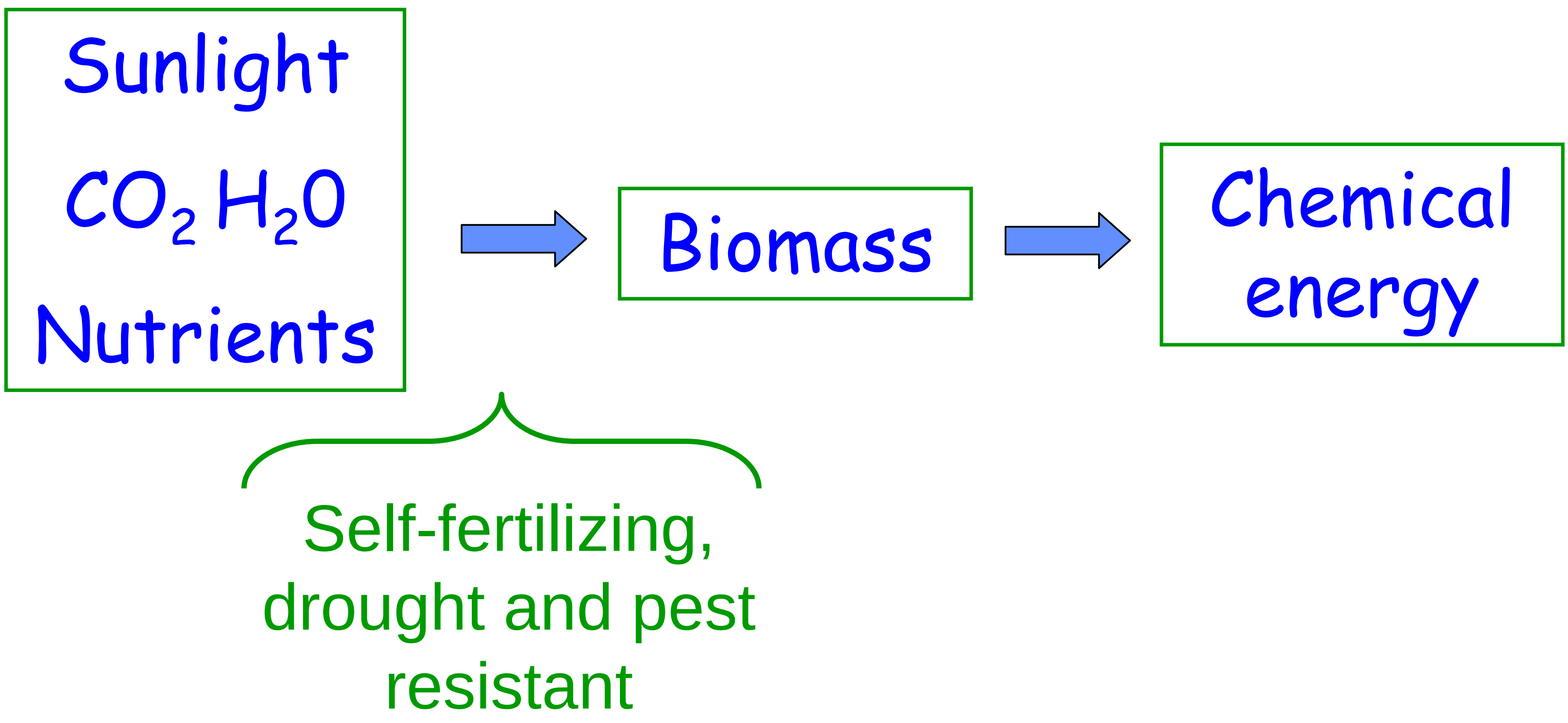

Electron transfer
Reaction-center chlorophyll
Photon
Primary electron acceptor
e⁻
Reaction center
Transfer of energy
Antenna pigment molecules
PHOTOSYSTEM

The nanotechnology challenges:

- Absorption of light and charge separation (easy)
- Charge transfer (molecular) transport (harder)
- Chemical conversion (the hardest part)

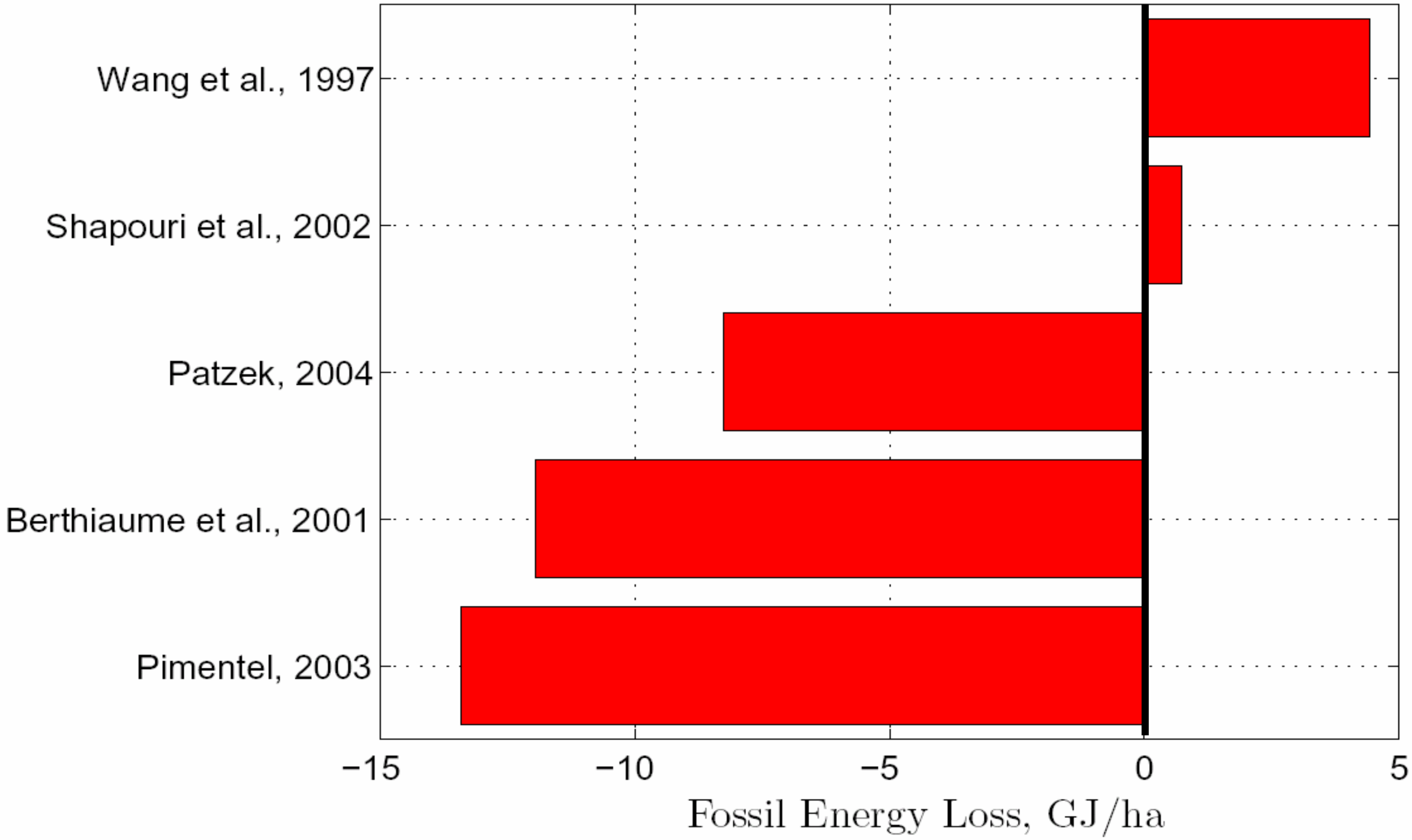
The majority of a plant is structural material

Cellulose	40-60% Percent Dry Weight
Hemicellulose	20-40%
Lignin	10-25%

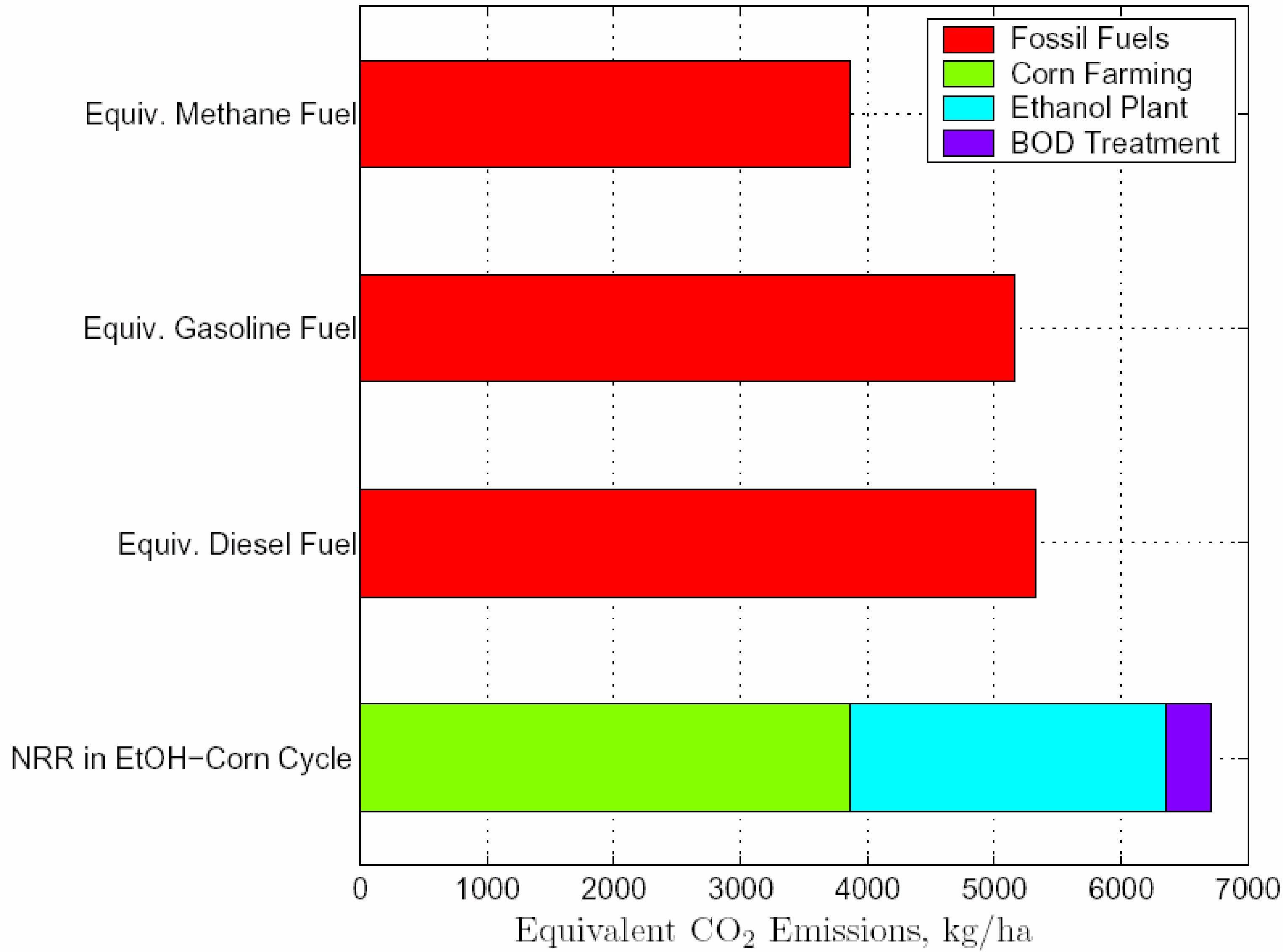


Corn

Net energy produced by growing corn for ethanol



Total CO_2 emissions of common fuels and corn production

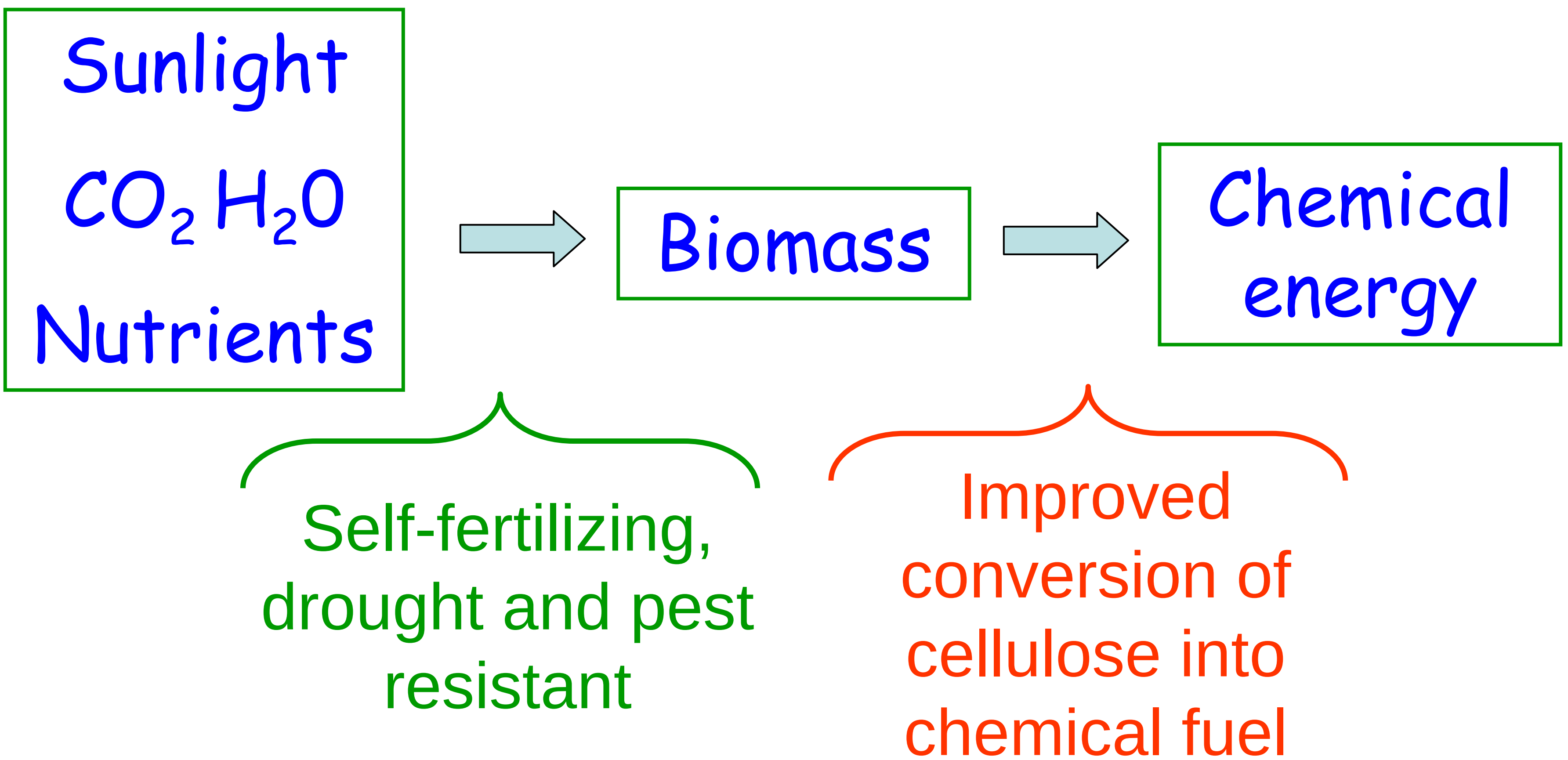


Sugar cane

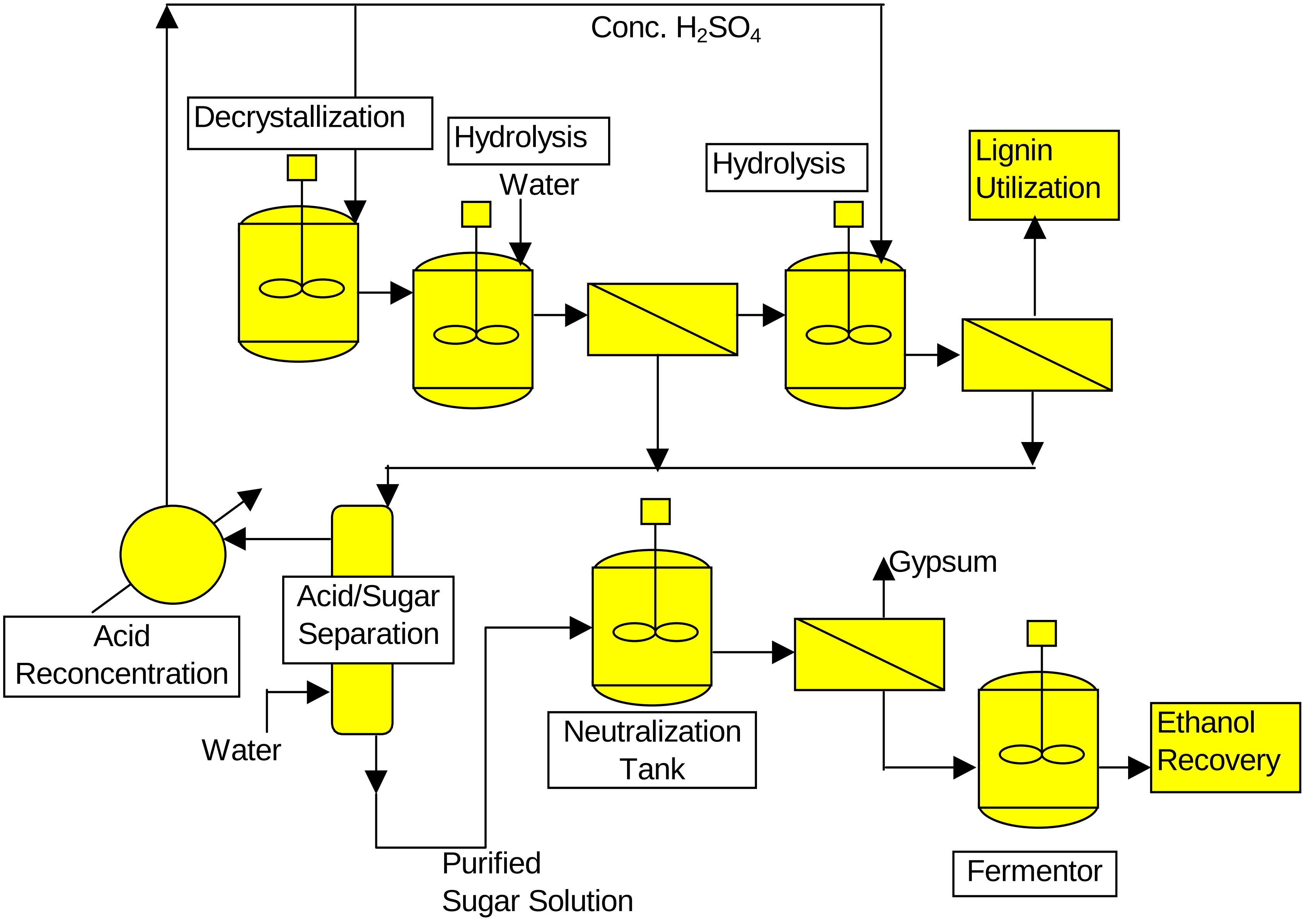
Switchgrass

The majority of a plant is structural material

Cellulose	40-60% Percent Dry Weight
Hemicellulose	20-40%
Lignin	10-25%

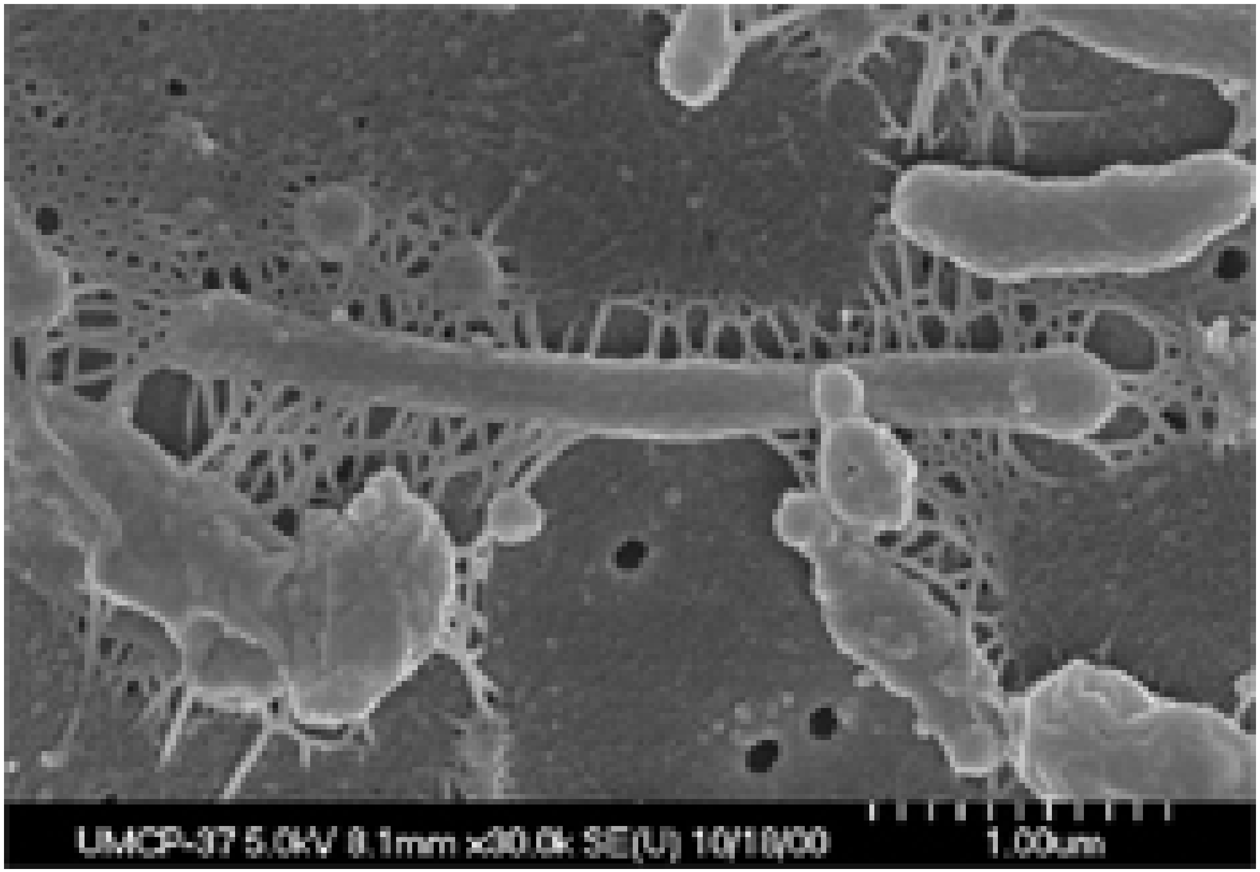


Commercial ethanol production from cellulose



Microbulbifer degradans

A group of microorganisms that degrades of a significant portion of the 50+ billion tons of cellulose

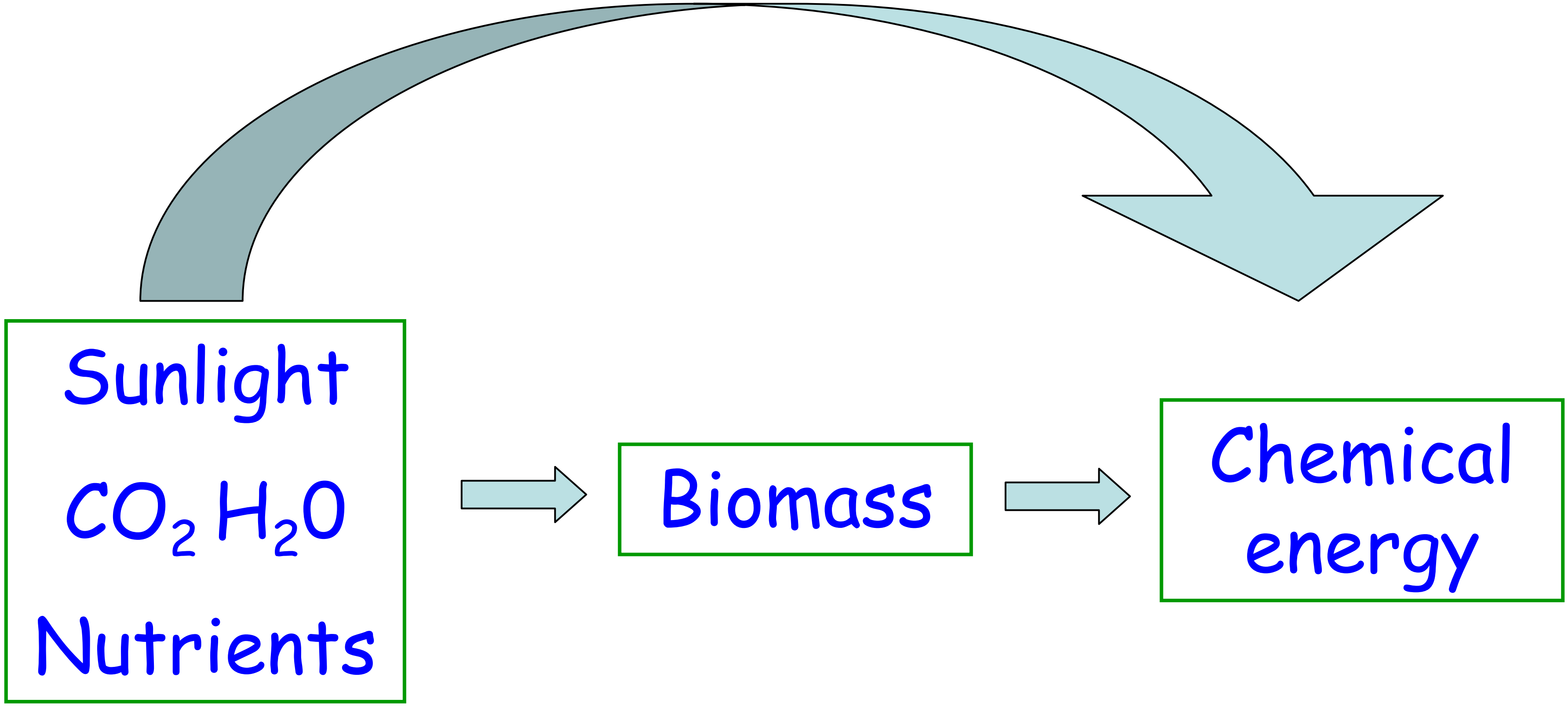


Synthetic Biology:

Production of artemisinin in bacteria Jay Keasling

Can synthetic organisms be engineered to produce ethanol, methanol or methane from cellulose?

Can we modify existing organisms or design new ones to directly produce energy?



A diversified portfolio of investments is needed

A solution may lie at the interface of biology
and
the physical sciences at the nano-scale

and International

National ^ Concerns

1) National security which is intimately tied to energy security

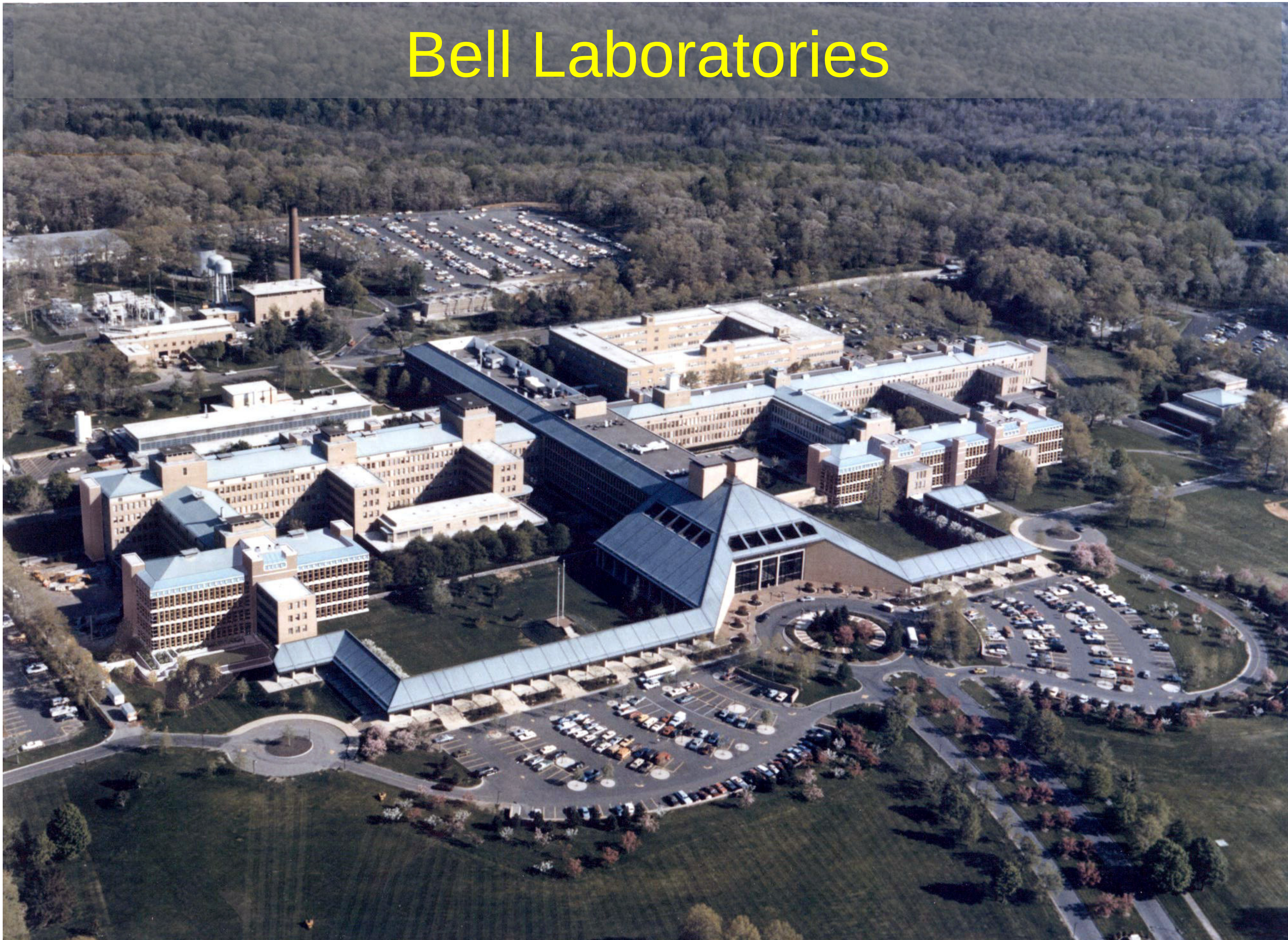
2) Economic prosperity

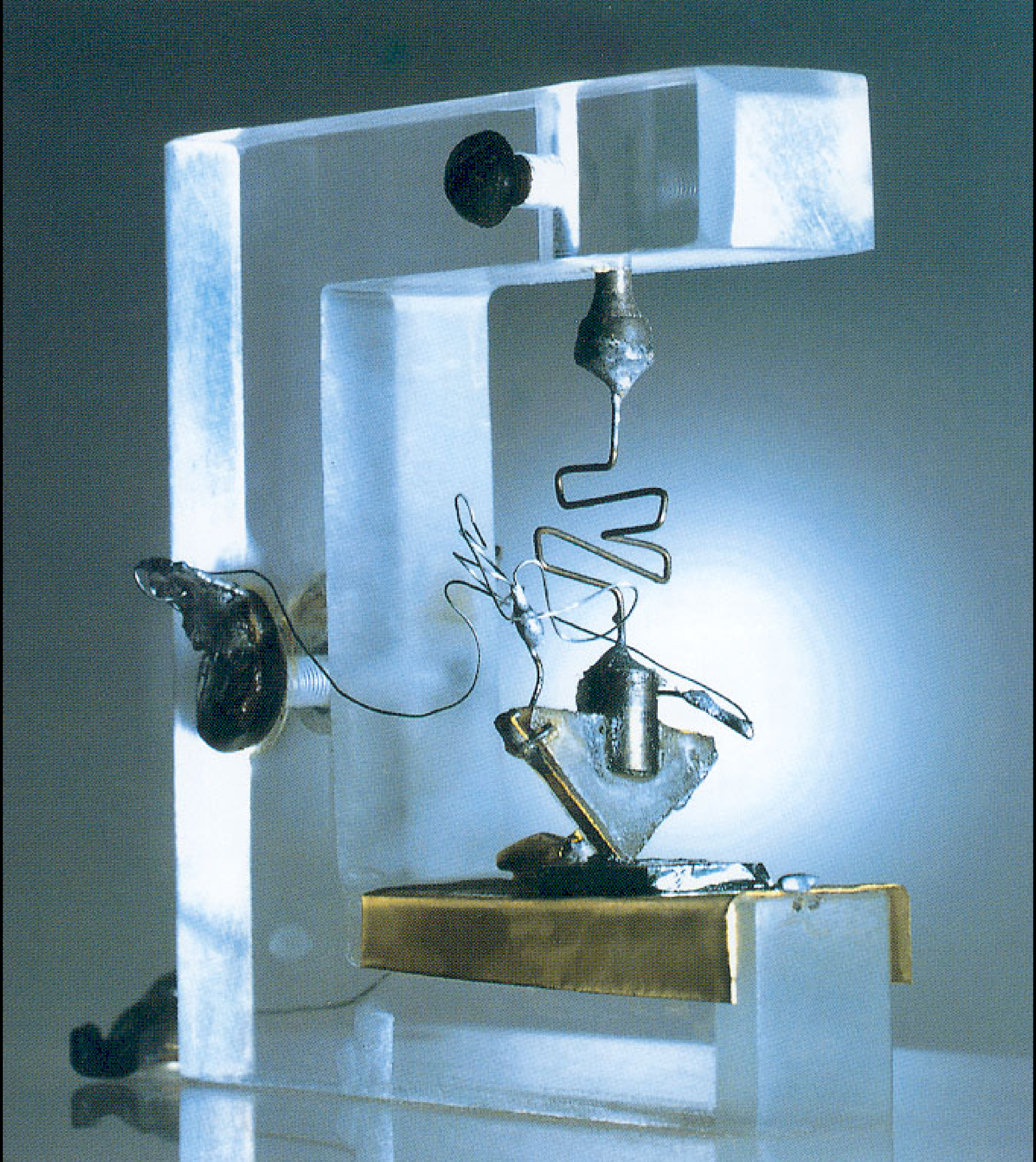
3) The environment

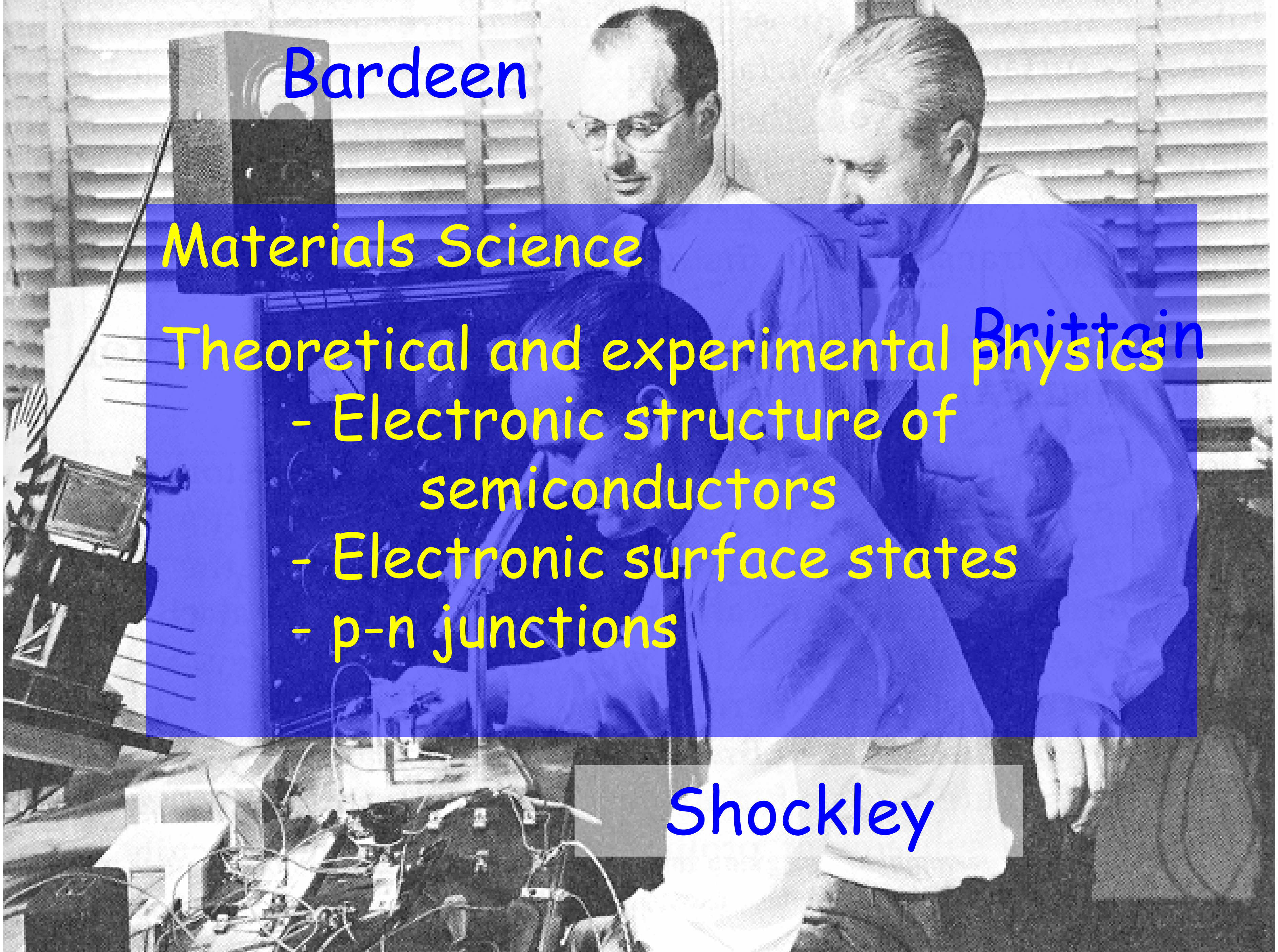
Sustainable, CO_2 neutral energy

Should we start an "Apollo Project" to solve the energy problem?

Bell Laboratories

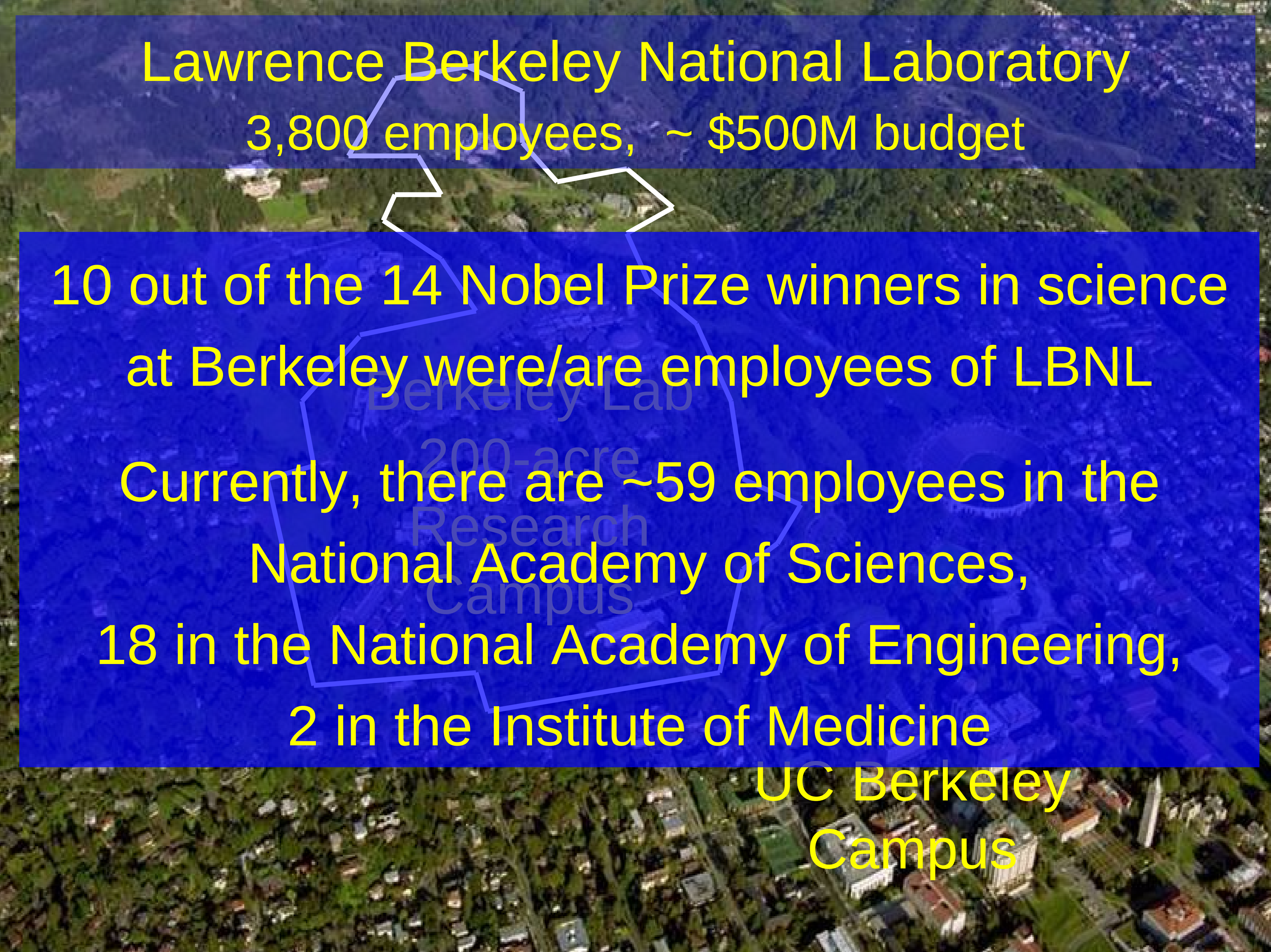




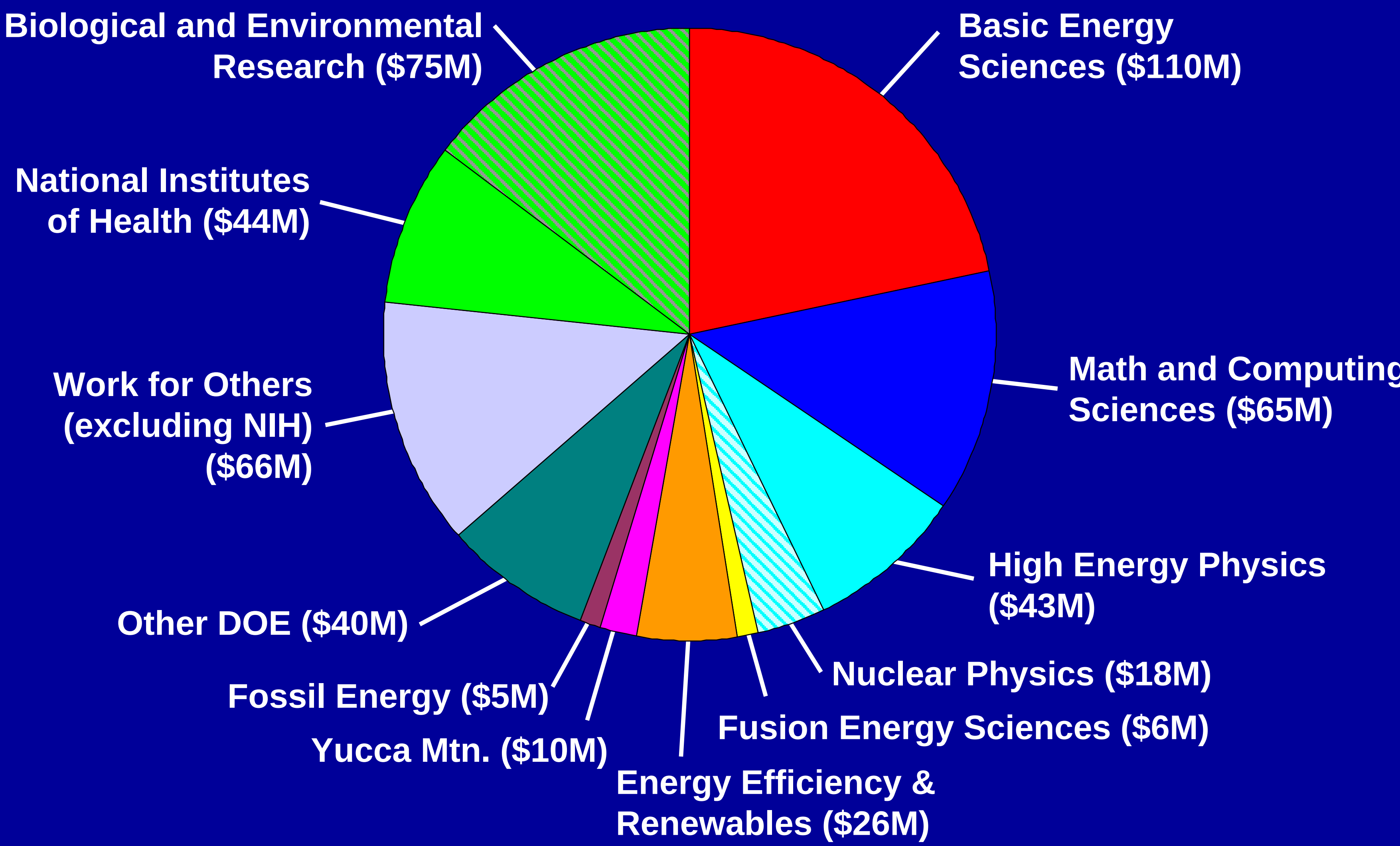

Bardeen
Materials Science
Theoretical and experimental physics
- Electronic structure of semiconductors
- Electronic surface states
- p-n junctions
Brittain
Shockley

“All the early lasers were developed first at industrial research organizations… what was needed was a big support organization which could focus different technologies on a common goal. At American Universities, you plod along with small groups of specialists.”

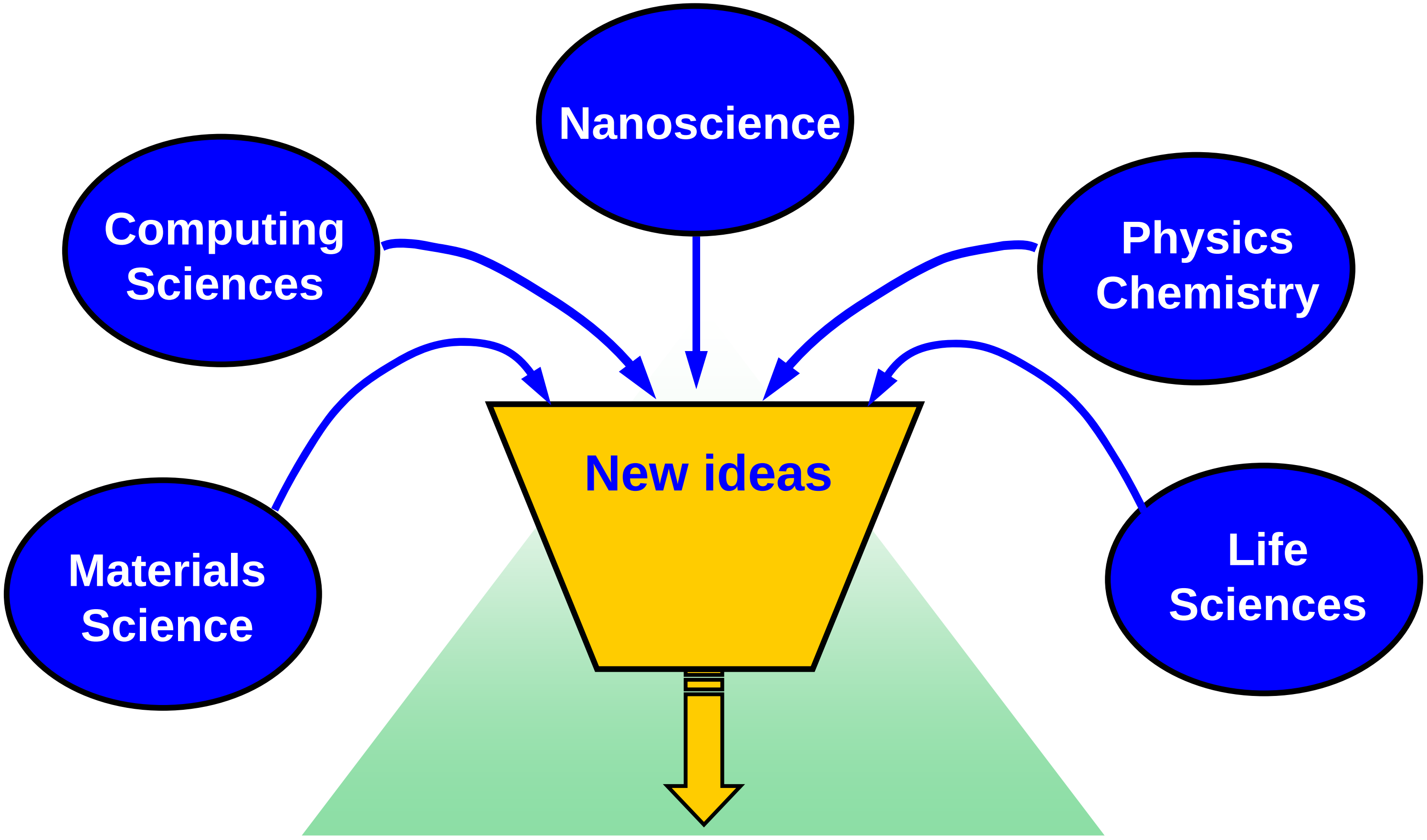
Nico Bloembergen,
On why he never tried to build the first laser


Lawrence Berkeley National Laboratory
3,800 employees, ~ $500M budget
10 out of the 14 Nobel Prize winners in science at Berkeley were/are employees of LBNL
Currently, there are ~59 employees in the National Academy of Sciences,
18 in the National Academy of Engineering,
2 in the Institute of Medicine
Berkeley Lab
200-acre
Research
Campus
UC Berkeley
Campus

~ 25% of the Lawrence Berkeley Lab budget is in the biological and biophysical sciences



Integration of many disciplines will be needed



Chemical Fuel From Solar Energy


Meanwhile, the polar ice
caps continue to melt.


Lawrence Berkeley National Laboratory