UC Berkeley Guest Lecture
Introduction to Environmental Studies

18 October 2007

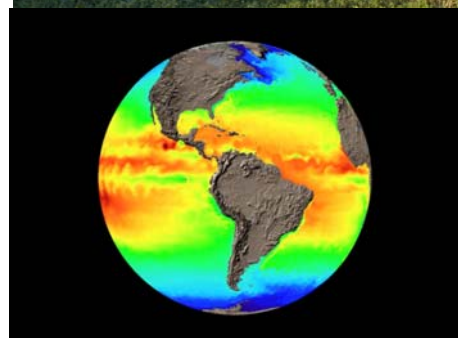
I. The Challenges

- Climate Change
- Alternative Fuels
- Energy Efficiency

II. The Role of Berkeley Lab

- Computational Research and Theory Facility
- Helios Energy Research Facility

  - Climate Change Simulation and monitoring (verification)
  - Energy Efficiency Technology



Potential effects of 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, coleara, dengue fever, …)
- Water Shortages

Emissions pathways, climate change, and impacts on California

Proceedings of National Academy of Sciences (2004)

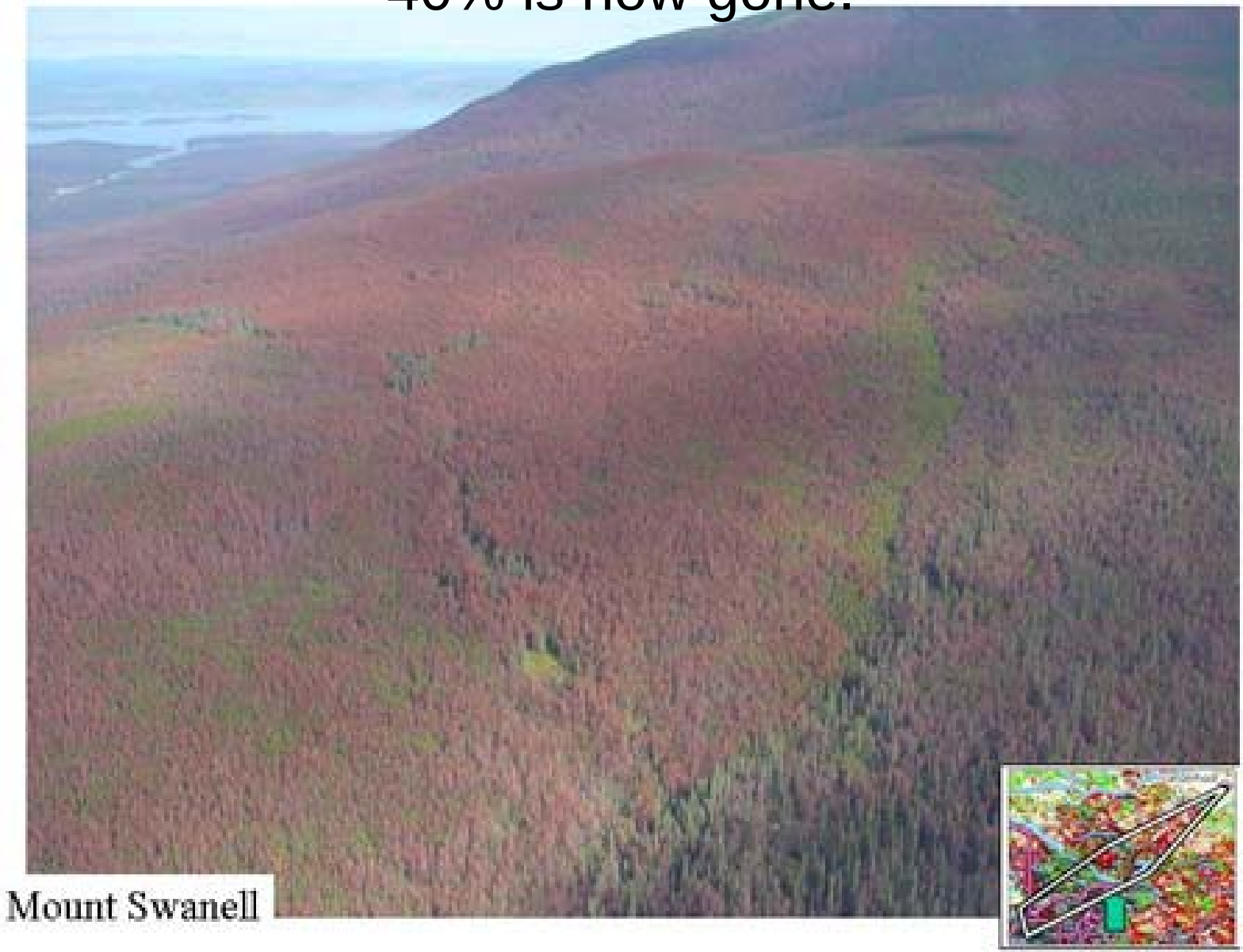
Using two climate models that bracket most of carbon emissions scenarios:

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

British Columbia: ~ 78% of the pine forests predicted to be dead within a decade due to pine beetle infestation.

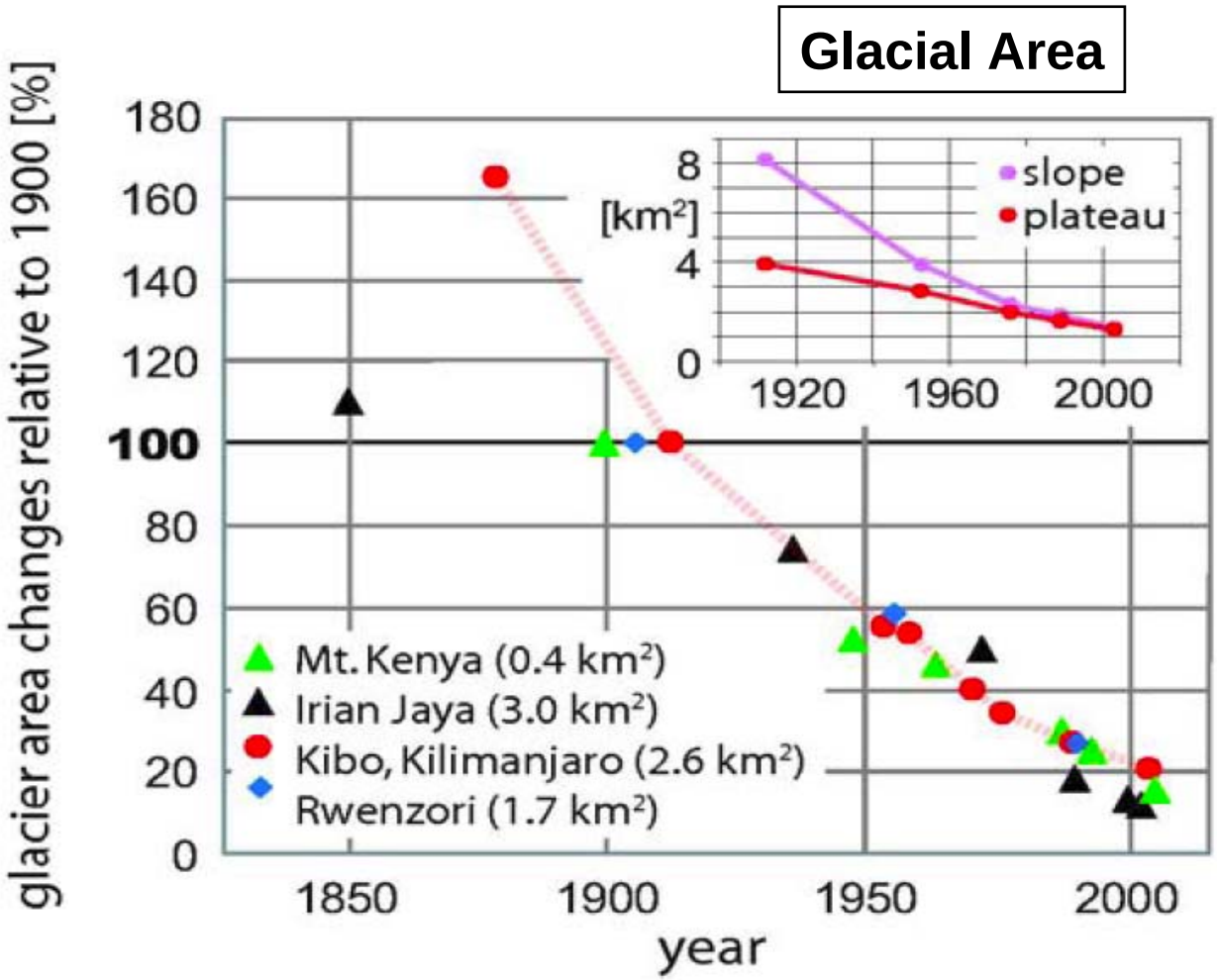
80% of British Columbia pine will have died by 2013.

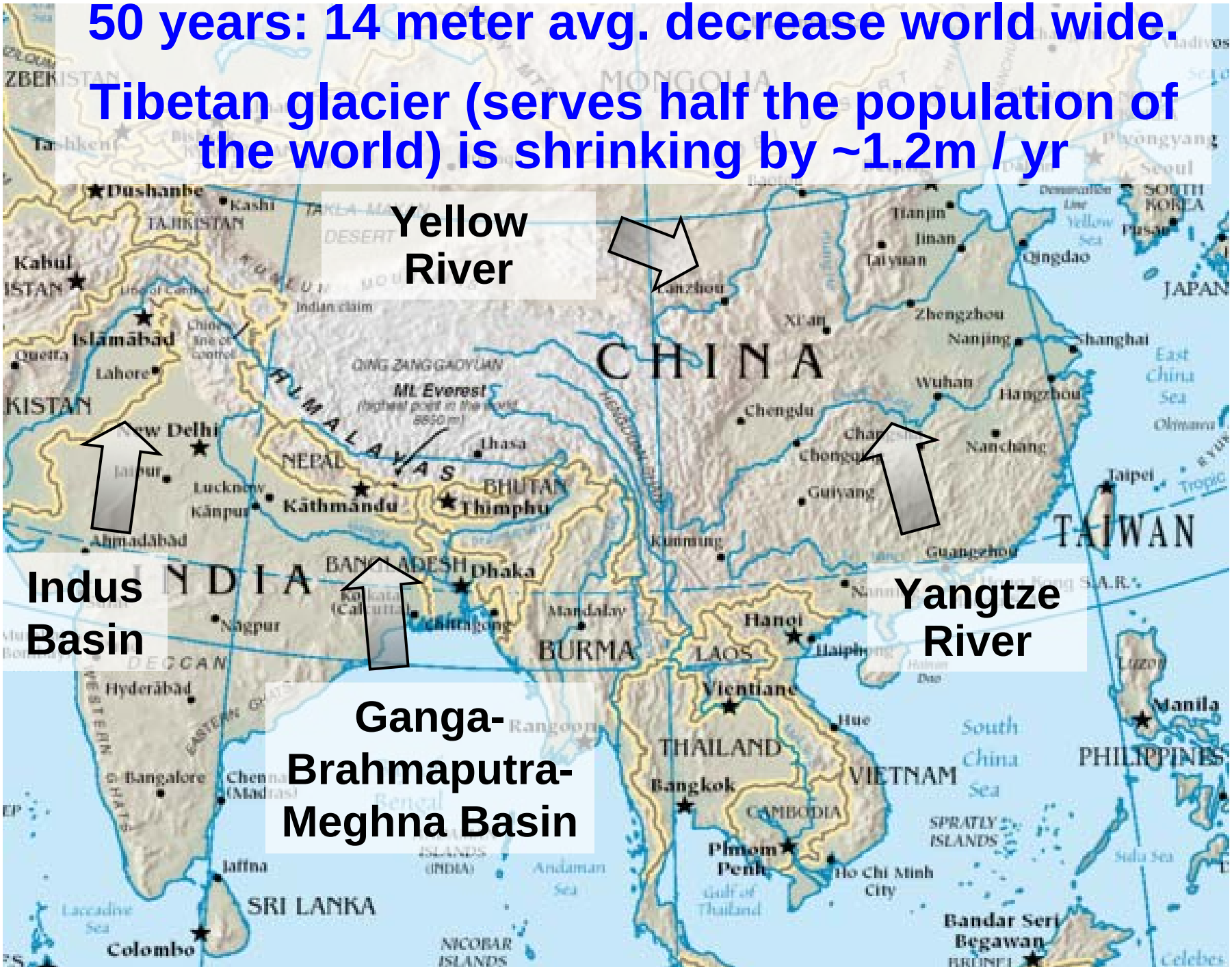
~ 40% is now gone.



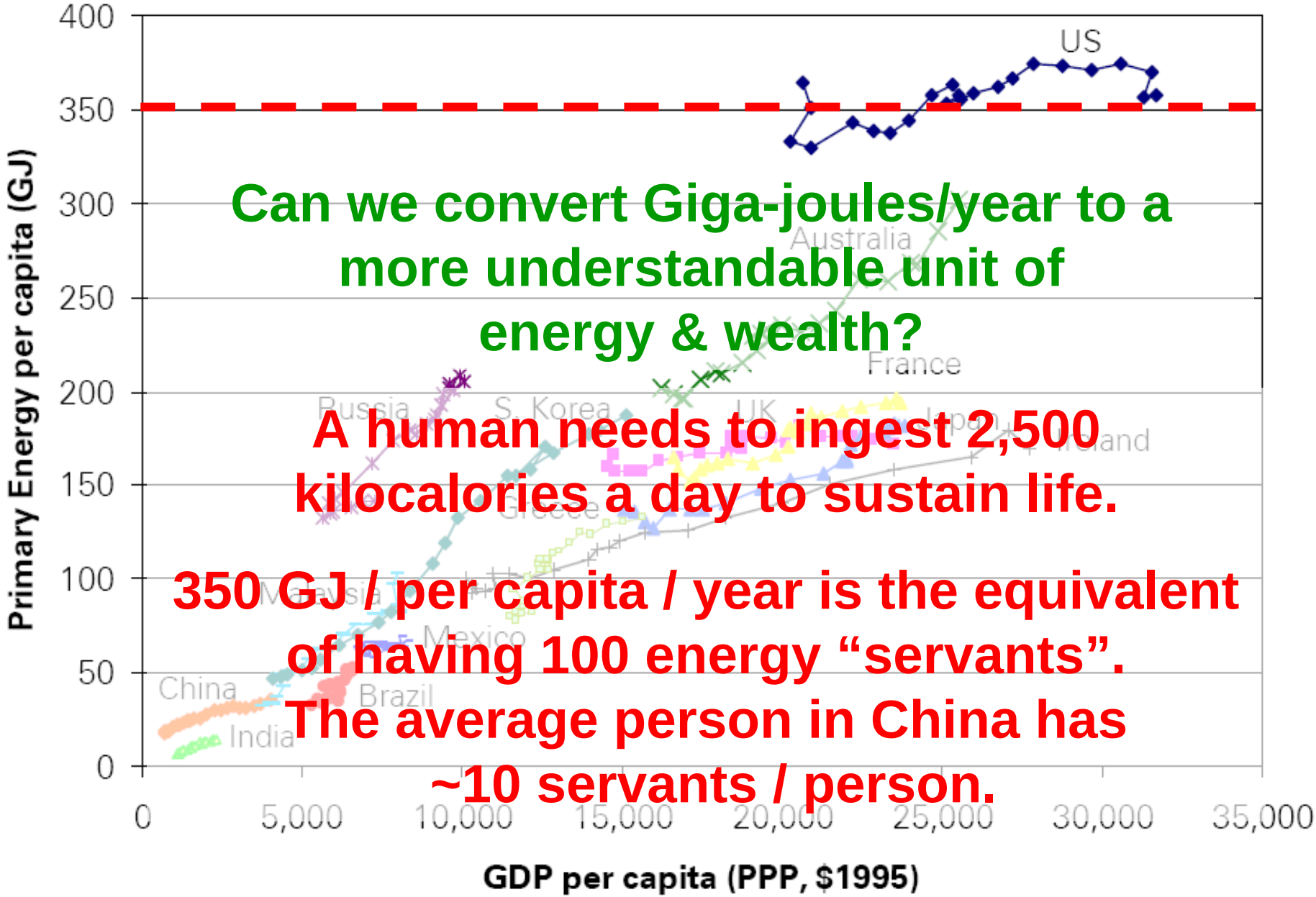
Mount Swanell

Change in other Glacial Areas around the world




50 years: 14 meter avg. decrease world wide.
Tibetan glacier (serves half the population of the world) is shrinking by ~1.2m / yr
Yellow River
Indus Basin
Ganga-Brahmaputra-Meghna Basin
Yangtze River
CHINA
INDIA
NEPAL
BHUTAN
BURMA
LAOS
THAILAND
VIETNAM
CAMBODIA
TAIWAN
PHILIPPINES
SRI LANKA
Dushanbe
Kabul
Islāmābād
Lahore
New Delhi
Lucknow
Kānpur
Kāthmāndu
Thimphu
Lhasa
Ahmadābād
Dhaka
Nāgpur
Hyderābād
Bangalore
Jaffna
Colombo
Mandalay
Hanoi
Vientiane
Bangkok
Phnom Penh
Ho Chi Minh City
Kunming
Chengdu
Lanzhou
Xi'an
Zhengzhou
Wuhan
Nanjing
Shanghai
Hangzhou
Nanchang
Guiyang
Guangzhou
Taipei
Manila
Tianjin
Jinan
Qingdao
Seoul
Pyongyang
JAPAN
SOUTH KOREA
Bandar Seri Begawan
Mt Everest

Energy demand vs. GDP per capita



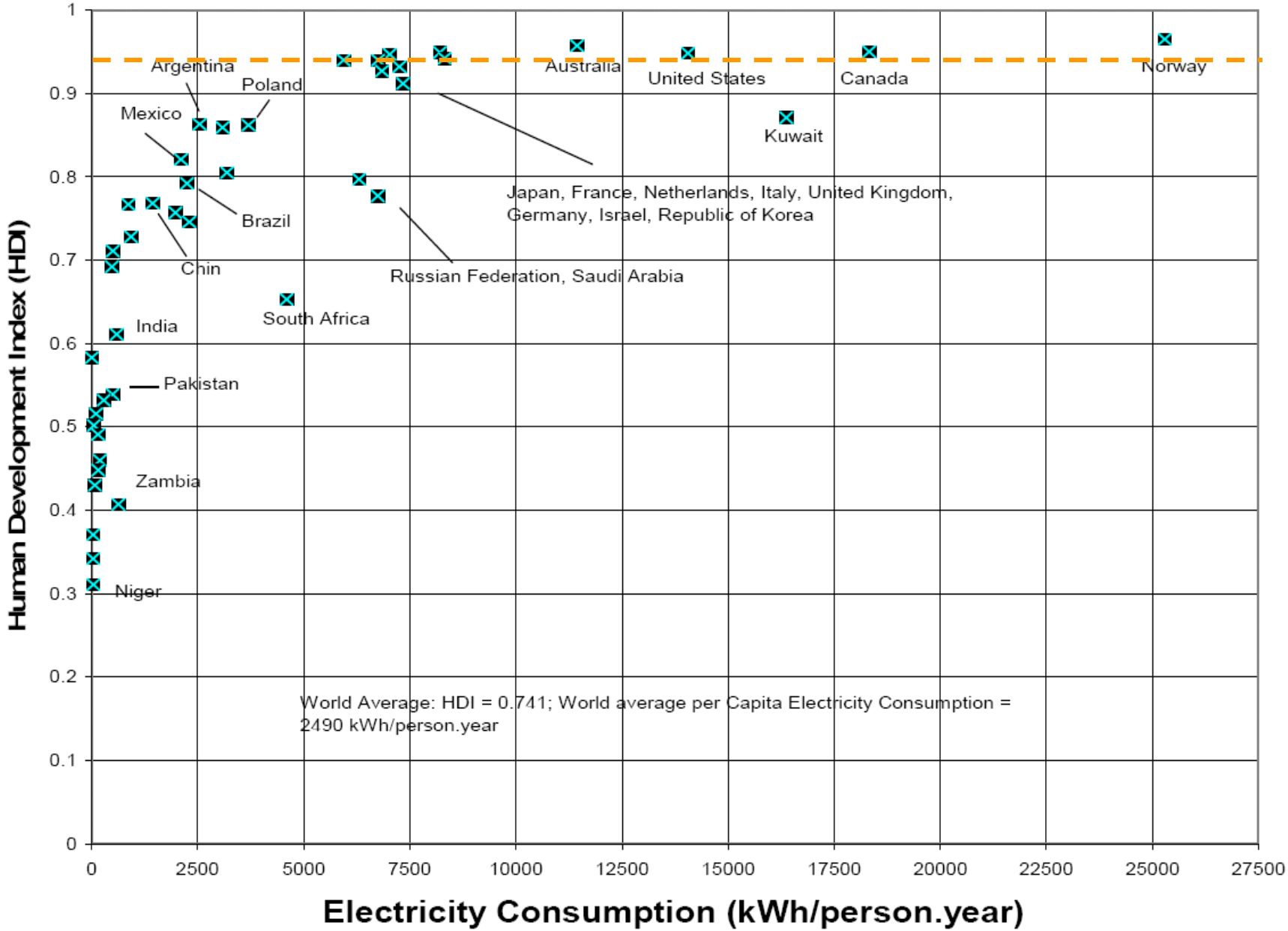
Can we convert Giga-joules/year to a more understandable unit of energy & wealth?

A human needs to ingest 2,500 kilocalories a day to sustain life.

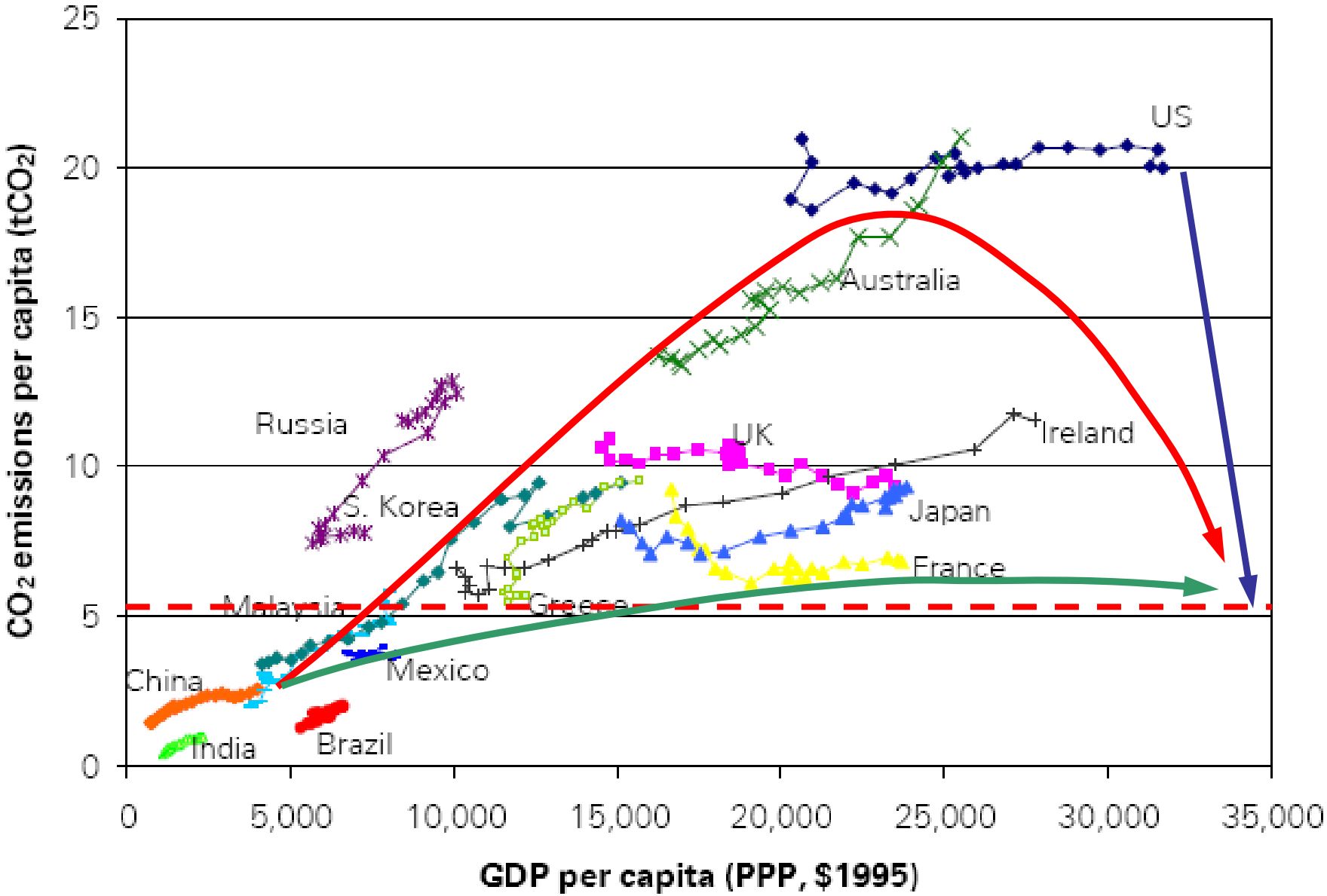
350 GJ / per capita / year is the equivalent of having 100 energy "servants". The average person in China has ~10 servants / person.

Source: UN and DOE EIA

Human Development Index vs. Energy consumption



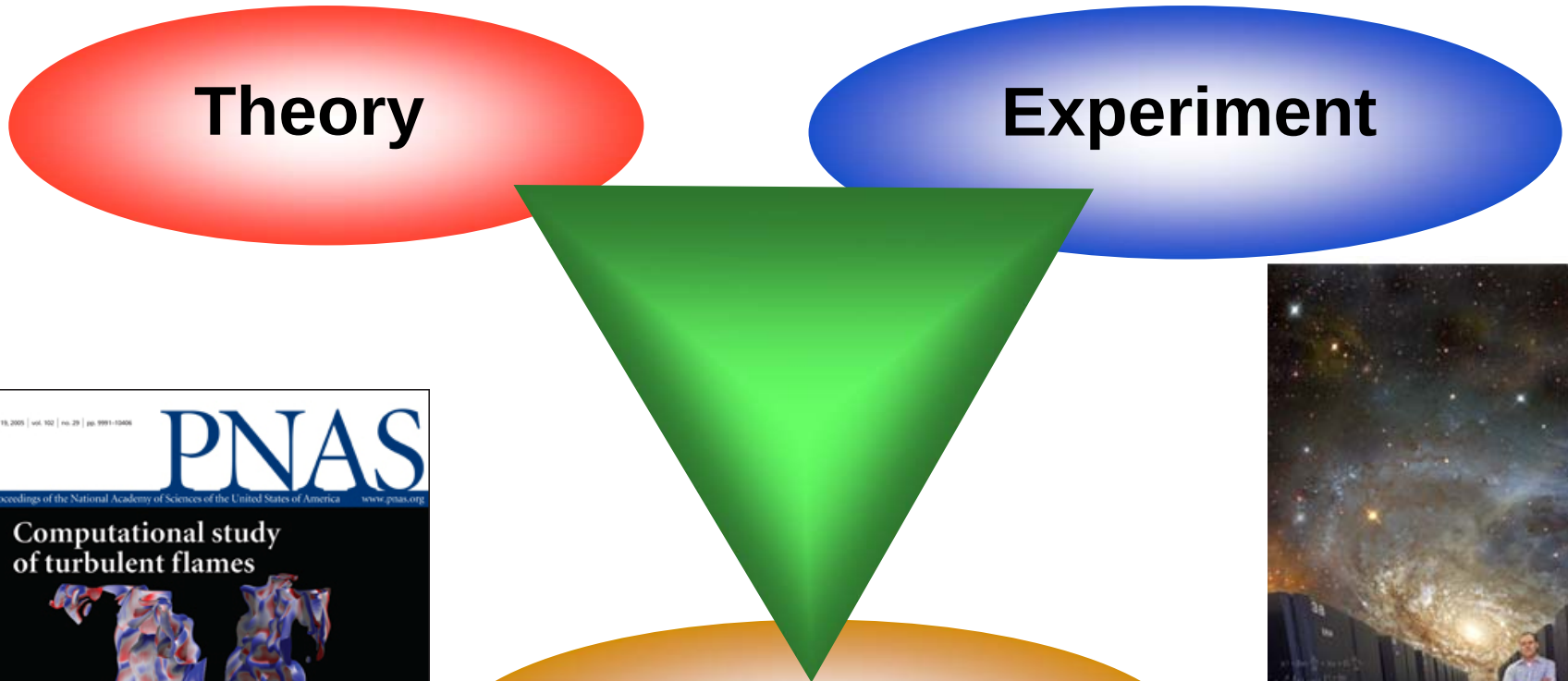
CO_2 emissions of selected countries

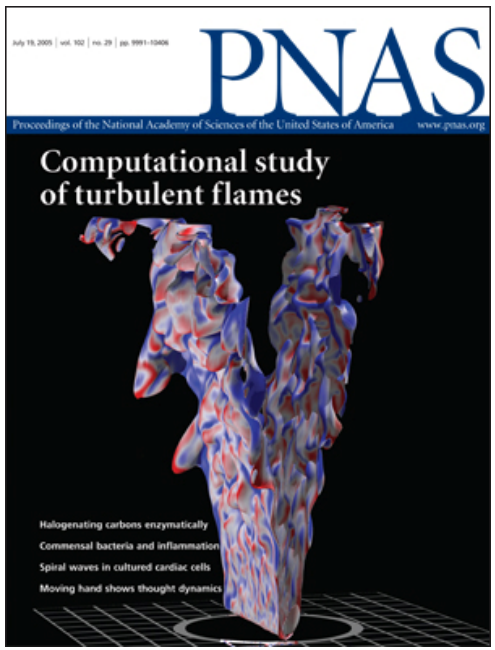


Energy Efficiency, Demand and Supply

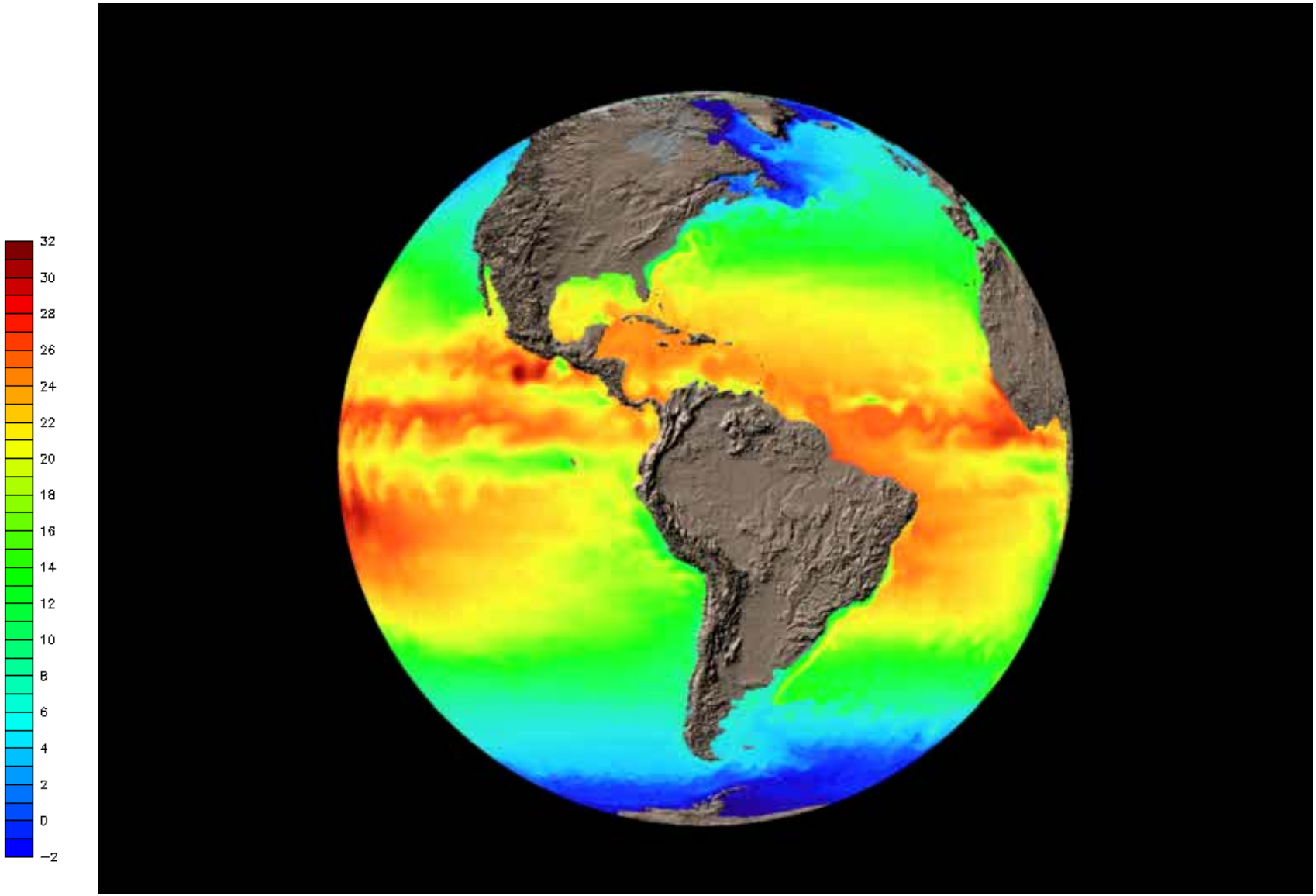
Energy efficiency and conservation is and will remains the lowest hanging fruit for the next several decades

Simulation is becoming and integral part of Science





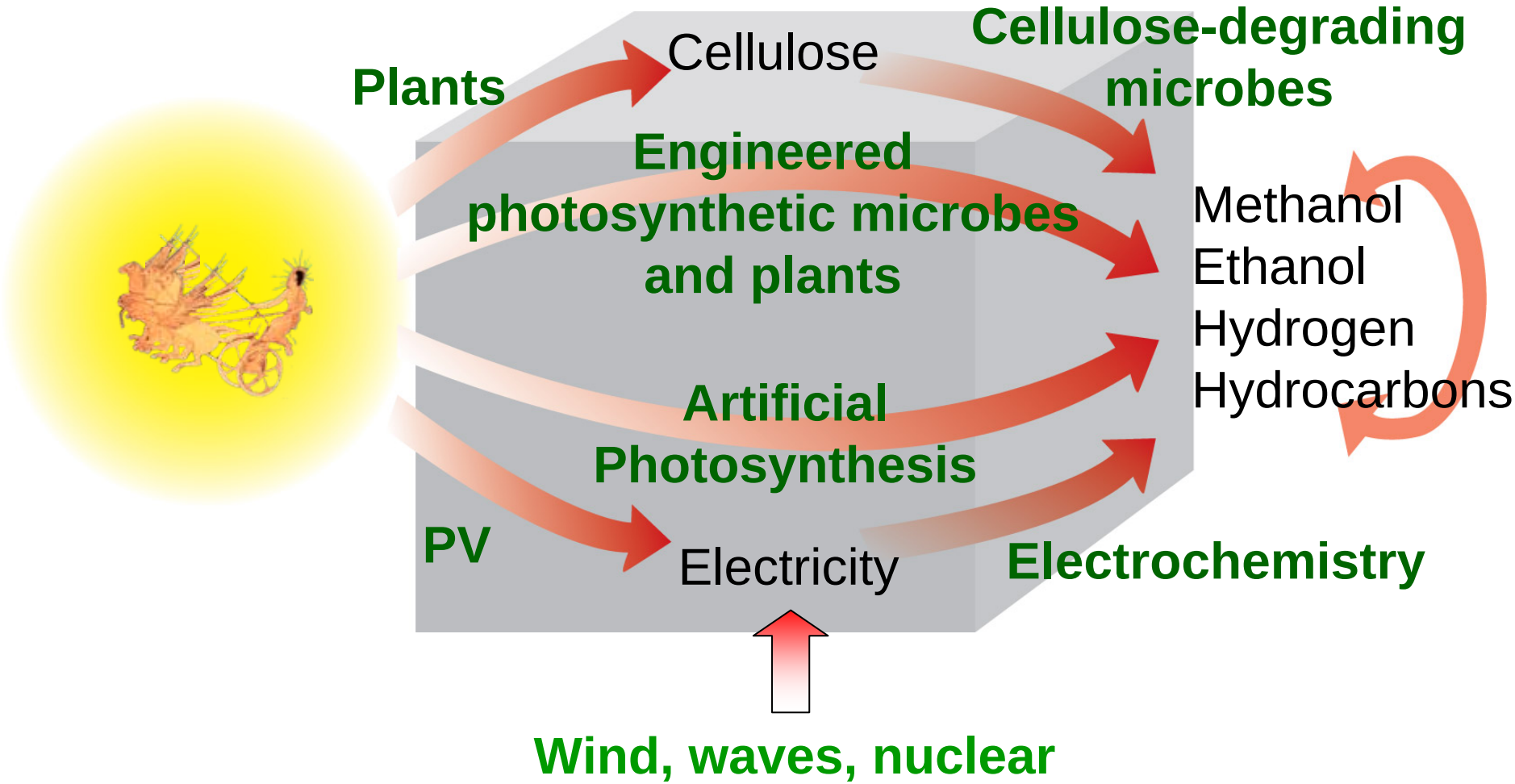
Supercomputing Simulation of Global Climate



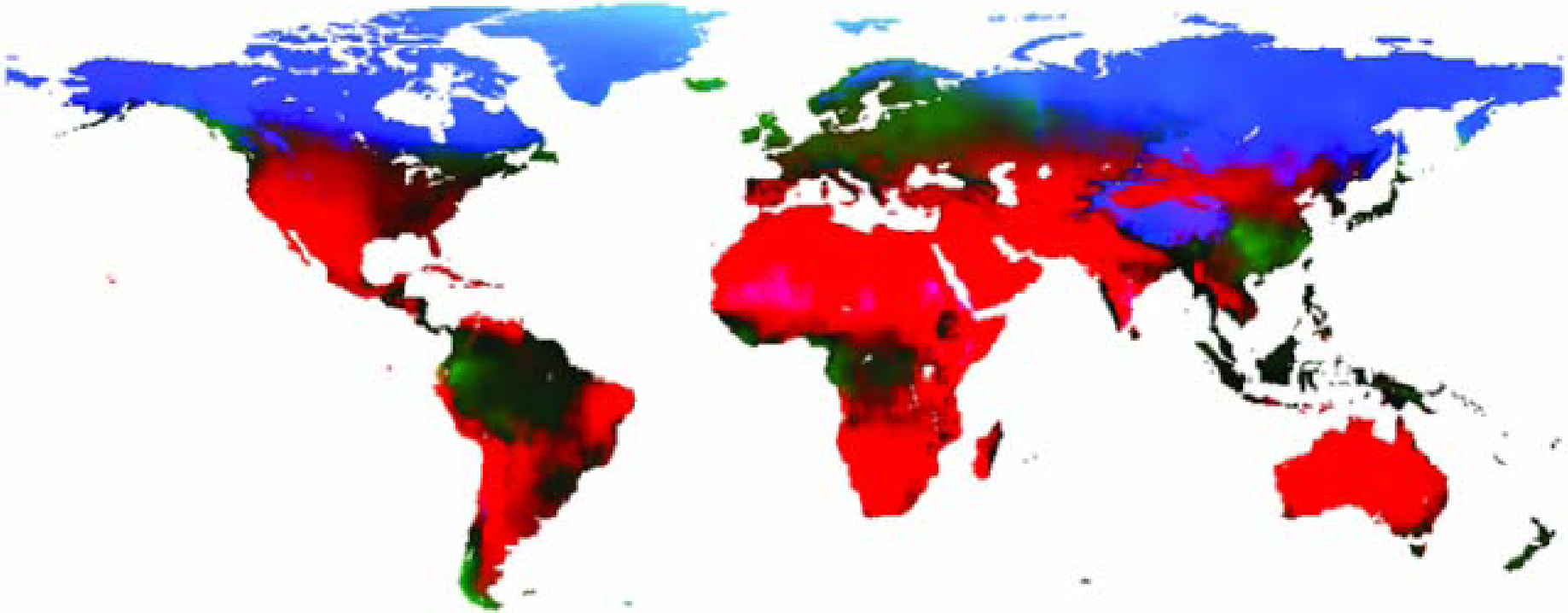
NERSC at Berkeley Lab

- NERSC came to Berkeley Lab in 1996 and was located “on the hill”.
- In 2000, because High Performance Computers (HPC) grew in size, NERSC moved to a larger, leased building in Oakland (20th & Broadway), Oakland Scientific Facility.
- Lease to expire soon, and NERSC will outgrow the Oakland Scientific Facility.
- The CRT building will be the permanent home for this national user facility.

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

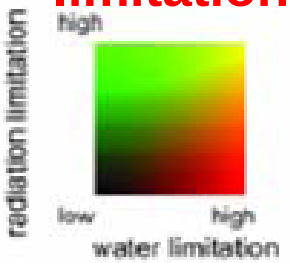


Limiting factors for plant productivity

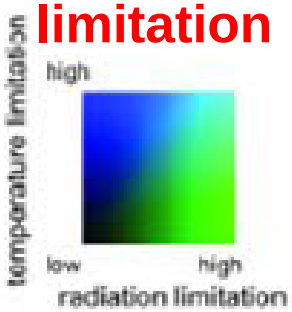


Temp/water limitation

Rad/water limitation

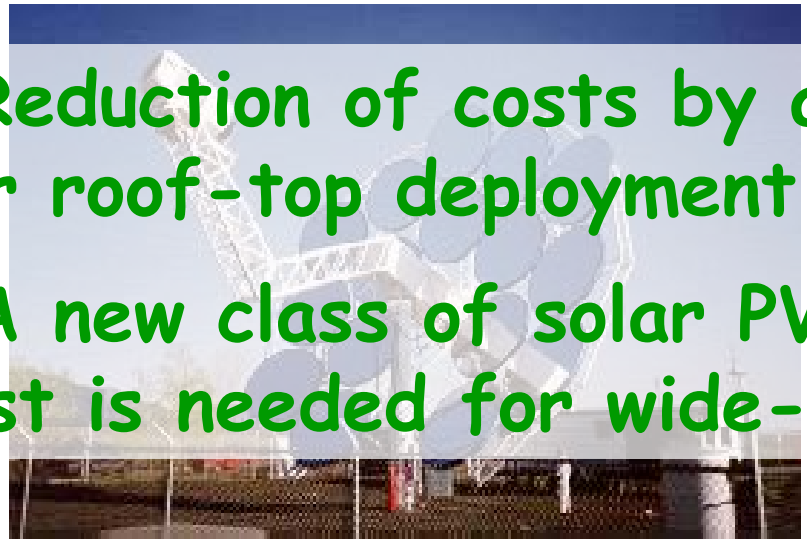


temp/water limitation

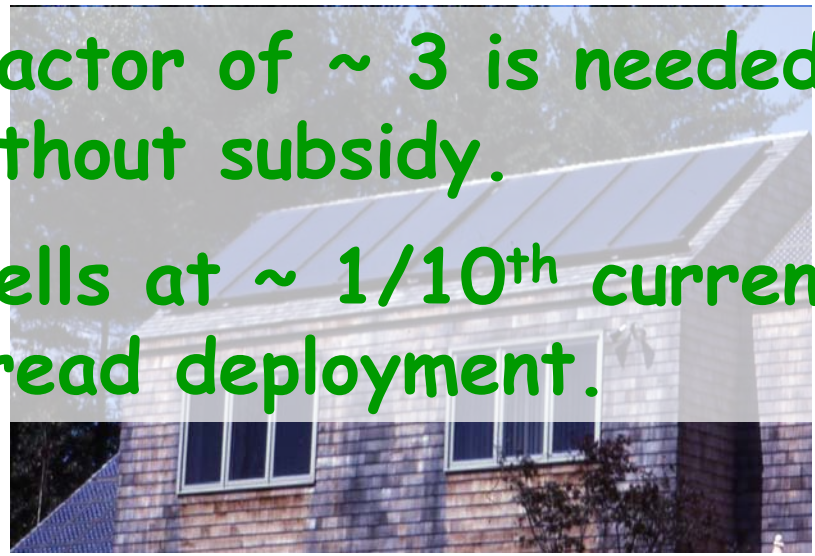


Baldocchi et al. 2004 *SCOPE 62*

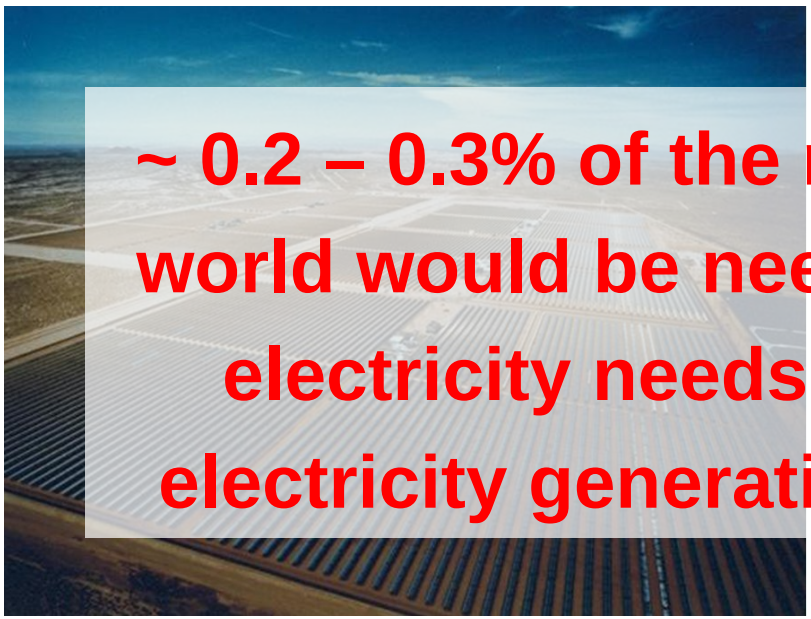
Solar thermal

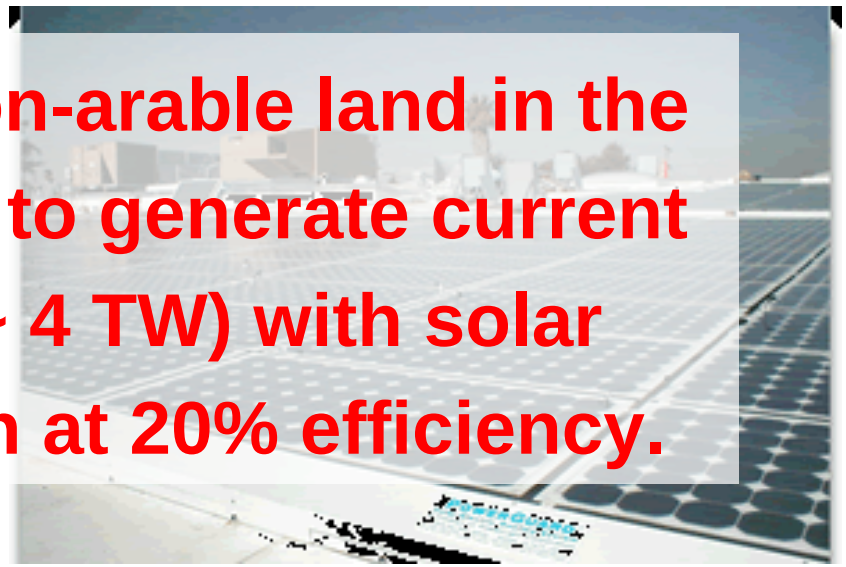


Solar photovoltaic



- 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.



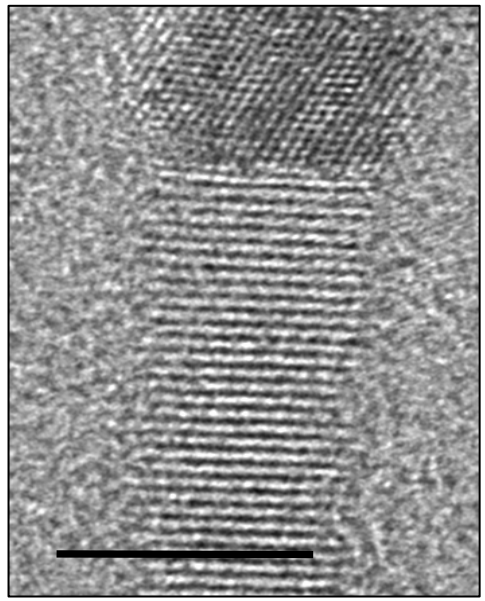


~ 0.2 – 0.3% of the non-arable land in the world would be need to generate current electricity needs (~ 4 TW) with solar electricity generation at 20% efficiency.

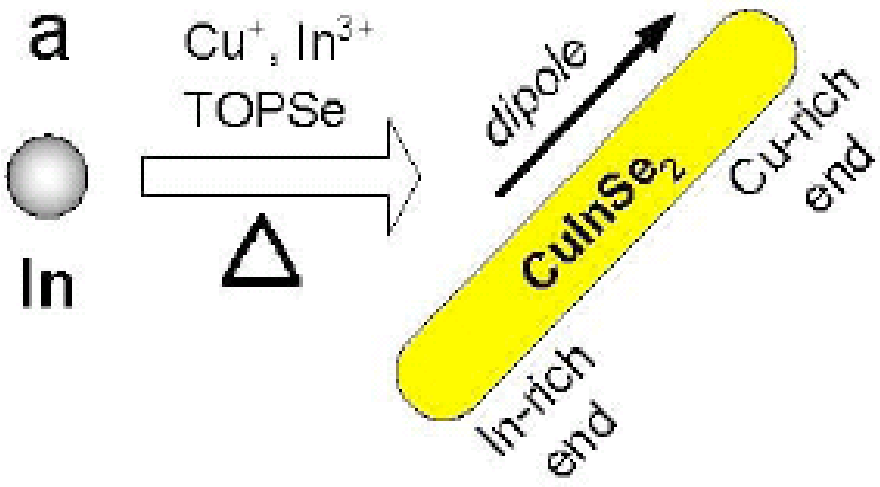
The Molecular Foundry:
a new nano-technology research building

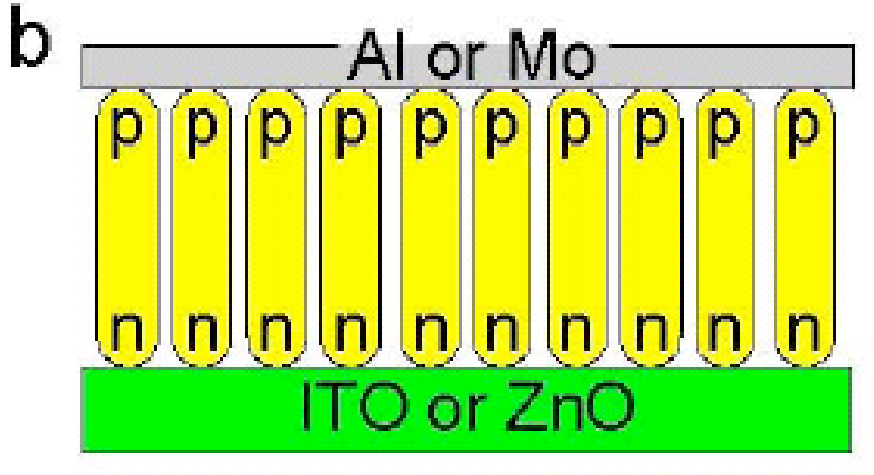
Nanotechnology-based solar cells: The benefits of going small

" .. A diamond of double the weight costs around 4 times more."



- Perfect building blocks at low cost
- Atomic level control of essential interfaces
- New physics and chemistry



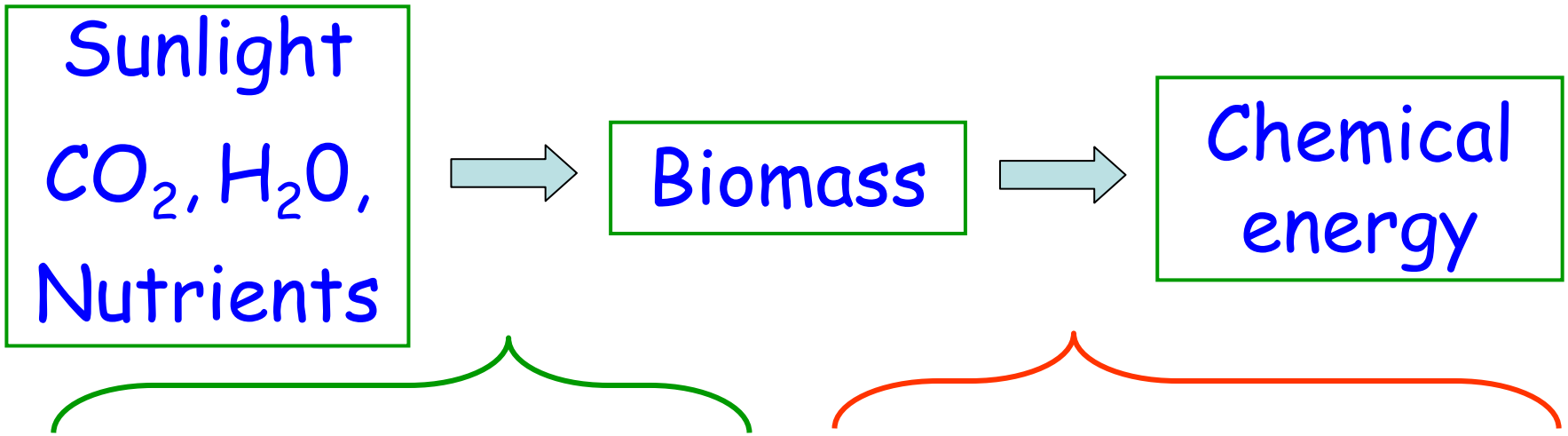


$CuInSe_2$ electric dipoles conduct electrons and holes to opposite electrodes.

An electric field can be used to align the nano-particles in assembly.

D.A. Durkee, et al. Adv. Materials, **2005**, 17 (2003)

Sunlight to energy via Bio-mass



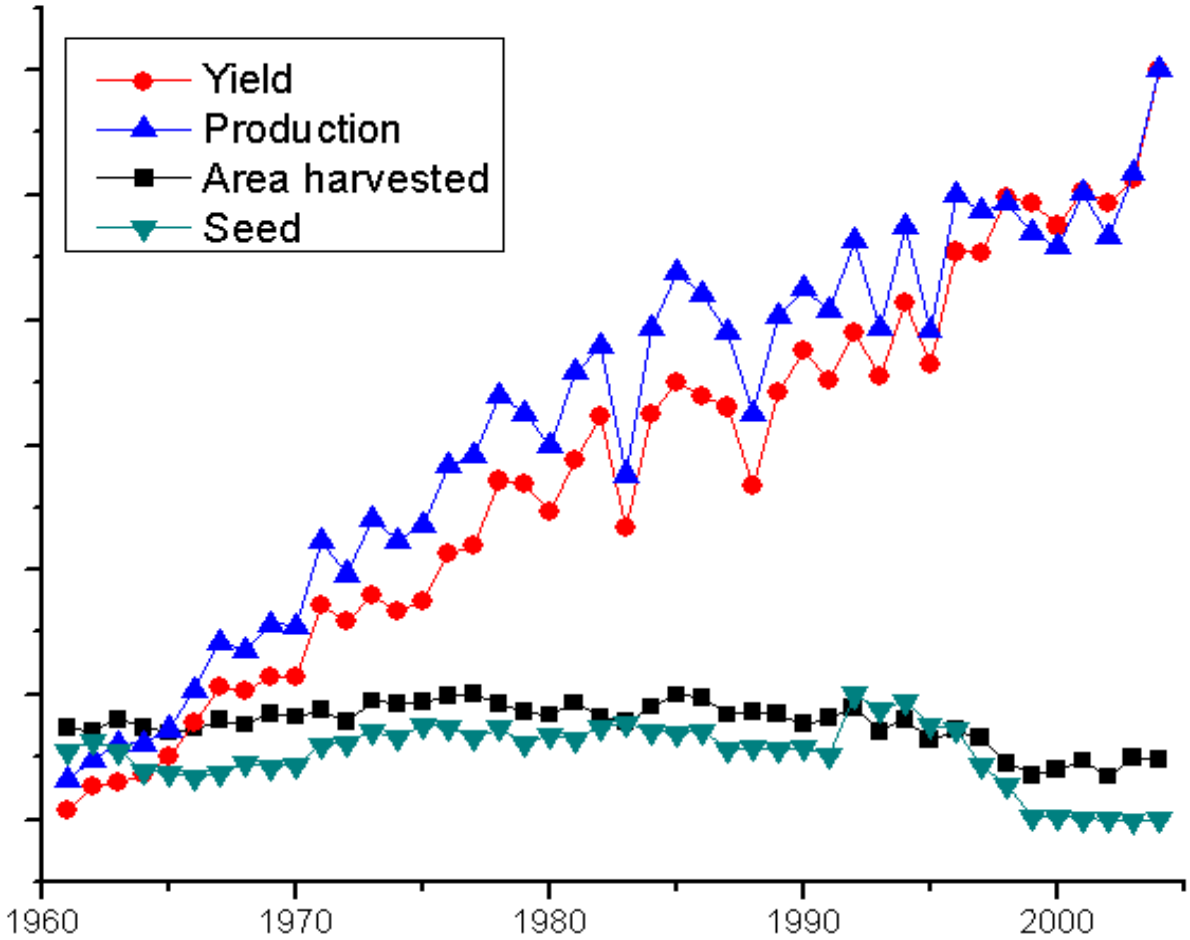
More efficient use of water, sunlight, nutrients.

Drought and pest resistant

Improved conversion of cellulose into fuel.
New organisms for biomass conversion.

The amount of energy supplied by bio-fuels will be limited by the availability of water and sunlight.

World Production of Grain (1961 – 2004)



1960:
Population = 3 B

2005:
Population = 6.5 B

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

Feedstock grasses (*Miscanthus)* is a largely unimproved crop.

Non-fertilized, non-irrigated test field at U. Illinois can yield

10x more ethanol / acre than corn.

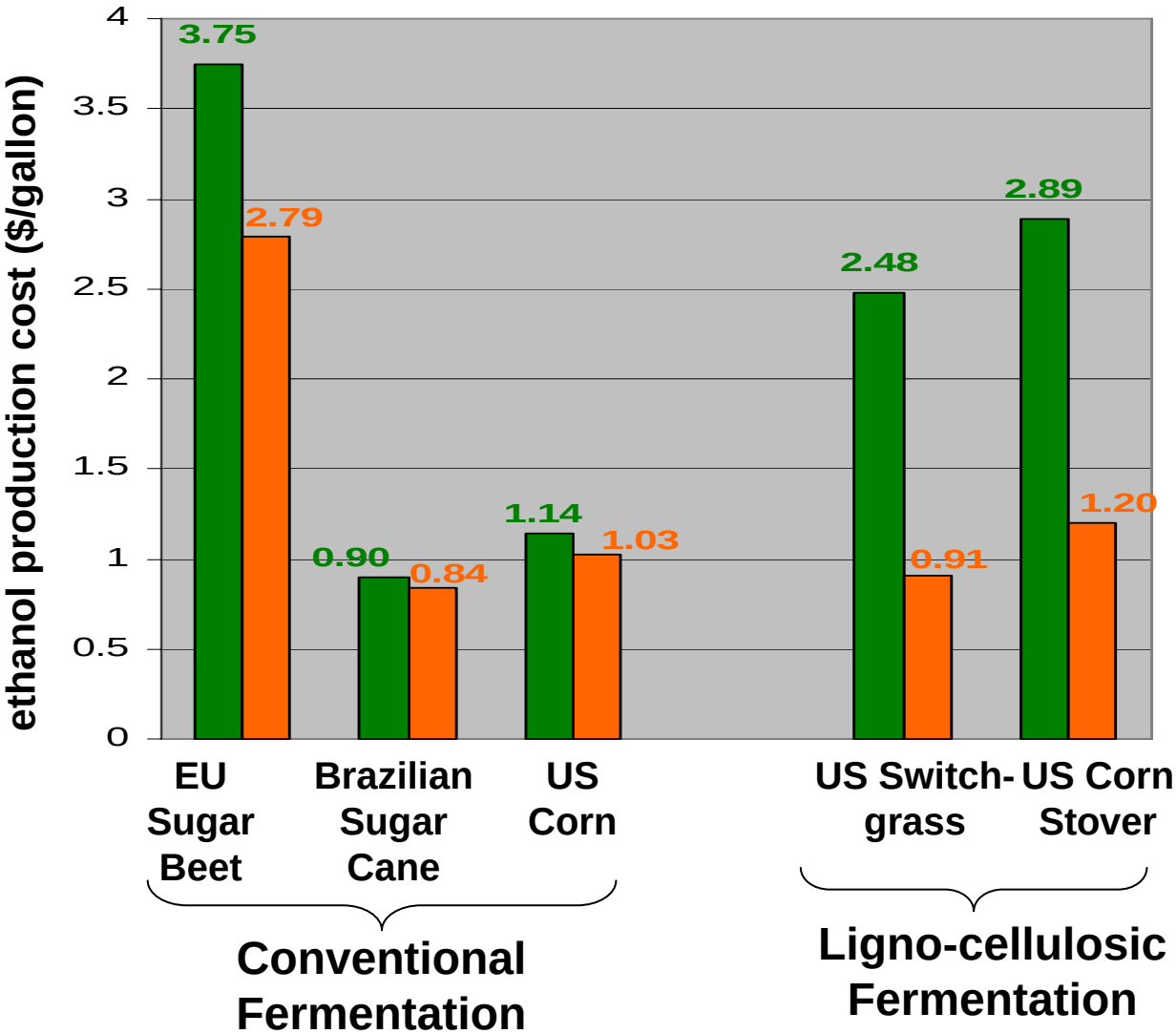
50 M acres of energy crops plus agricultural wastes (wheat straw, corn stover, wood residues, etc.) can produce ***half*** to ***all*** of current US consumption of gasoline.

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.)

Current and projected production costs of ethanol

Courtesy Steve Koonin, BP Chief Scientist



Source: BP Analysis, NREL, CERES, NCGA

Energy Biosciences Institute

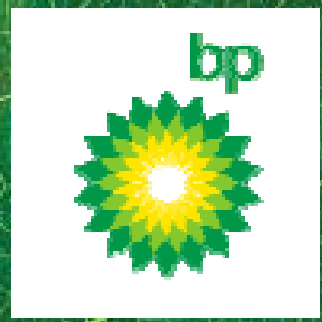
Joint Bio-Energy Institute (JBEI)

LBNL, Sandia, LLNL, UC Berkeley, Stanford, UC Davis

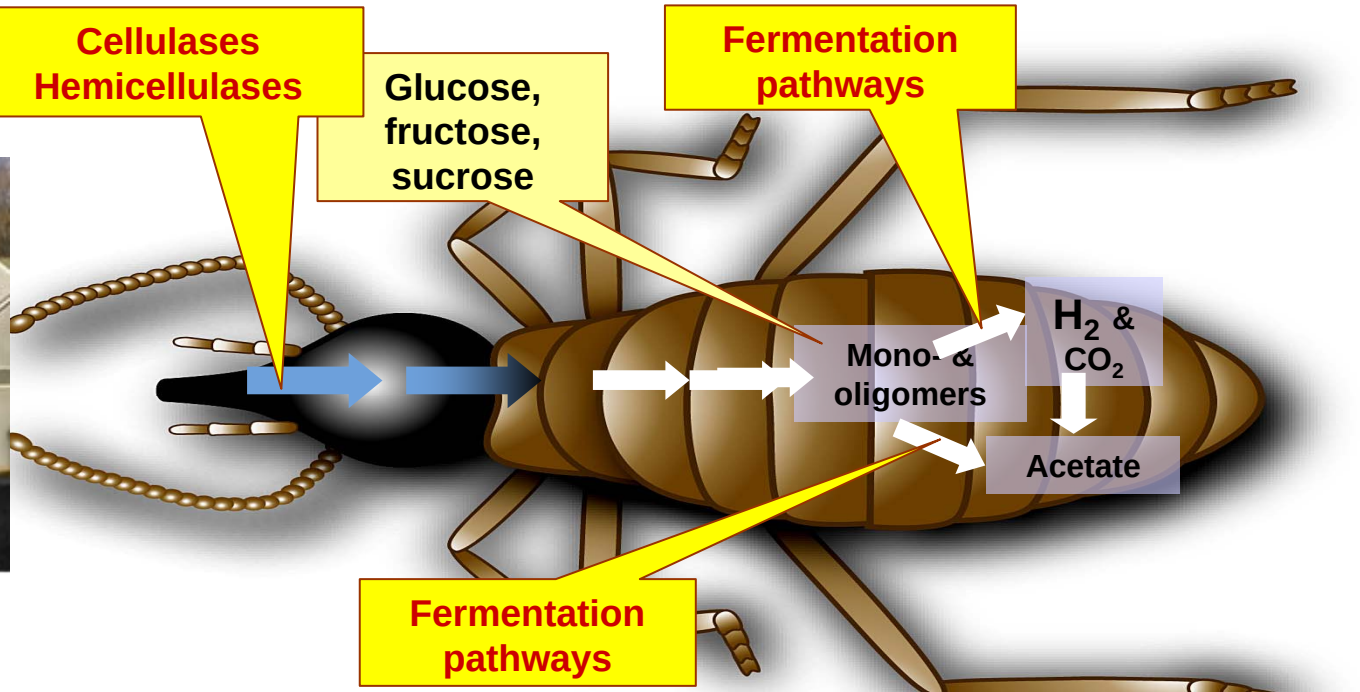
Univ. California, Berkeley

Lawrence Berkeley National Lab

Univ. Illinois, Urbana-Champaign



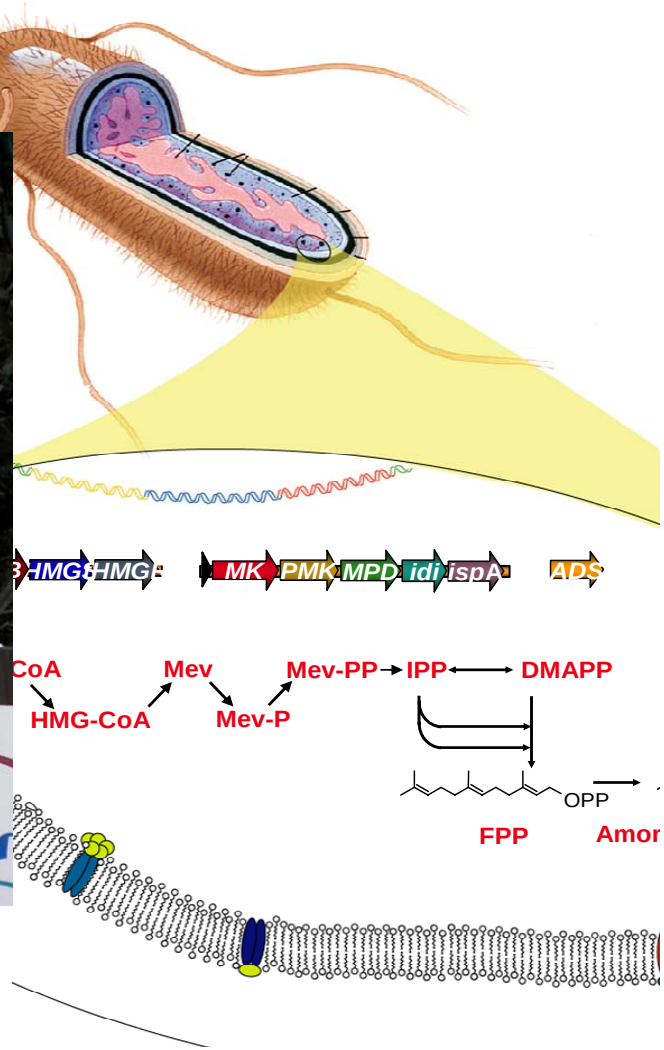
Termites have many specialized microbes that efficiently digest lignocellulosic material



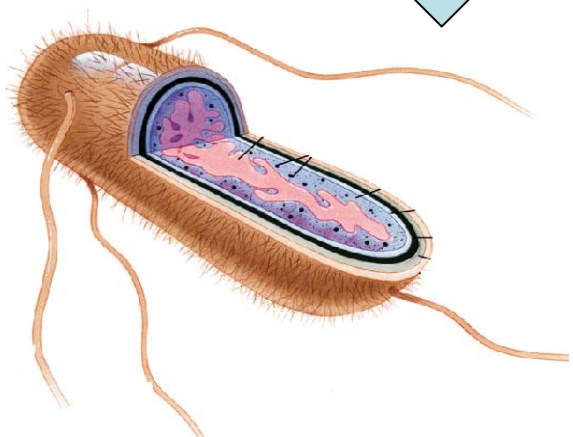
Production of artemisinin in bacteria

Jay Keasling

Director of Physical Biosciences Division



Research, Development & Delivery



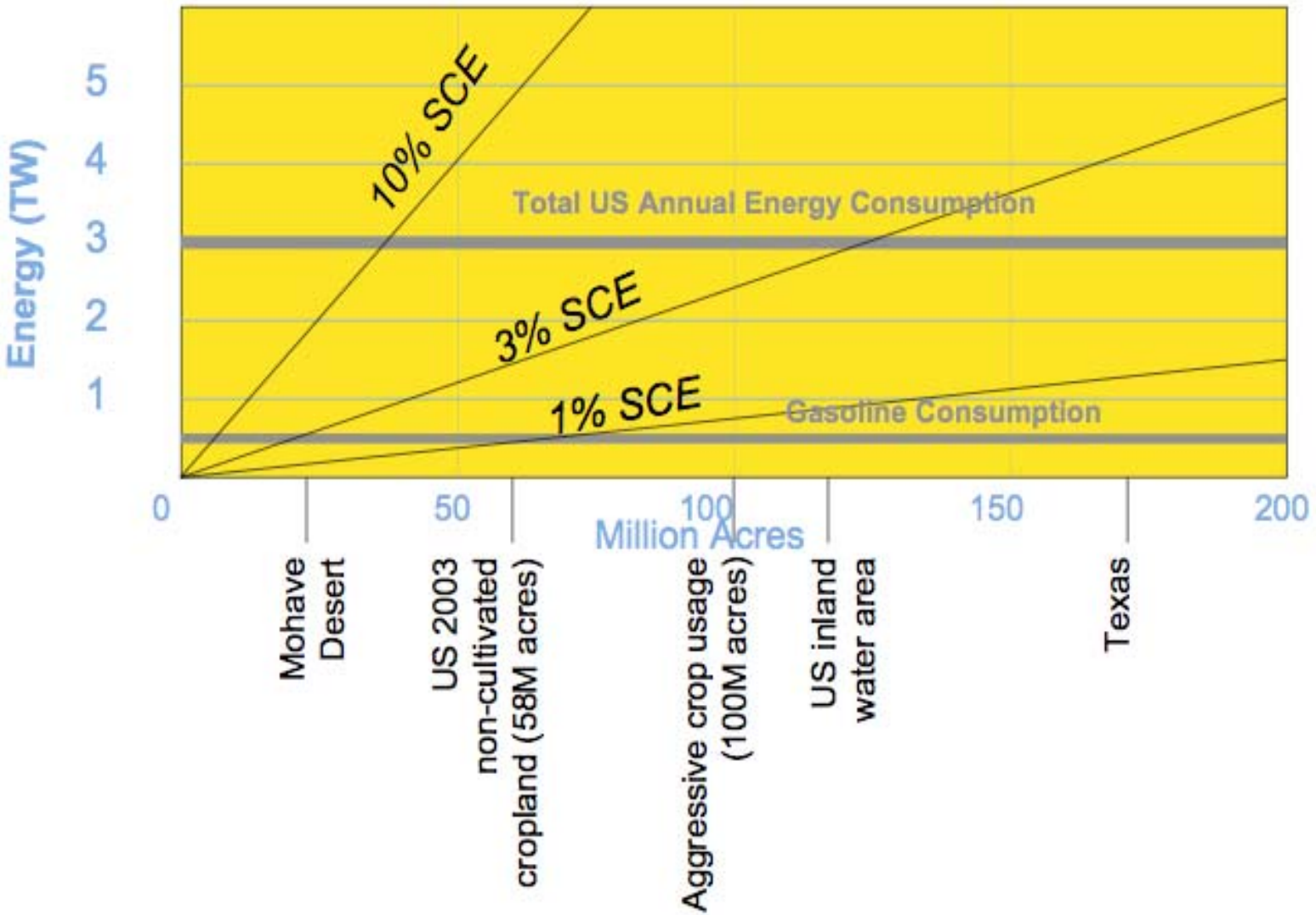
Keasling Laboratory

Amyris Biotechnologies

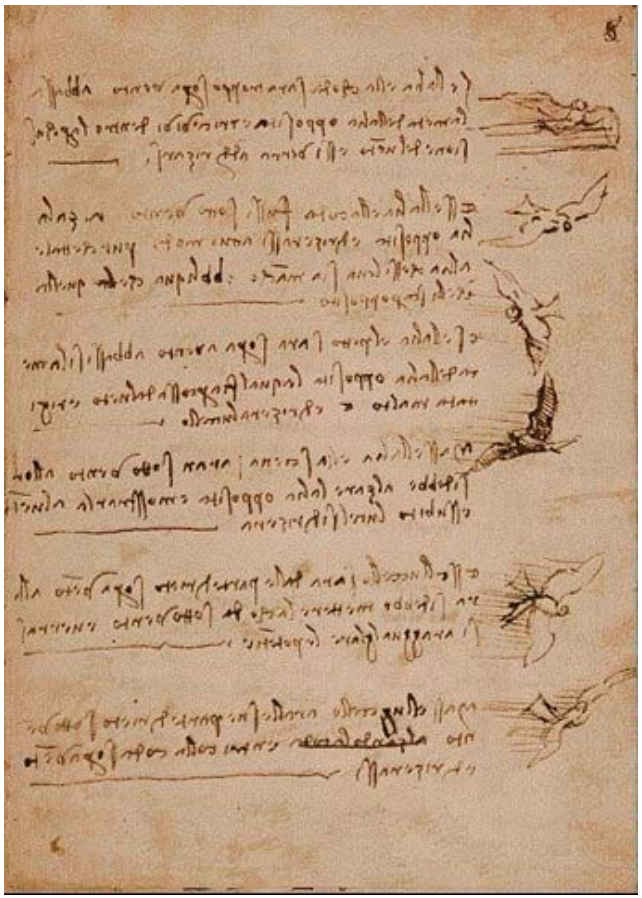
Institute for OneWorld Health

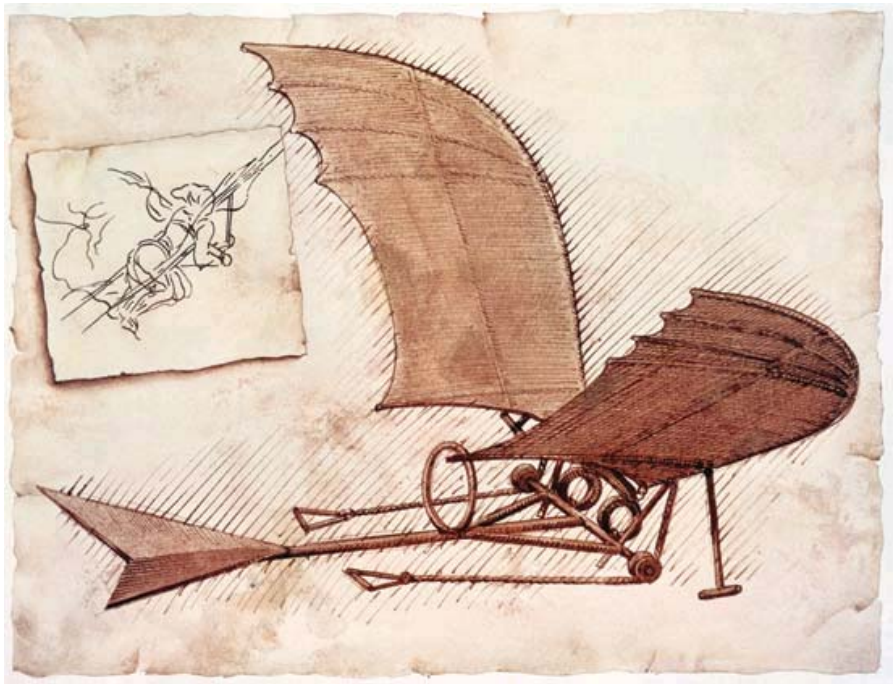
Cost
20¢ /cure

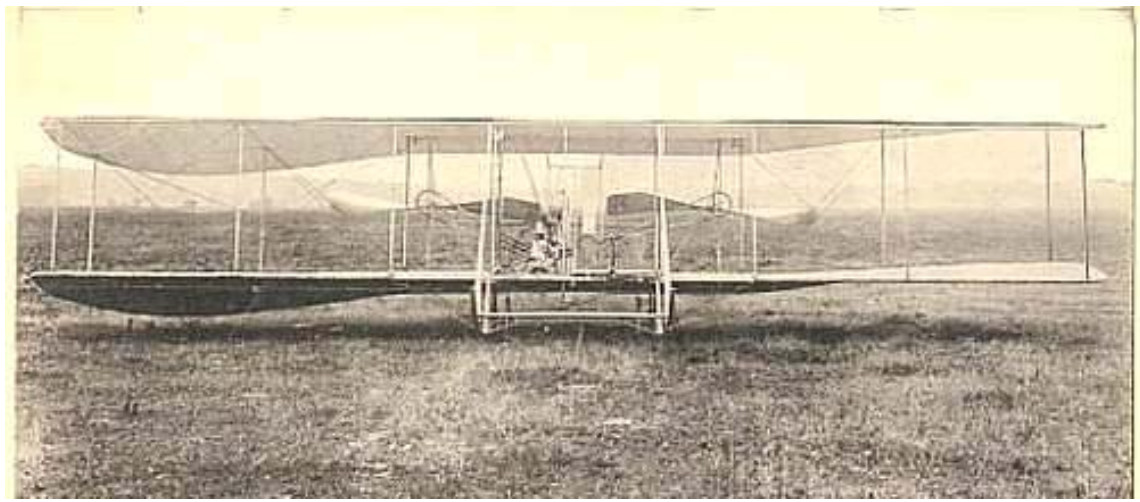
Energy output vs. land usage requirements at various levels of solar conversion efficiency



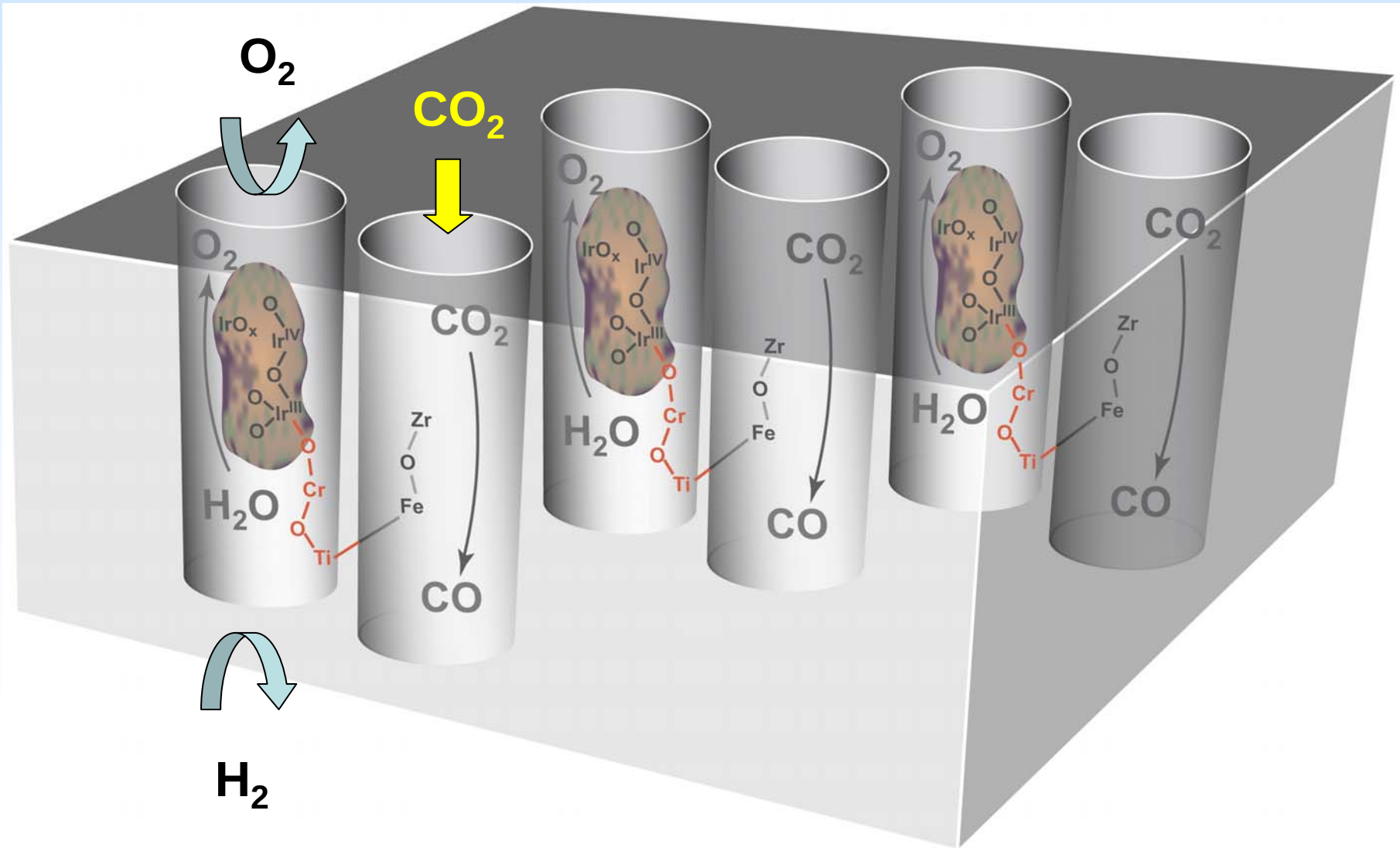
Man first learned to fly by imitating nature



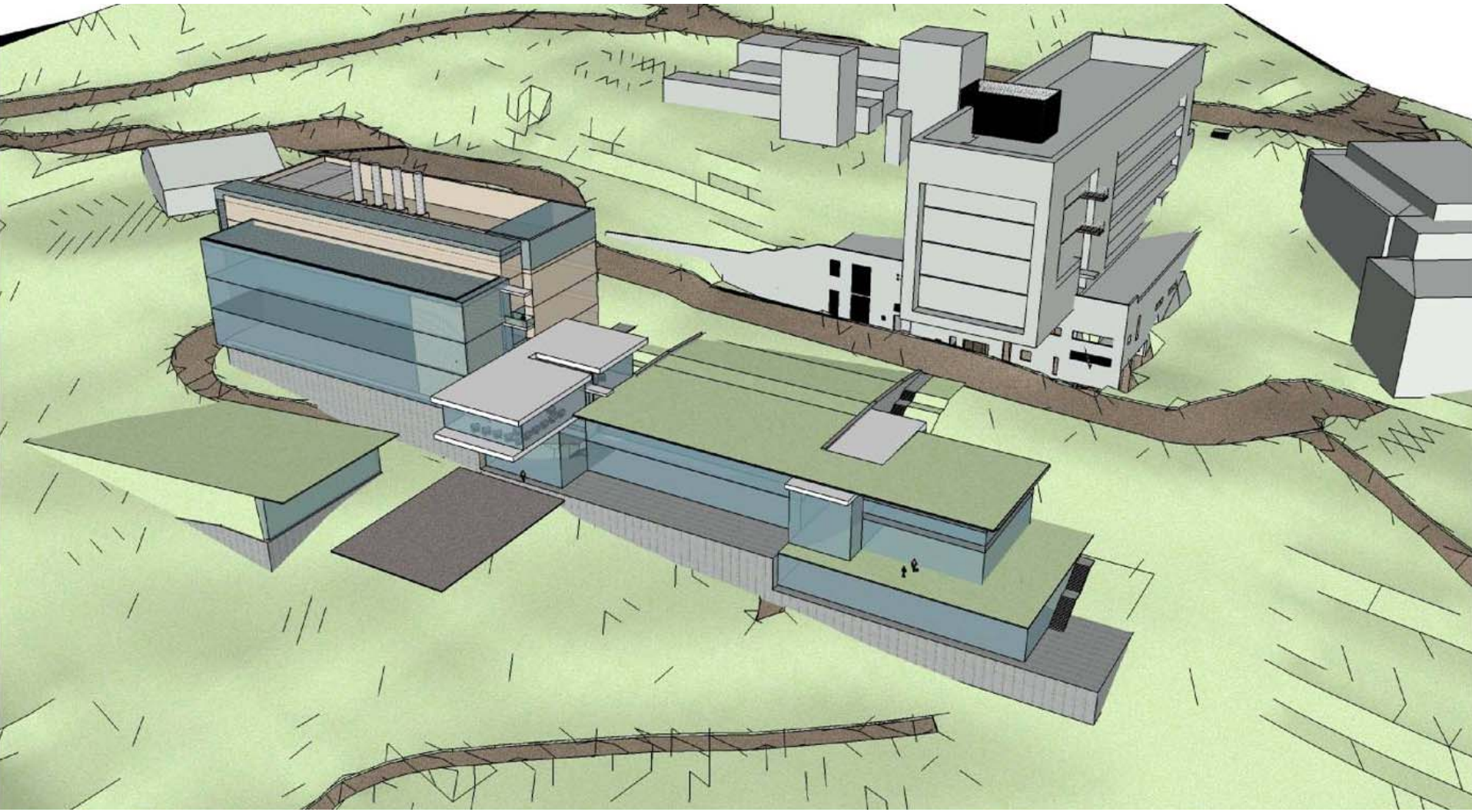




Is it possible to engineer an artificial photo-synthetic system that is powered by either sunlight or electricity?



Concept design of the Helios Building



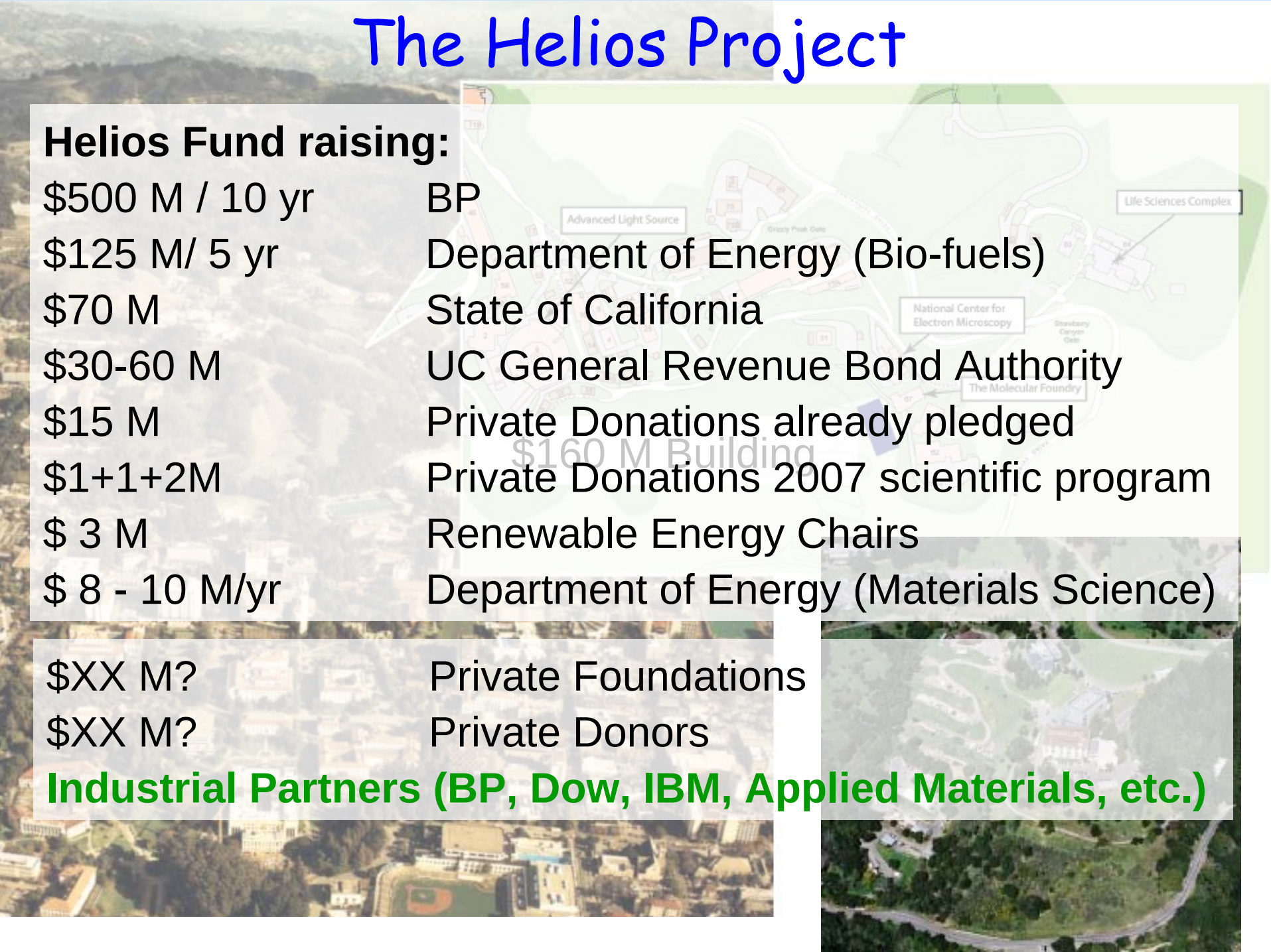
The Helios Project

Helios Fund raising:

$500 M / 10 yr	BP
$125 M/ 5 yr	Department of Energy (Bio-fuels)
$70 M	State of California
$30-60 M	UC General Revenue Bond Authority
$15 M	Private Donations already pledged
$1+1+2M	Private Donations 2007 scientific program
$ 3 M	Renewable Energy Chairs
$ 8 - 10 M/yr	Department of Energy (Materials Science)

$XX M?	Private Foundations
$XX M?	Private Donors

Industrial Partners (BP, Dow, IBM, Applied Materials, etc.)



Lawrence Berkeley National Laboratory

3,800 employees, ~$520 M / year budget

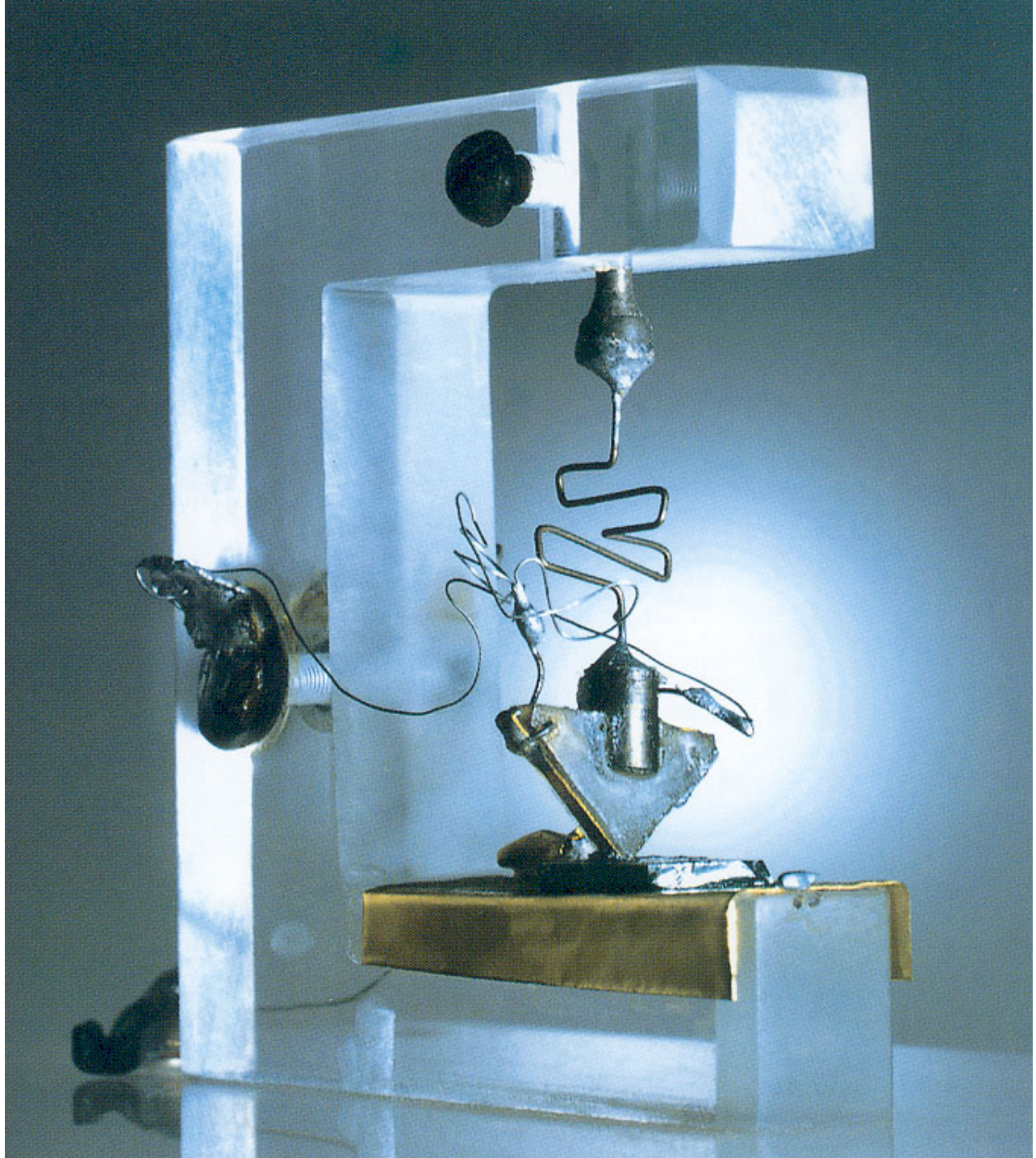
11 employees were awarded the Nobel Prize,
(9 did their Nobel work at the Lab.)
(Over 43 Nobel Laureates either trained or had significant collaborations at LBNL)

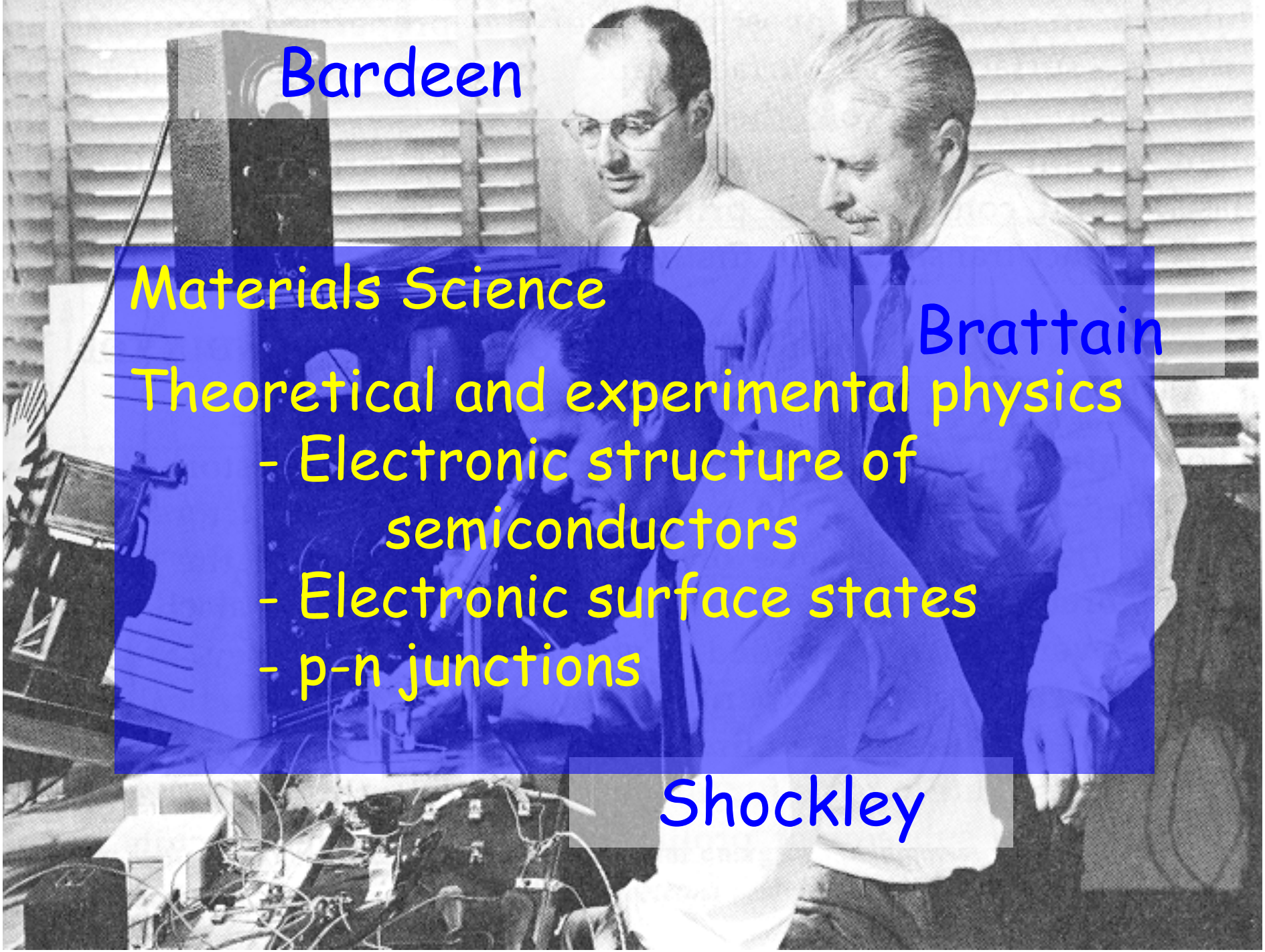
Today:

59 employees in the National Academy of Sciences,
18 in the National Academy of Engineering,
2 in the Institute of Medicine

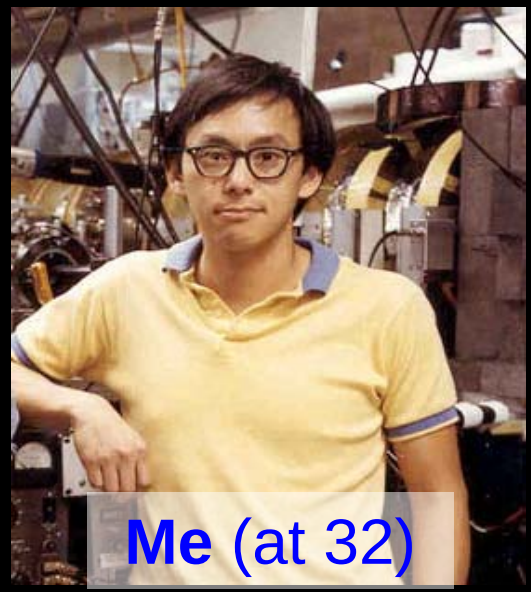
Bell Laboratories (Murray Hill, NJ)

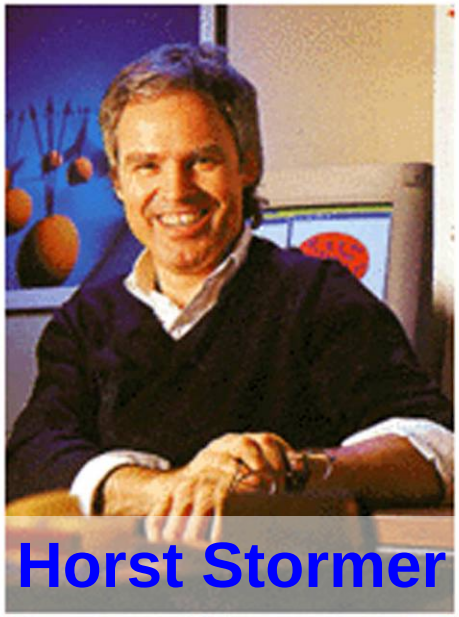
15 scientists who worked at AT&T Bell laboratories received Nobel Prizes.

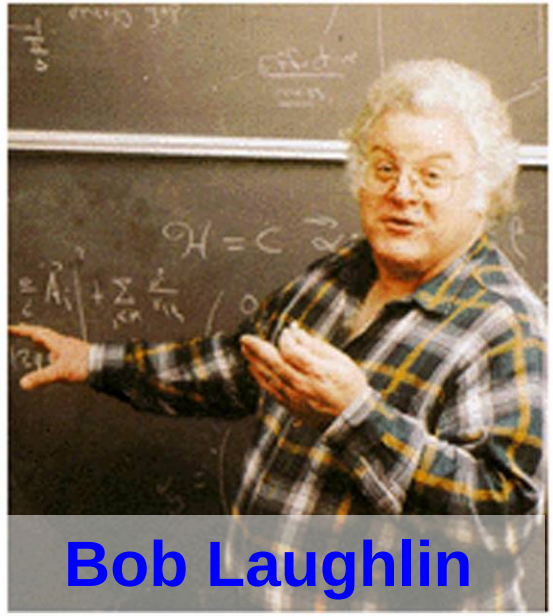



Bardeen
Materials Science
Brattain
Theoretical and experimental physics
- Electronic structure of semiconductors
- Electronic surface states
- p-n junctions
Shockley

Nobel Prize Members at Bell Labs hired in 1977-78



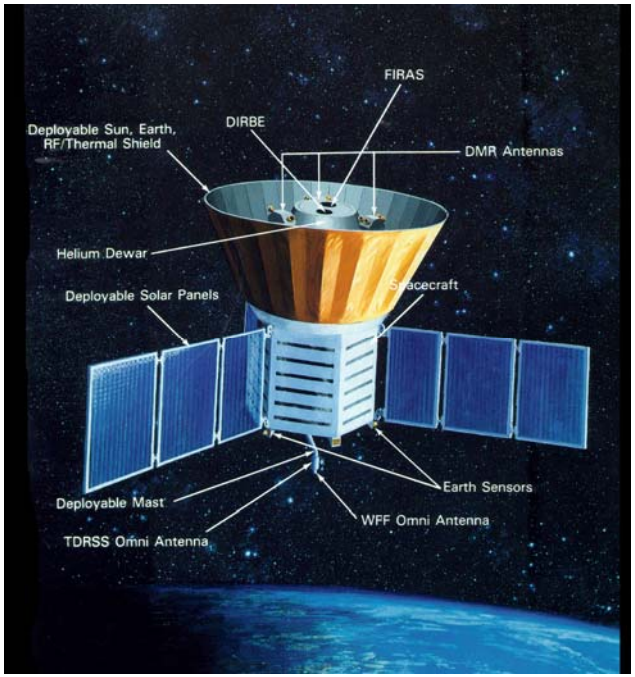




E.O. Lawrence introduced the idea of "team science"

Ernest Lawrence, Robert Serber, Luis Alverez, Edwin McMillian, Robert Oppenheimer, Robert R. Wilson, …

The tradition of E.O. Lawrence continues …



COBE: Cosmic Background Explorer

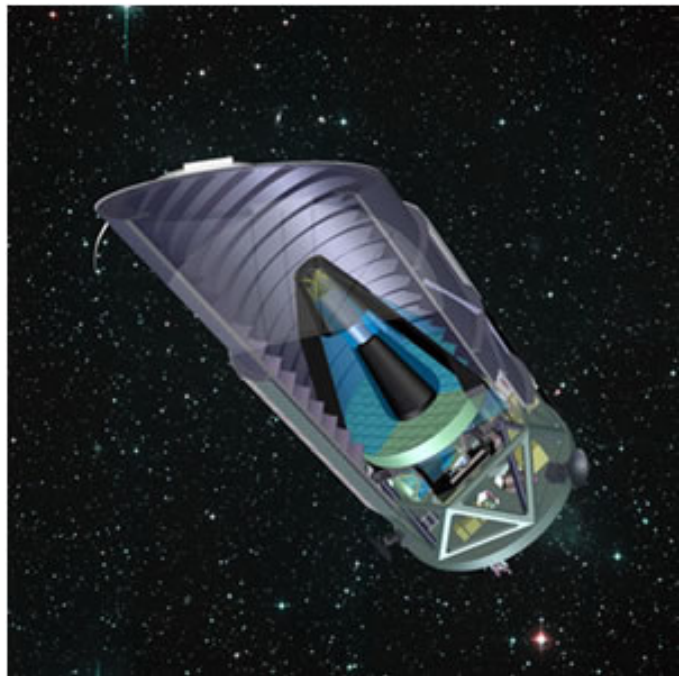
2006 Nobel Prize in Physics

George Smoot (LBNL & UCB) and John Mather (Goddard)

Dark Energy

Saul Perlmutter (LBNL and UCB)

(2006 Run Run Shaw Prize, Fretinelli Prize)



Organizational culture

- Individual genius was nurtured, but individuals were also encouraged to quickly form teams to rapidly exploit ideas.
- The scientific direction was guided by collective wisdom and “managed” by top scientists with intimate, expert knowledge.
- Bold approaches were encouraged; some failure was expected, but there was an emphasis on recognizing failure quickly, and moving on to other opportunities.

Earthrise from Apollo 8 (December, 1968)

There *are* solutions to the energy/climate change problem:

"We believe that aggressive support of energy science and technology, coupled with incentives that accelerate the concurrent development and deployment of innovative solutions, can transform the entire landscape of energy demand and supply …

What the world does in the coming decade will have enormous consequences that will last for centuries; it is imperative that we begin without further delay."

“On December 10, 1950, William Faulkner, the Nobel Laureate in Literature, spoke at the Nobel Banquet in Stockholm,

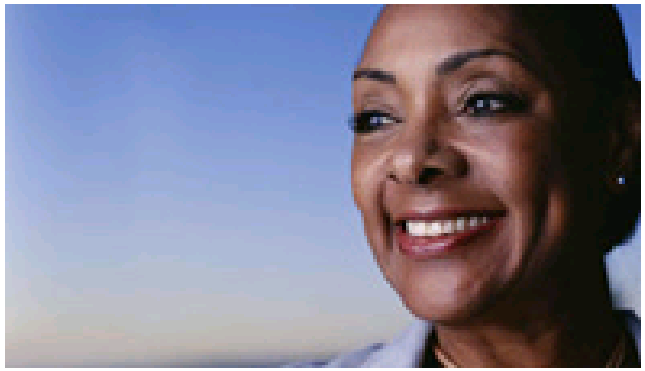
… I believe that man will not merely endure: he will prevail. He is immortal, not because he alone among creatures has an inexhaustible voice, but because he has a soul, a spirit capable of compassion and sacrifice and endurance.’

With these virtues, the world can and will prevail over this great energy challenge.”

Steven Chu (USA)
José Goldemberg (Brazil)

InterAcademy Council

About the IAC



Mobilizing the World's Best Science to Advise Decision-makers.

"Lighting the Way: Toward a Sustainable Energy Future"

Public release: October 12, 2007
in China and Brazil

Co-chairs: Jose Goldemberg, Brazil
Steven Chu, USA

The Role of Government

Free market incentives need to play a major role in stimulating industry.

Question: How many free-market economists does it take to change a light bulb?

Answer: None. If it needed changing, free-market forces would have taken care of it.

A combination of incentives, fiscal polices, and regulations will be needed.

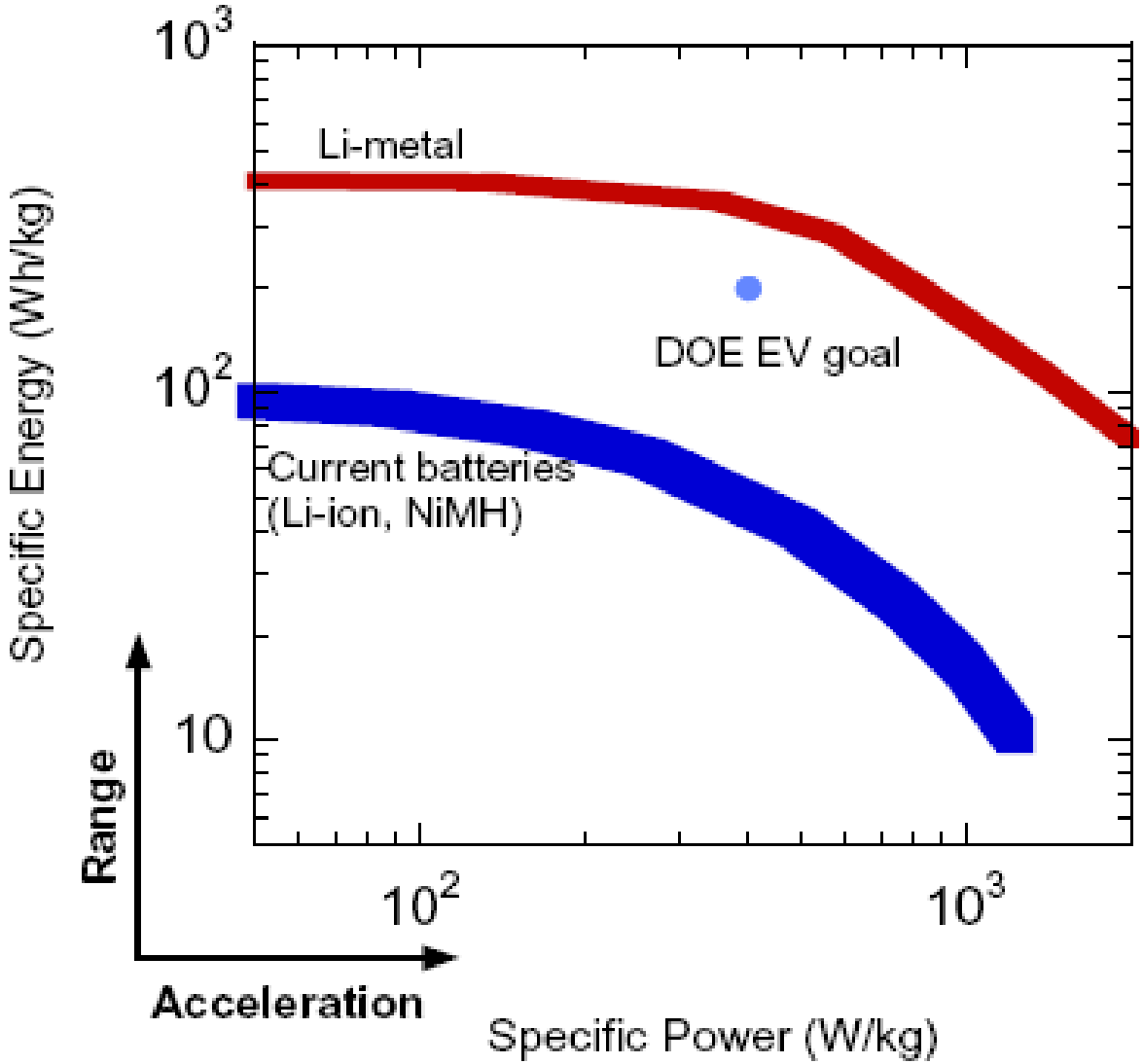
Free markets fail if there is a "commons problem":

- Water and air pollution
- International fishing
- Access to clean water across national borders
- Climate change

The role of Science and Technology

Plug-in Hybrid replacement battery for a Prius

Plug-in hybrids will require improved batteries capable of ~ 3,000 deep-discharge cycles



A lithium – metal battery with a dry, block copolymer separator that shows promise. (Nitash Balsara)

> 200 cycles and no signs of degradation