Energy Course-Introduction

Vikram Dalal
Whitney Professor of Electrical and Computer Engr.
Iowa State University

Energy

- Global warming is a reality
- Human impact a very likely cause
- What can we do to reduce the impact of humans on the environment?

Introduction

- Energy is a multi-dimensional problem – a climate problem, a national security problem, an economic problem, a pollution problem
- What are the dimensions of this problem?
- How are three of the major economies coping with it?

Energy=Environmental problem

- How?

Energy and Environment

- Impact on climate
- Impact on "common" resources such as air and water
- Impact on land
- Impact on health
- Impact on noise levels
- Impact on radiation exposure
- ?

Energy and Economics

- Impact on wealth of nation-aggregate capital infrastructure
- Impact on GDP-both positive and negative-costs
- Impact on employment
- Indirectly through health and environment
- Impact on technology, which then impacts GDP and wealth of the nation

Energy and national security- How?

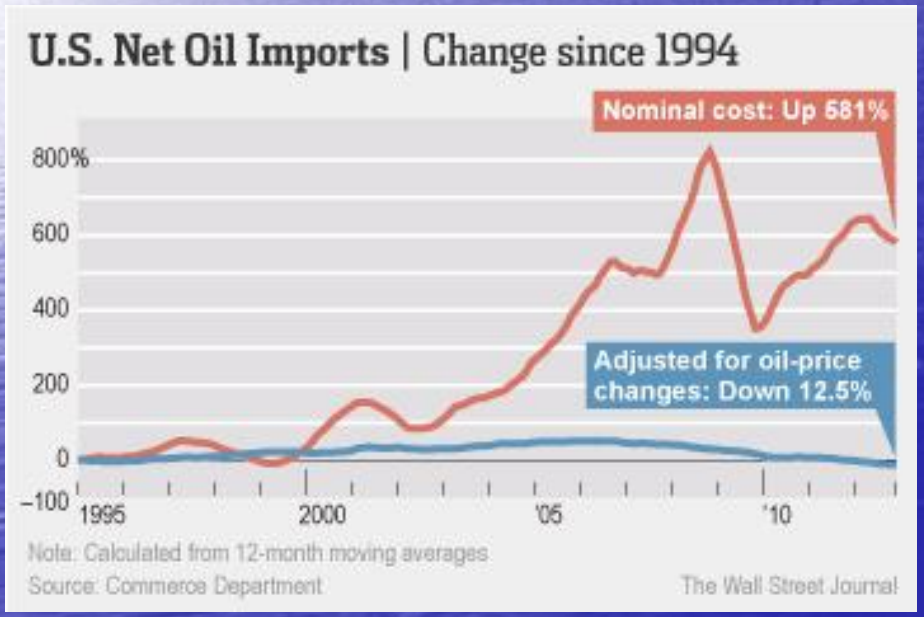
Energy and national security

- Nations want secure sources of energy (eg China and Iran)
- US wants to keep Persian Gulf oil secure- hence Navy Base in Bahrain and Air Force bases in Saudi Arabia and Kuwait
- Export of $ to overseas to buy energy depresses economy

Q?

- How much oil does the US import and how much does it cost?

US oil import costs



Cost at 9 MMBPD ~ $900 MM/day

- Q: What % of GDP is that?
- What is US GDP?

Energy-Land Problem

- How?

Land problem

- By mining-particularly strip-mining
- Blasting off mountain tops in Appalachia-KY,WVA,VA, TN
- Polluting streams
- Destroying towns and villages
- Toxic metals get into water

Forest into moonscape

Energy - Health

- What happened in Beijing last week?

Women in Beijing wearing air masks-Particulate pollution (soot) level ~750 ppm – Highest in the world – 20X times what WHO recommends as safe levels [NY was 19 ppm that day]

Energy and technology

- How?

Energy and technology

- Lead to new "renewable" technology – solar, wind, geothermal, tides
- Better pollution control technology
- Technology that reduces energy use/output of goods

In this course, we will study

- Energy and climate
- Sources of energy-Renewable and non-renewable
- Use of energy in various sectors
- Technology for energy conversion
- Renewable energy conversion technologies
- Energy storage
- Economics of energy technologies-methods of economic analysis
- Energy and environment (briefly)
- Some health impacts (briefly)
- International perspective – study energy sectors in US , India, China, Brazil

Grading

- There will be 2 exams, 30% each
- ~10 quizzes, basically on Wednesdays, 10%
- 2 papers, each worth 10% -do not plagiarize – we have software to detect it
- 5-6 HW, worth 10%
- TA is Brian Modtland

Energy and Climate!

Solar Energy :Global Warming is unequivocal

- The recent IPCC report has clearly stated that "Warming of the climate system is unequivocal" and it is "very likely" caused by human activities.

- Moreover, most of the observed changes are now simulated by climate models over the past 50 years adding confidence to future projections.

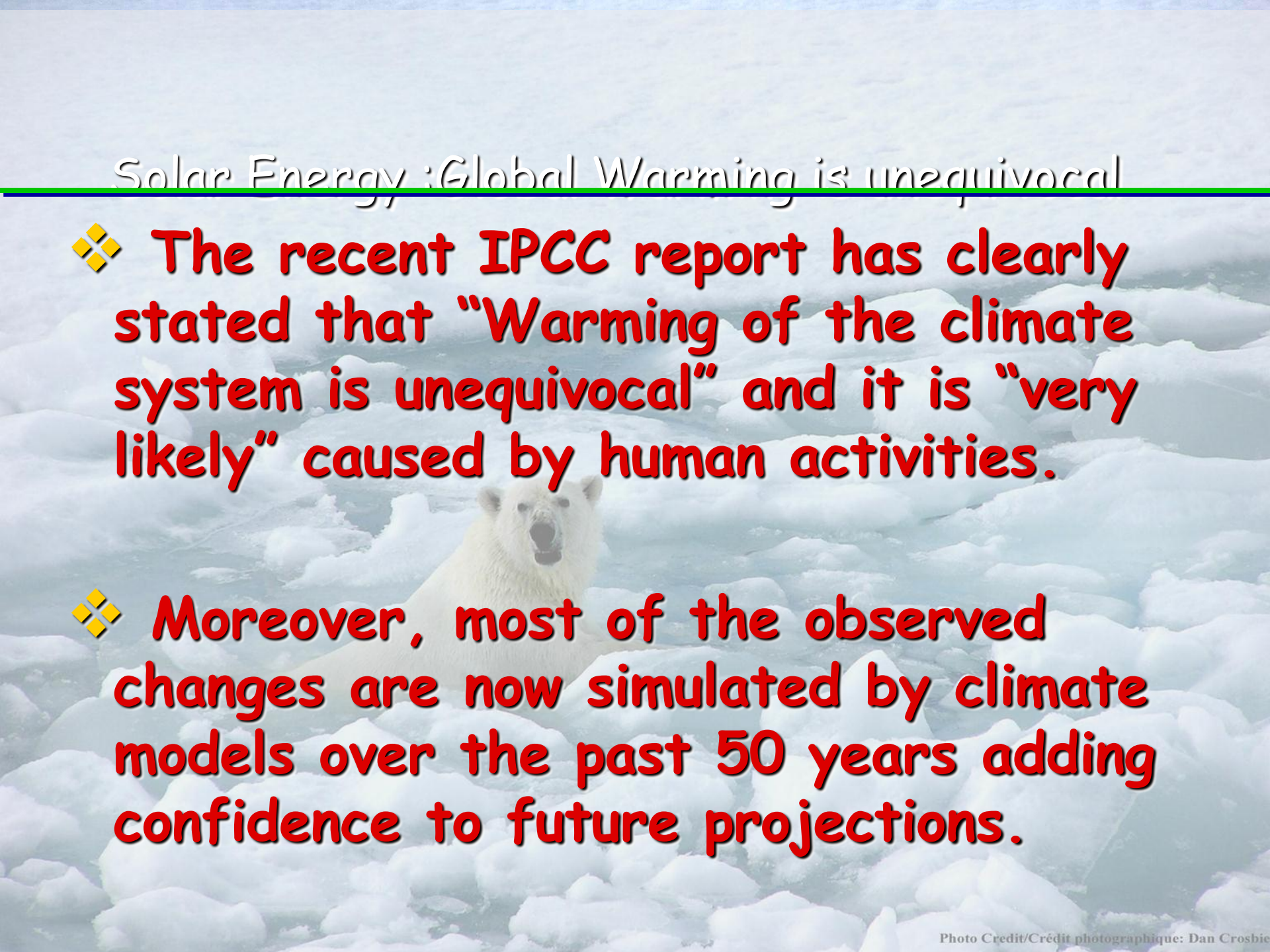
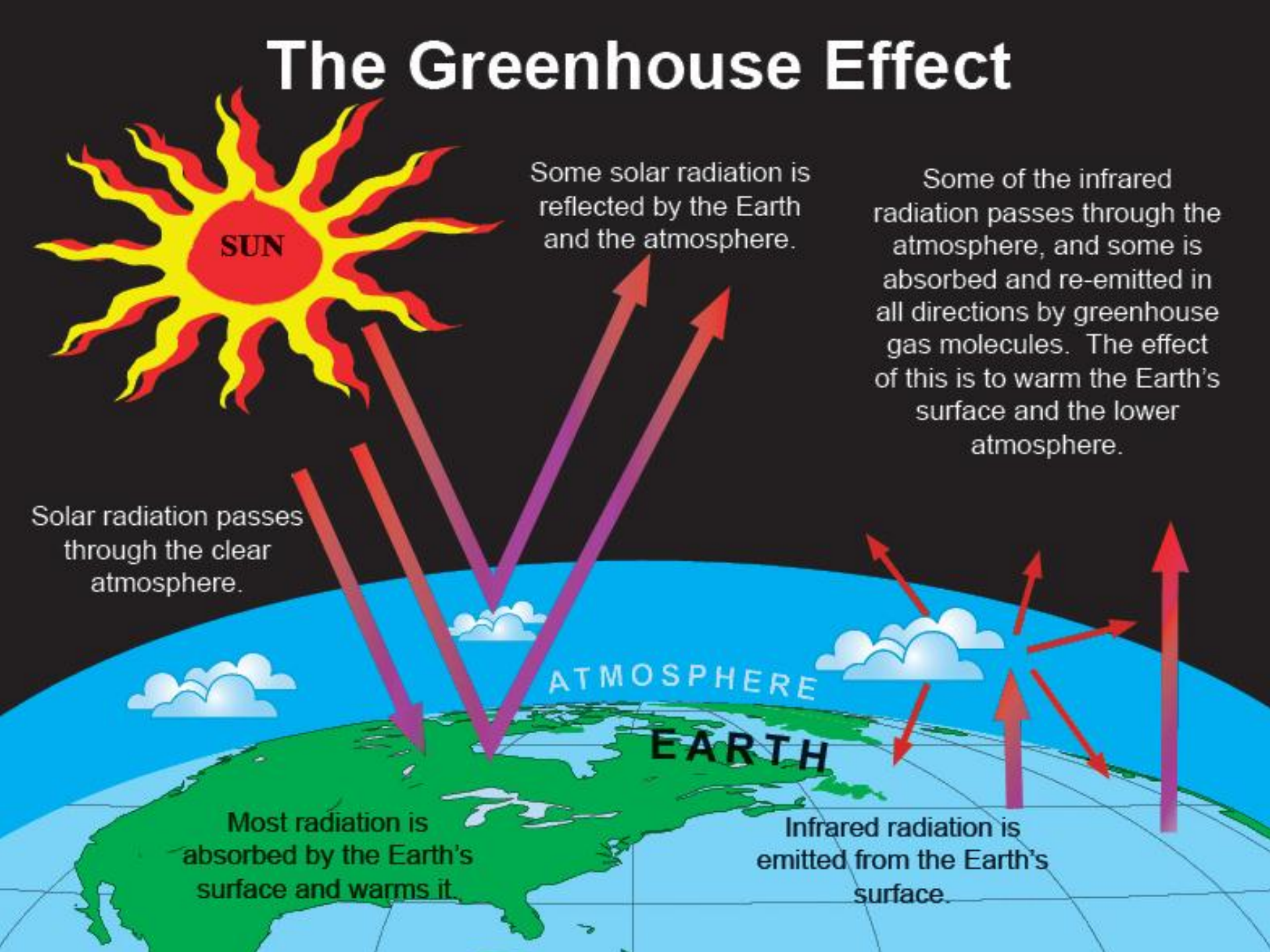
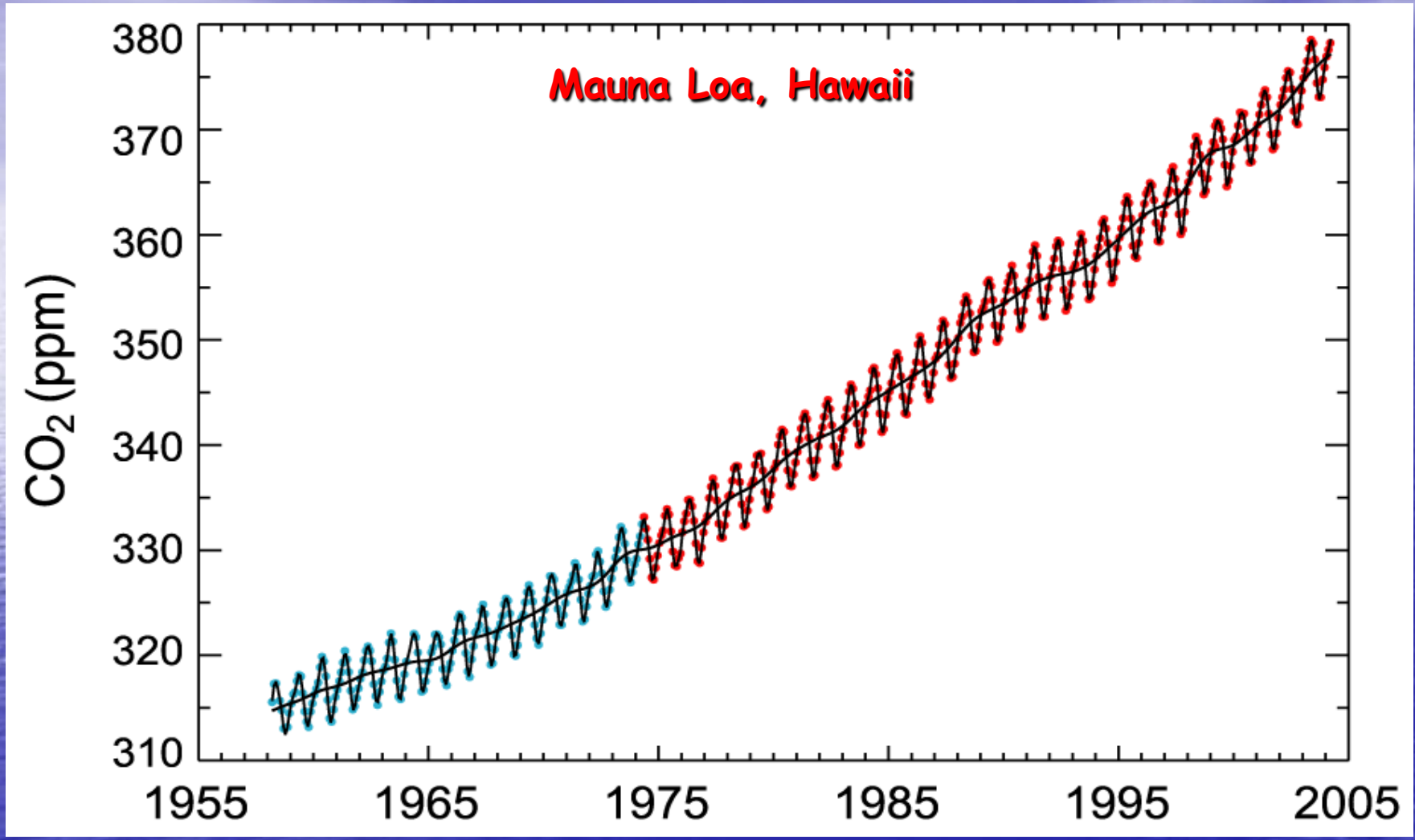


Photo Credit/Crédit photographique: Dan Crosbie

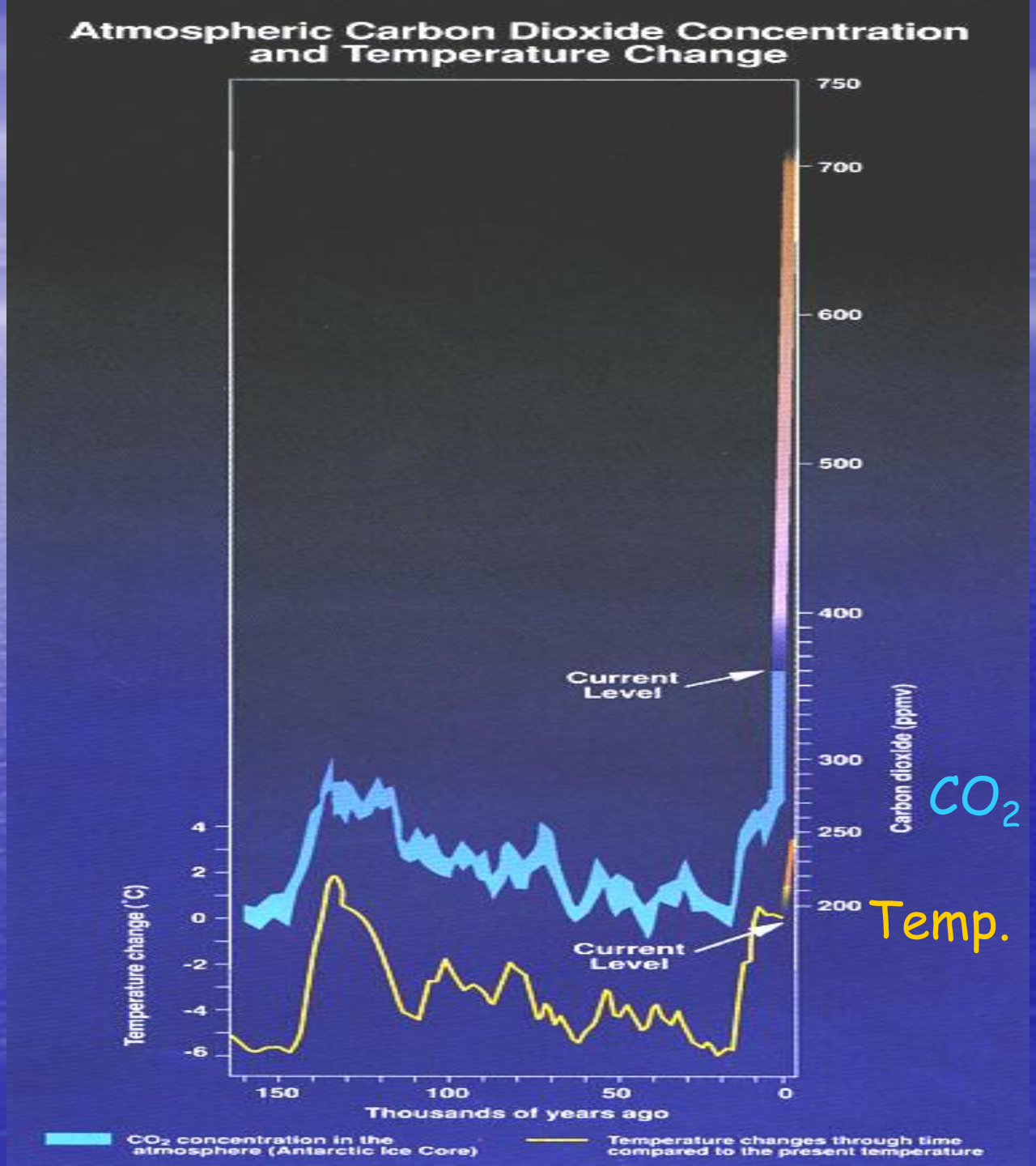
The Greenhouse Effect



Changing atmospheric composition: CO_2

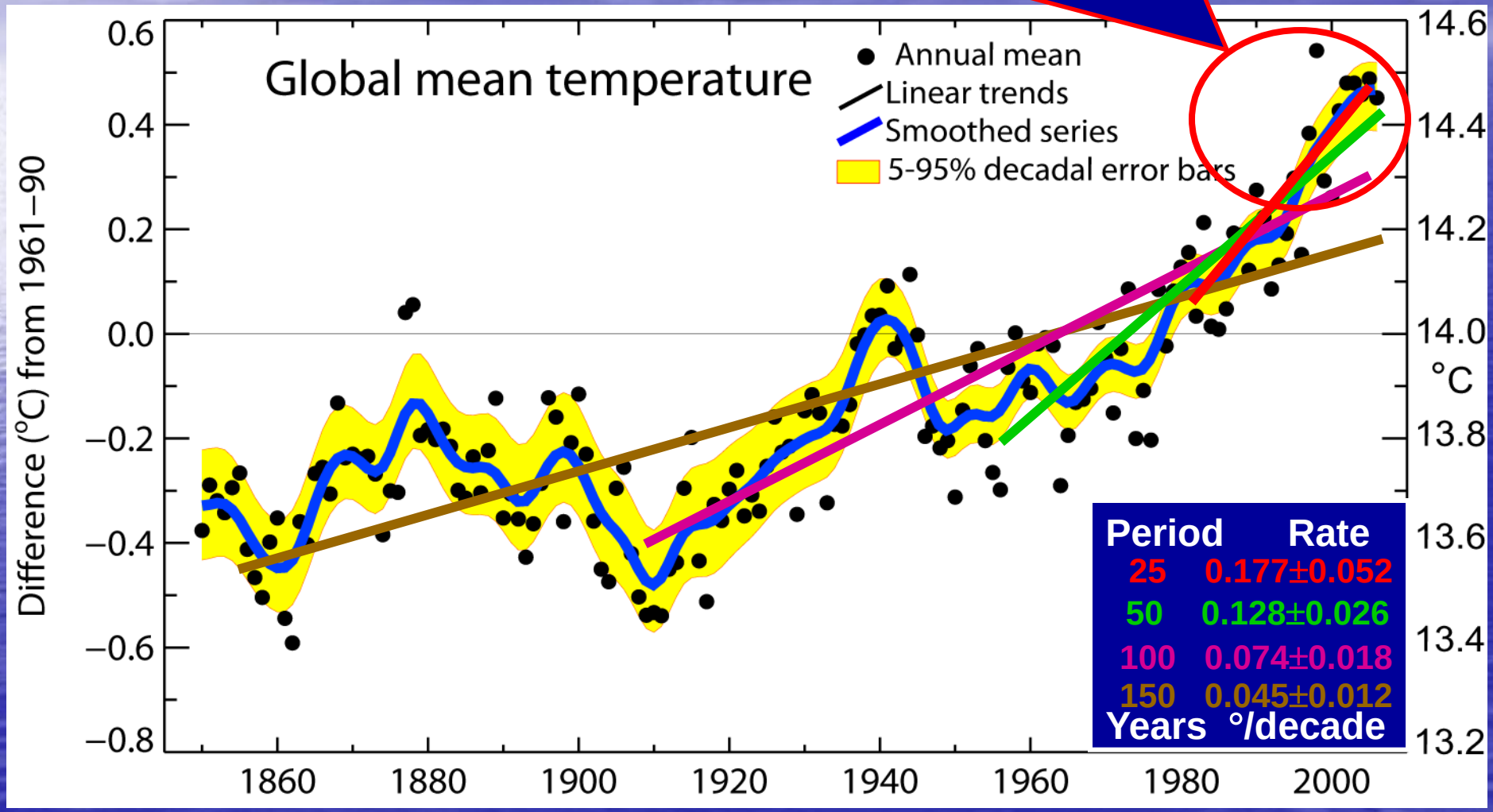


Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1973 from C. Keeling, Scripps Inst. Oceanogr.


Atmospheric Carbon Dioxide Concentration and Temperature Change
750
700
600
500
400
300
250
200
Carbon dioxide (ppmv)
Current Level
Current Level
4
2
0
-2
-4
-6
Temperature change (°C)
150
100
50
0
Thousands of years ago
CO2 concentration in the atmosphere (Antarctic Ice Core)
Temperature changes through time compared to the present temperature
CO2
Temp.

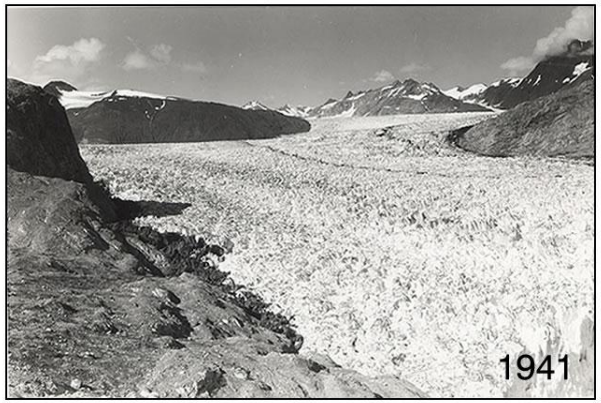
Global mean temper…ime

Warmest 12 years:
1998,2005,2003,2002,2004,2006,
2001,1997,1995,1999,1990,2000



Evidence for reality of climate change

Glaciers melting



Muir Glacier, Alaska

1909

Toboggan Glacier Alaska

2000

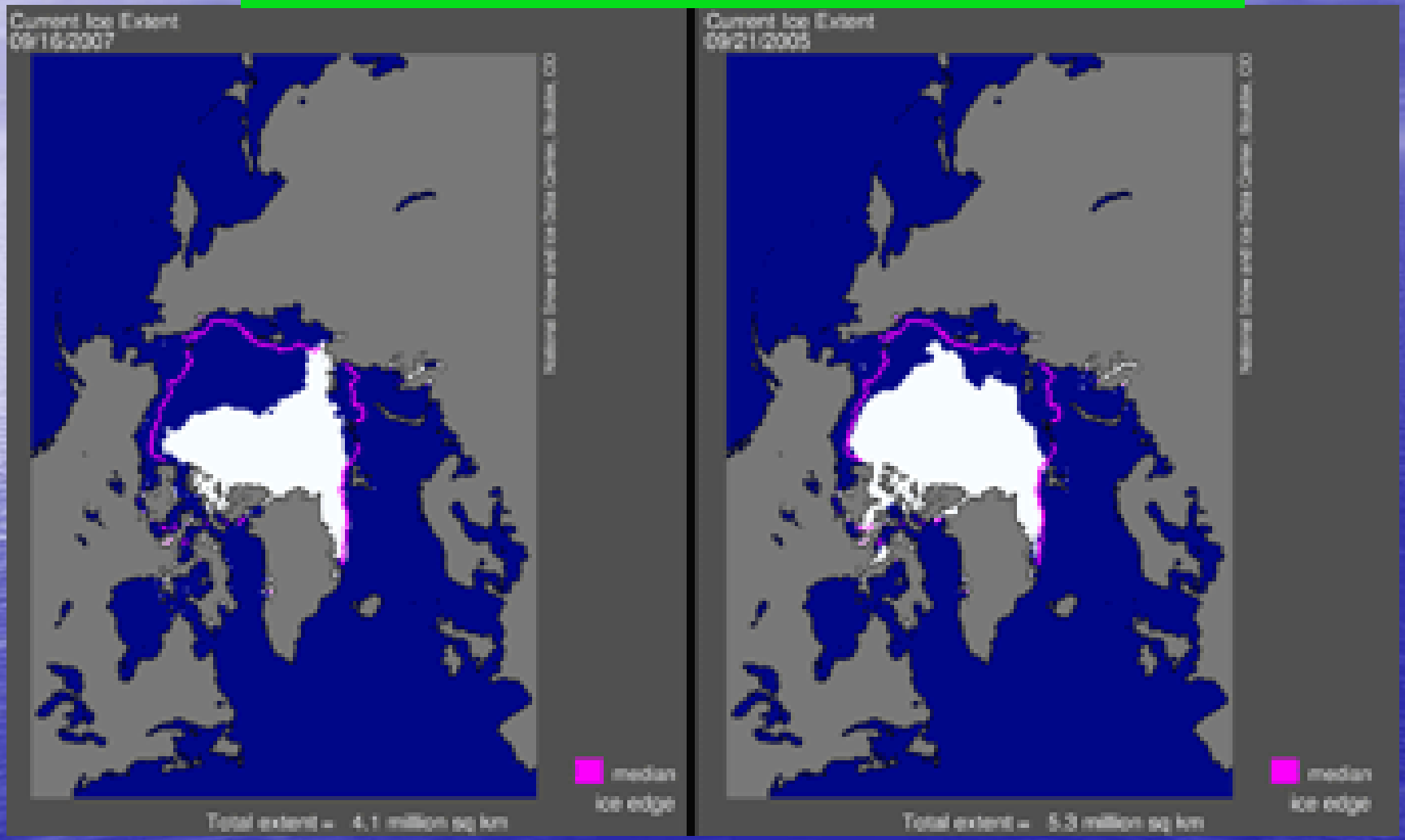
A. Circa 1900
Photo Source: Munich Society for Environmental Research

B. Recent

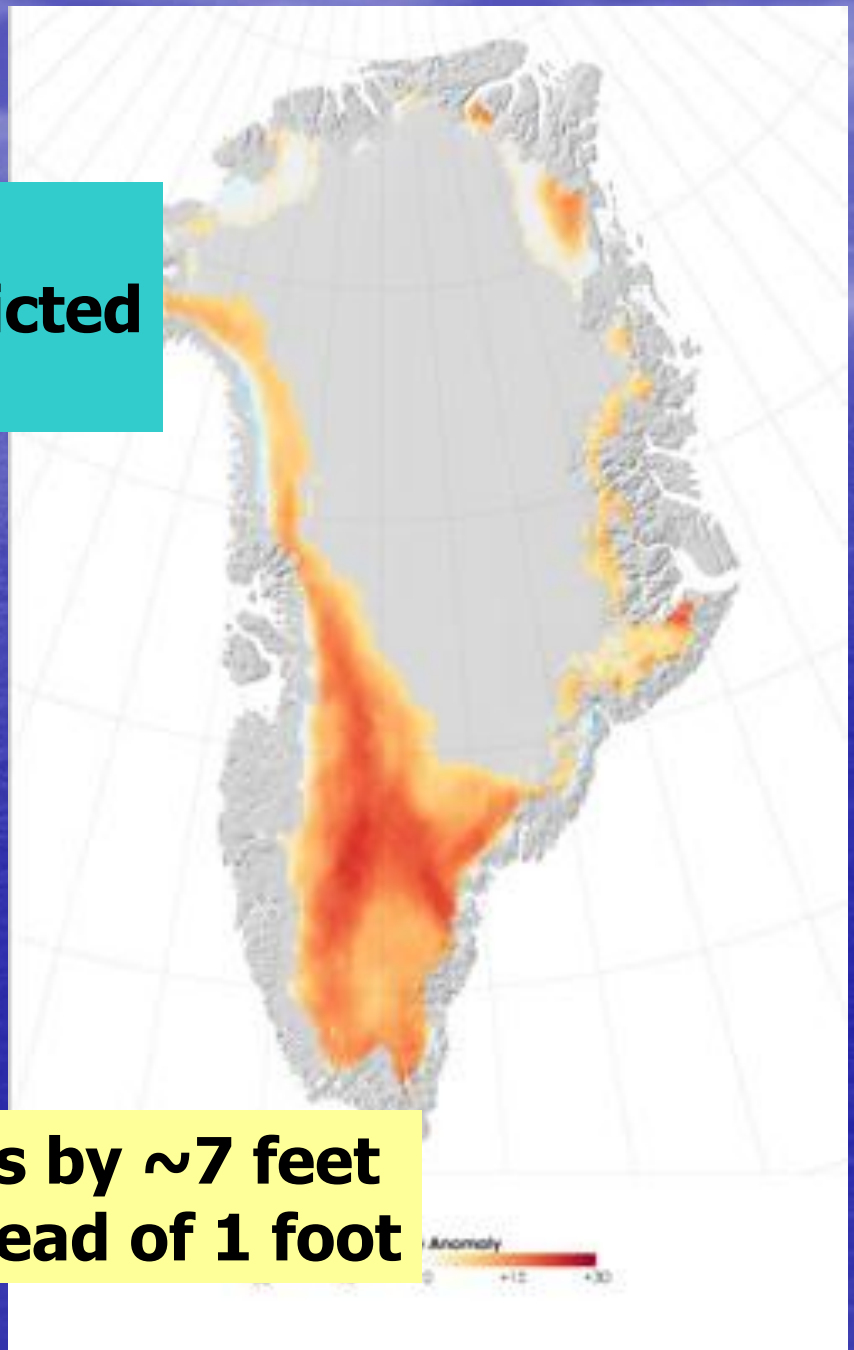
1900 2003

Alpine glacier, Austria

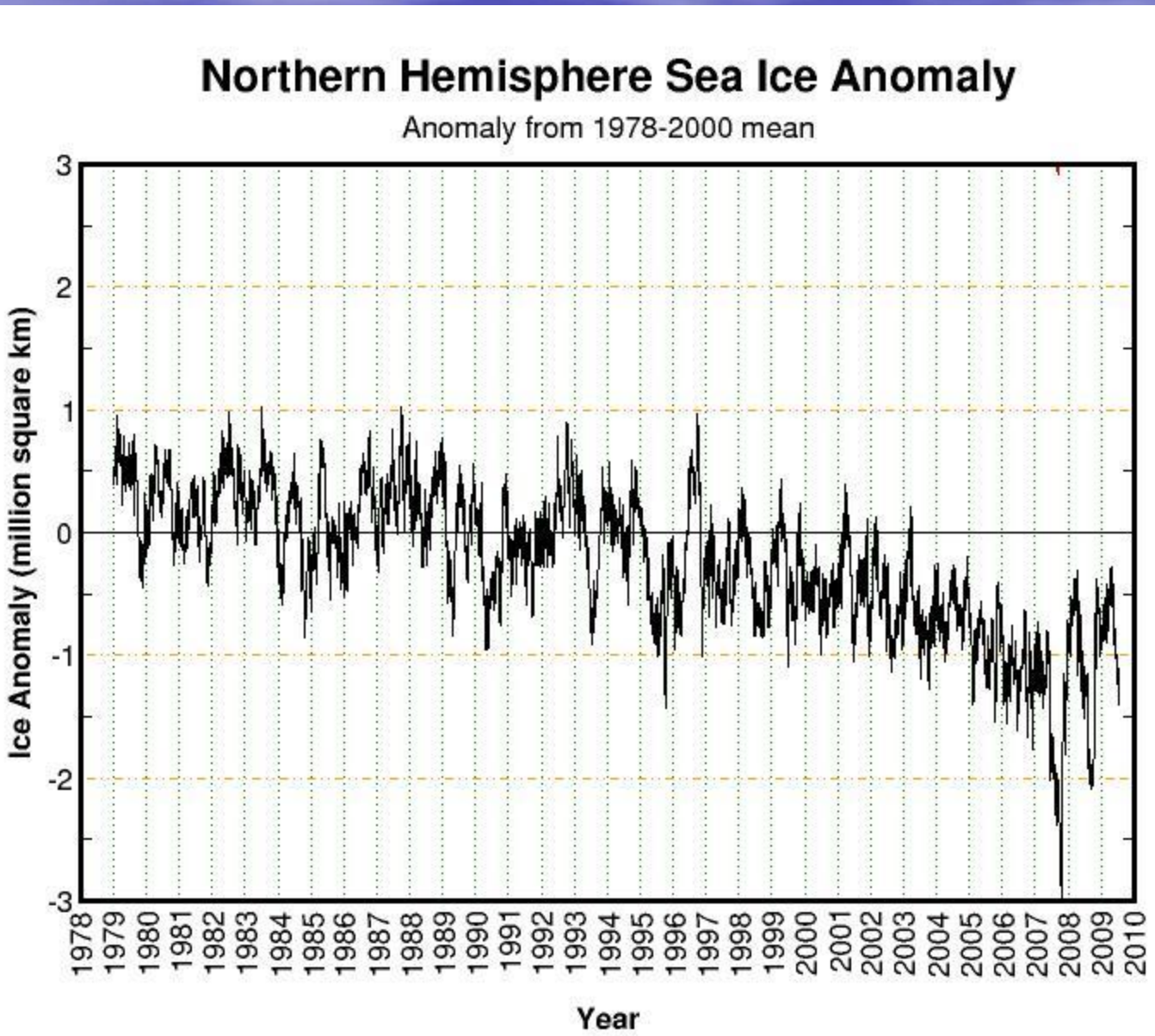
The Arctic is melting. For first time ever, the Northwest passage was open in 2008



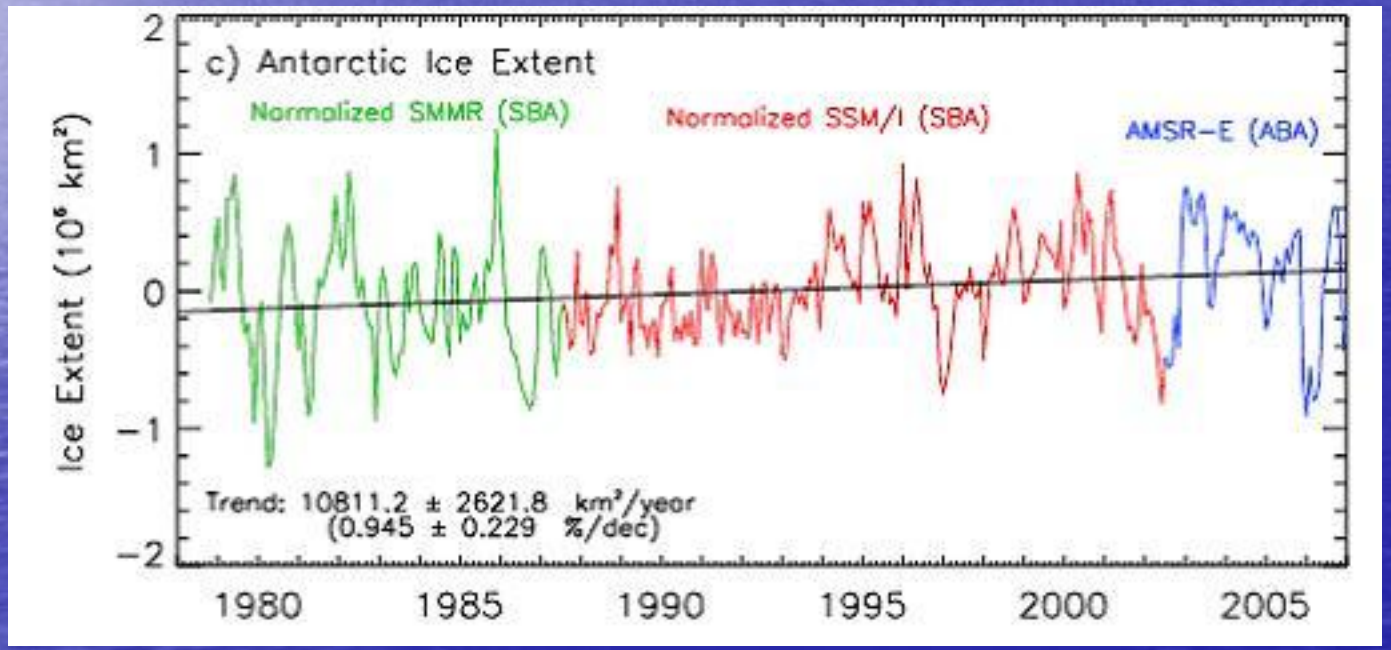
Greenland is melting
Much faster than predicted
By IPCC



May increase sea levels by ~7 feet
by end of century instead of 1 foot


Northern Hemisphere Sea Ice Anomaly
Anomaly from 1978-2000 mean
Ice Anomaly (million square km)
3
2
1
0
-1
-2
-3
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

Antarctic ice- not clear what is happening.



What is going on?

- Northern ice is melting
- Glaciers in northern hemisphere are melting
- Glaciers in Southern Island of New Zealand are increasing – more snowfall
- Why is north rapidly melting and south slowly?
- CO2 alone cannot do it!
- IPCC models are wrong – they do not predict the rapid melting of northern ice at all

Probable answer:

- SOOT – C and particles, not CO_2
- CO_2 does other harm- Changing the acidity of the ocean – destroying corals

SOOT

- From where?
- Thermal Power plants, diesel exhaust, wood burning (stoves)
- Particles deposit within one week at the poles
- C absorbs sunlight – change reflectivity of ice
- Positive feedback loop – water reflects less than ice

Where?

- Northern hemisphere – India, China, Middle East: severely polluting
- China builds 88 GW of power plants a year
- Southern hemisphere:
- Only two major industrial countries- Brazil and Australia
- Brazil does not use coal
- Australia has stringent pollution controls – China and India and Middle East do not

India

Brown/Black soot
Leads to rapid melting
Of ice

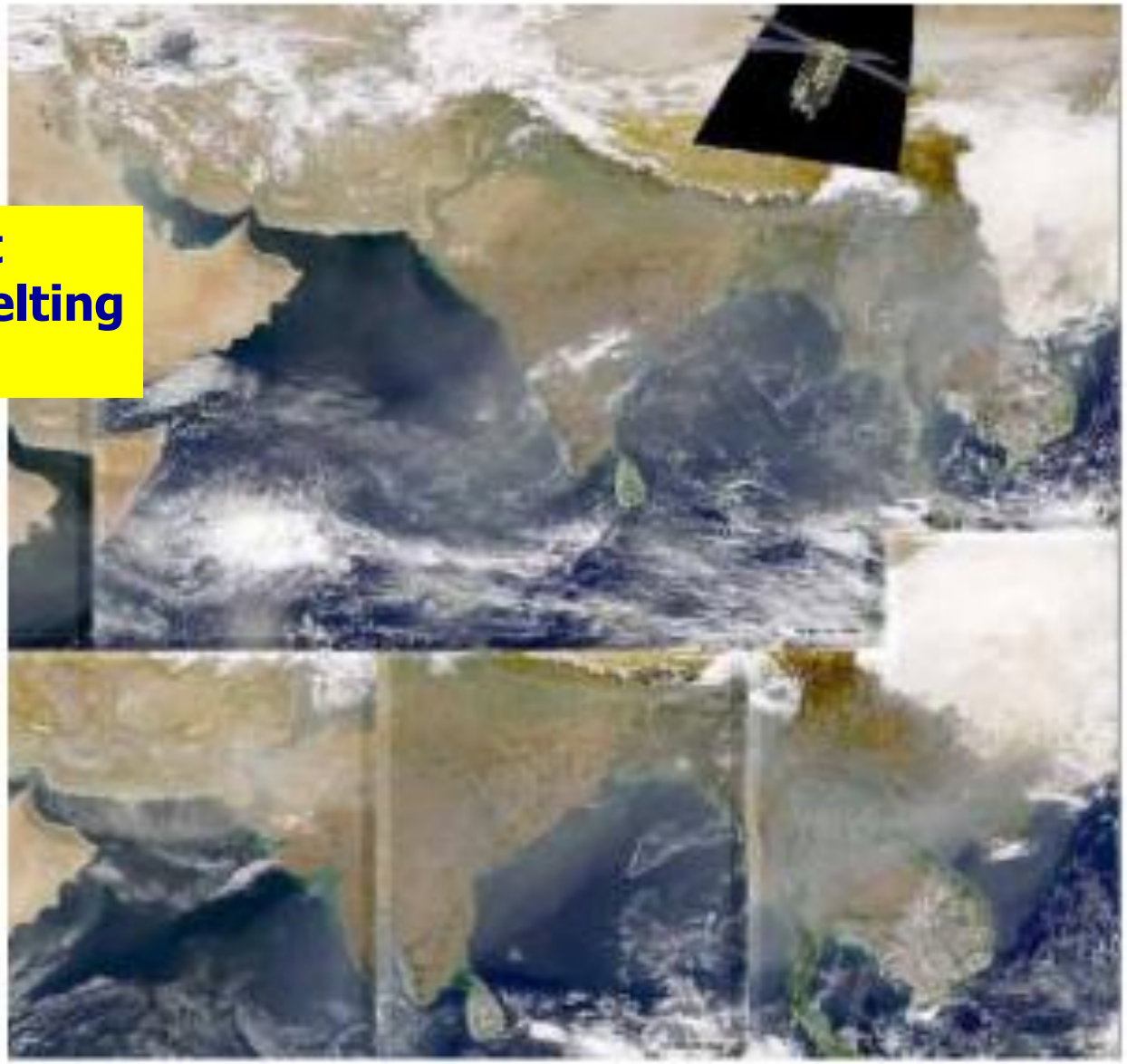


Figure 3.6: Satellite images of the INDOEX pollution cloud over the Indian Ocean. These observations were performed by NASA with the Seal#035 instrument during INDOEX in the period January-March 1998.

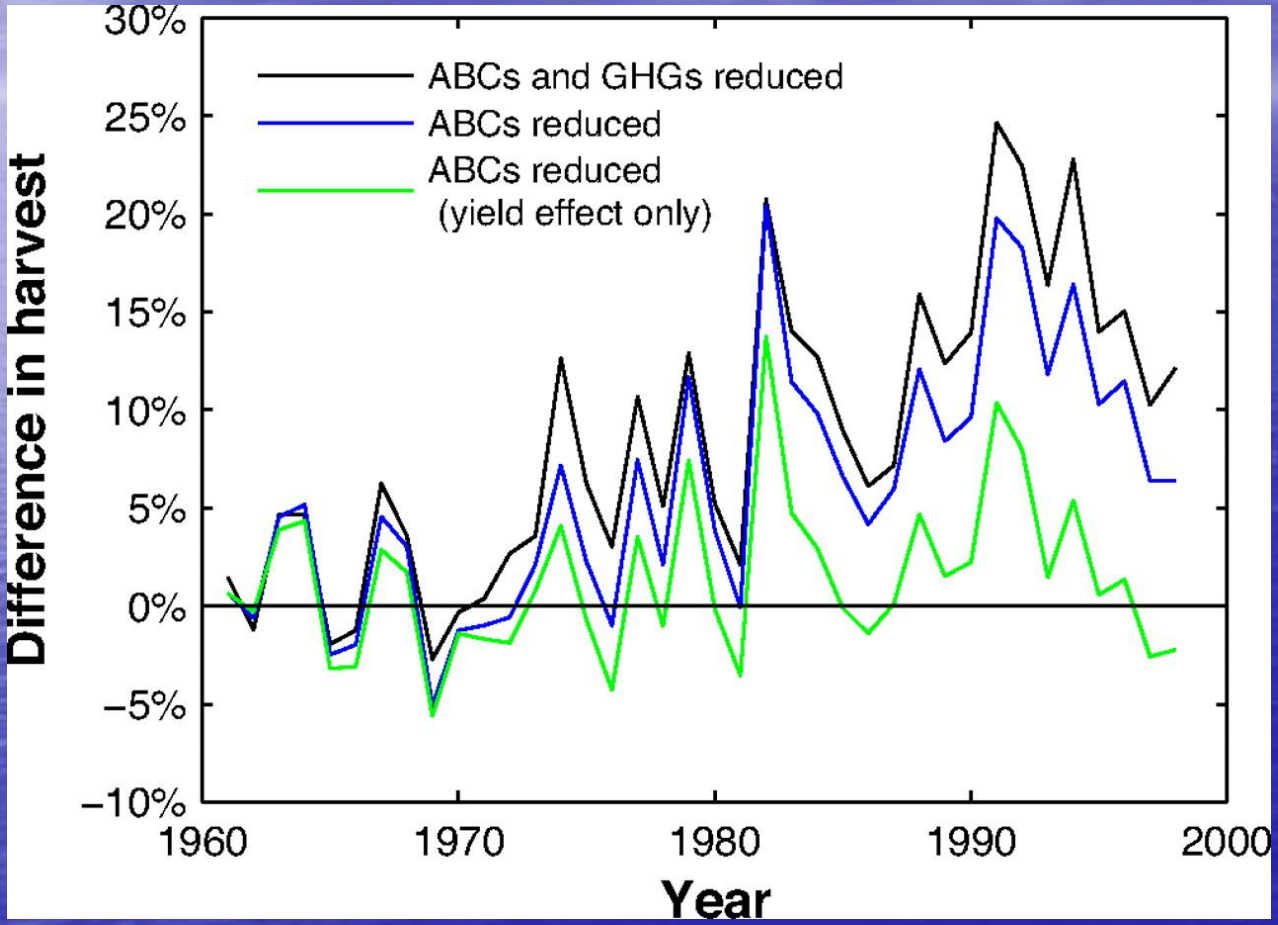
China

Acid rain in China (Coal!)

Figure 7-14 Map of Regional Distribution of Acid Rain in China in 2006

Source: Ministry of Environmental Protection, China.

Severe impact on food production : Influence of brown cloud on rice production in India – Reduction in sunlight And impact of acid rain



Ref. Aufflhammer et al, PNAS, 103(2006)

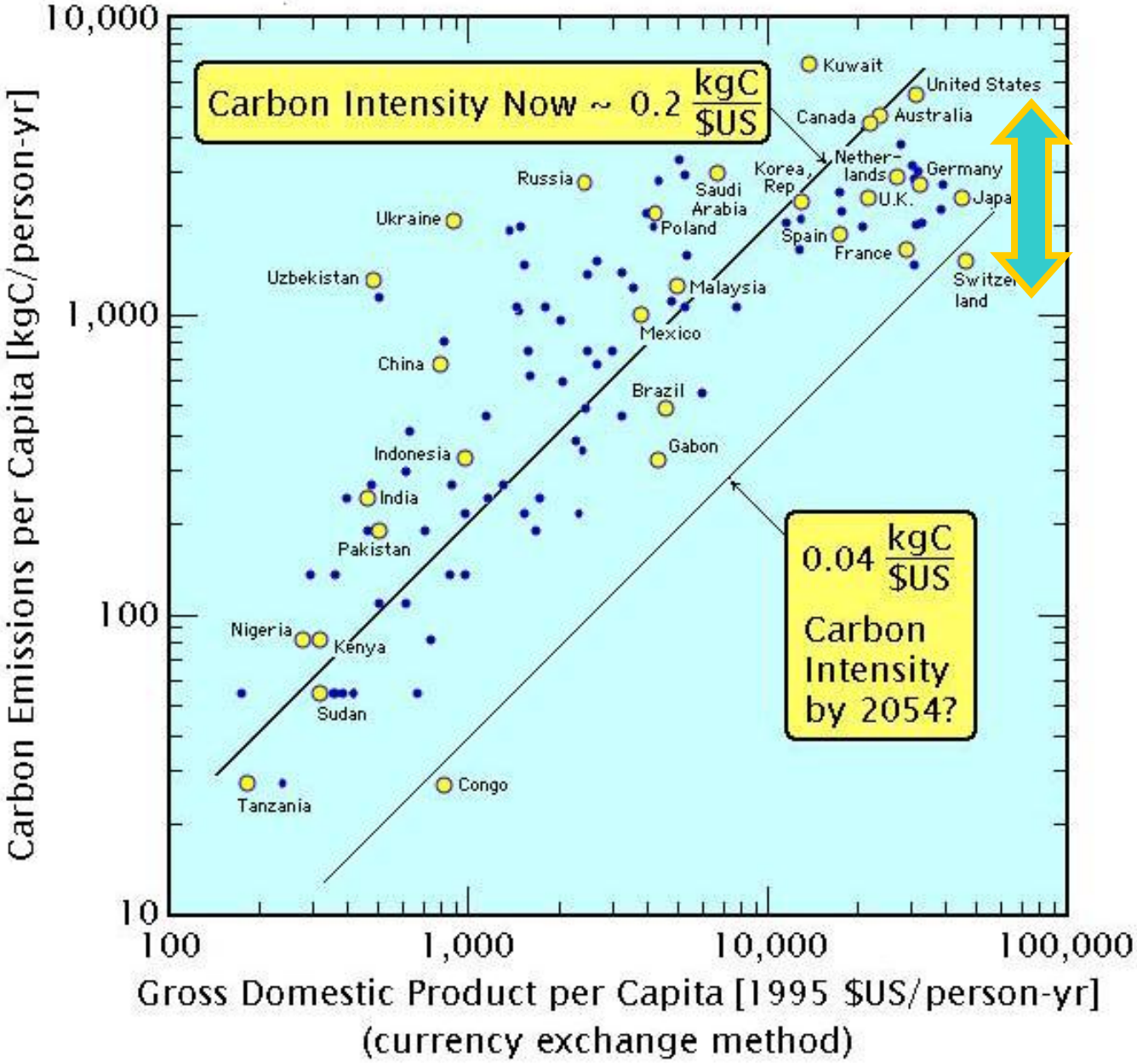
Local Problem-Local solutions

- **It is good for India and China and the Middle East to reduce pollution**
- It will automatically reduce melting of ice
- Tech. solutions exist – eg Mercedes and VW "Blue Tech" diesels- meet California and EU standards for particulate emissions
- Electrostatic precipitators and sulfur dioxide treatment plants for coal burning power plants
- The West is way ahead of India and China on this control

Energy

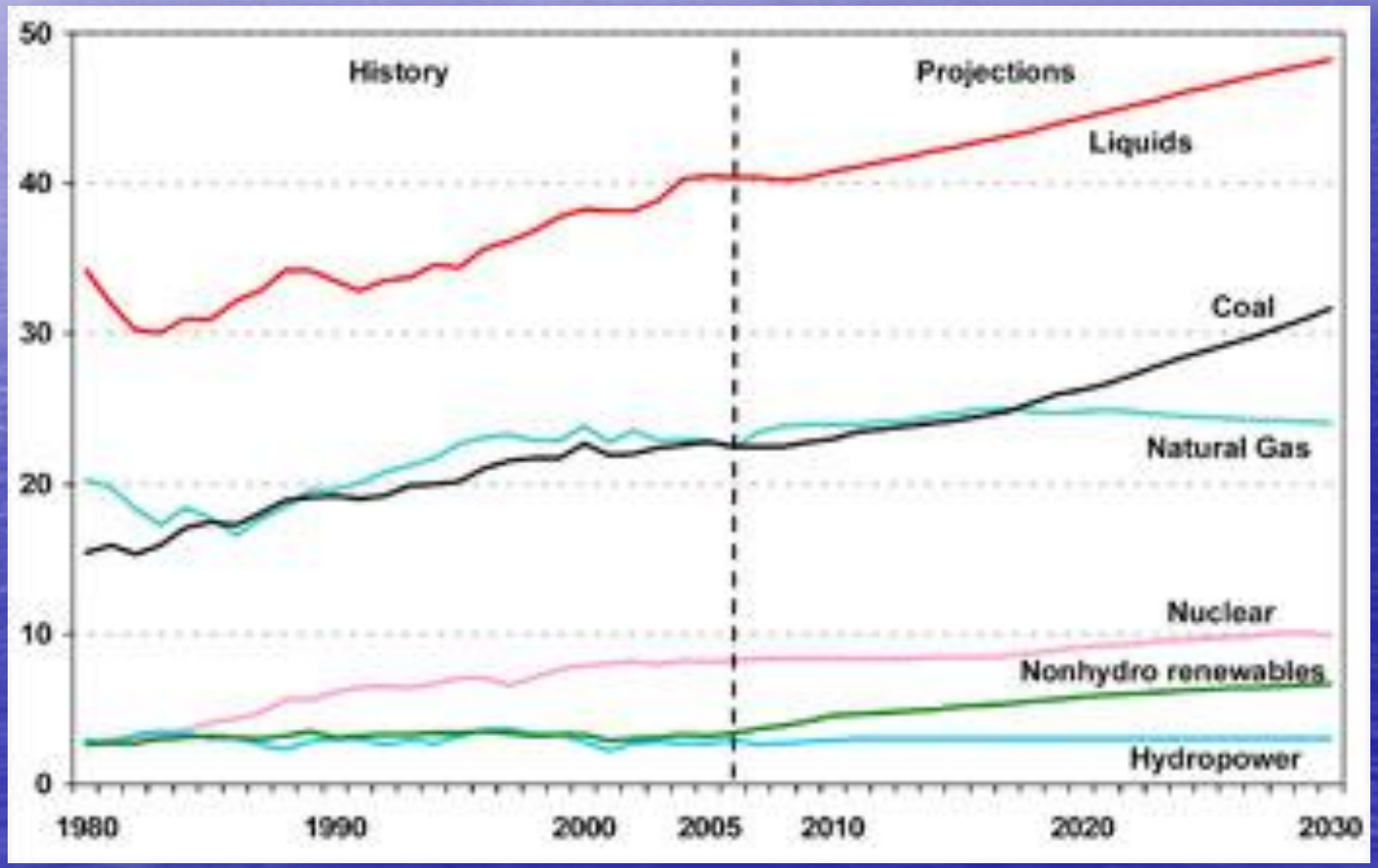
- Energy is not an end in itself – we do not use more energy because it is fun
- Major Exception- weapons
- We use energy to achieve an end – transportation, heating, manufacturing etc
- **Greatest immediate impact on global warming would be from increasing efficiency of energy utilization**

Carbon Intensity vs GDP



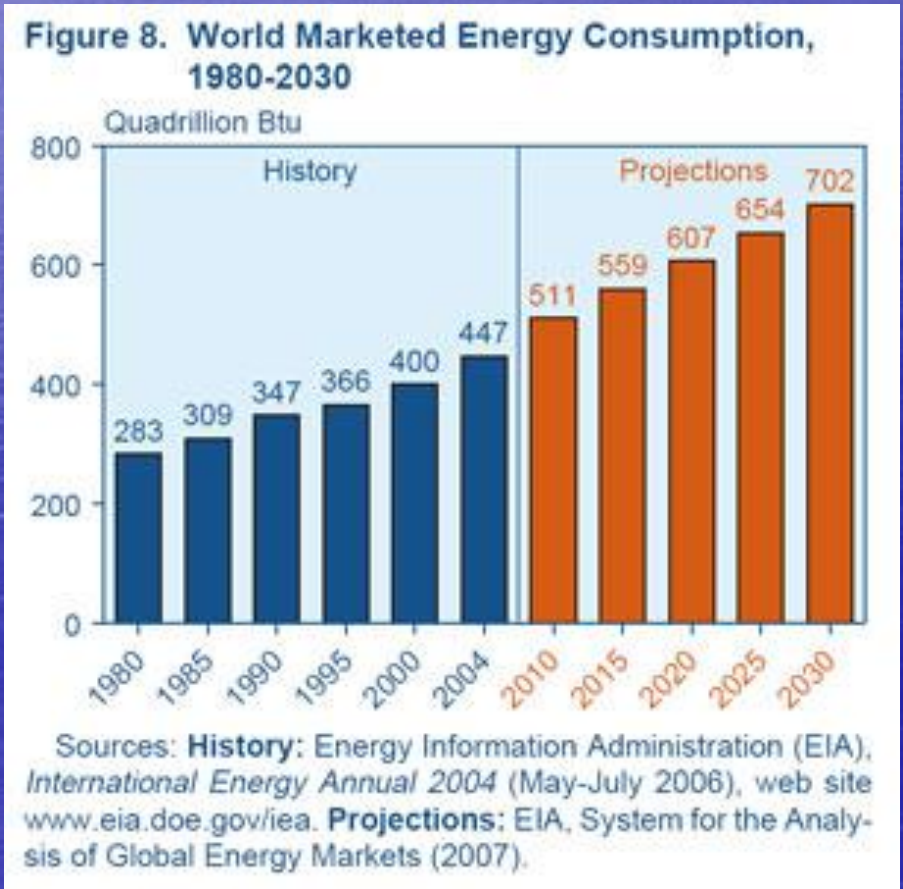
Significant Opportunity To reduce Energy/unit of GDP-factors of 2-3

How much energy does humanity use? – US consumption in Quadrillion (10^{15}BTU's) -~100 Q [eqvlt. to 3.3 terrawatts of power (~3300 nukes)]



The world-about 500 Q
(17 terawatts of continuous power)-only measures marketed energy – does not account for rural use

(eg wood, cow dung for cooking)



How do we reduce energy consumption?Example: Power Plant Efficiency

- **Typical US coal fired plant (old) ~33-35%**
- **Modern Hitachi plant (Japan) ~ 49.8%(Highest in the world), ~ca. 2002**
- **Reduction in CO2 per unit of energy delivered: 32%**
- **Advanced combined cycle:**

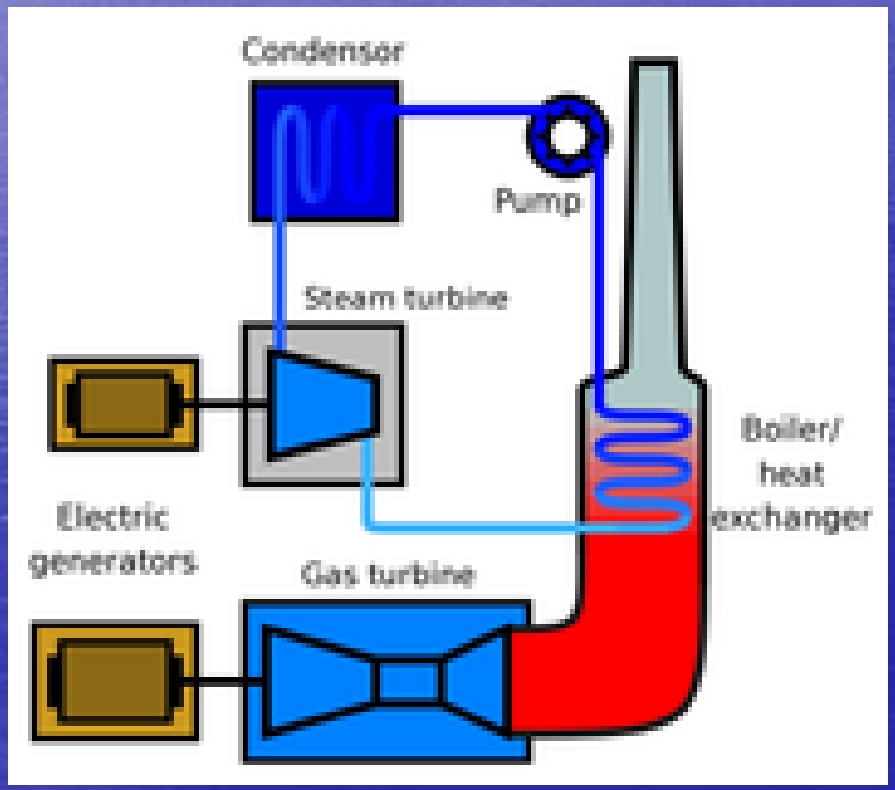
Coal gasification – use gas in turbines

Use exhaust from turbine to preheat water for steam turbine

~ 60% efficiency possible

Reduction in Co2: factor of ~2/kWh

Combined cycle plant



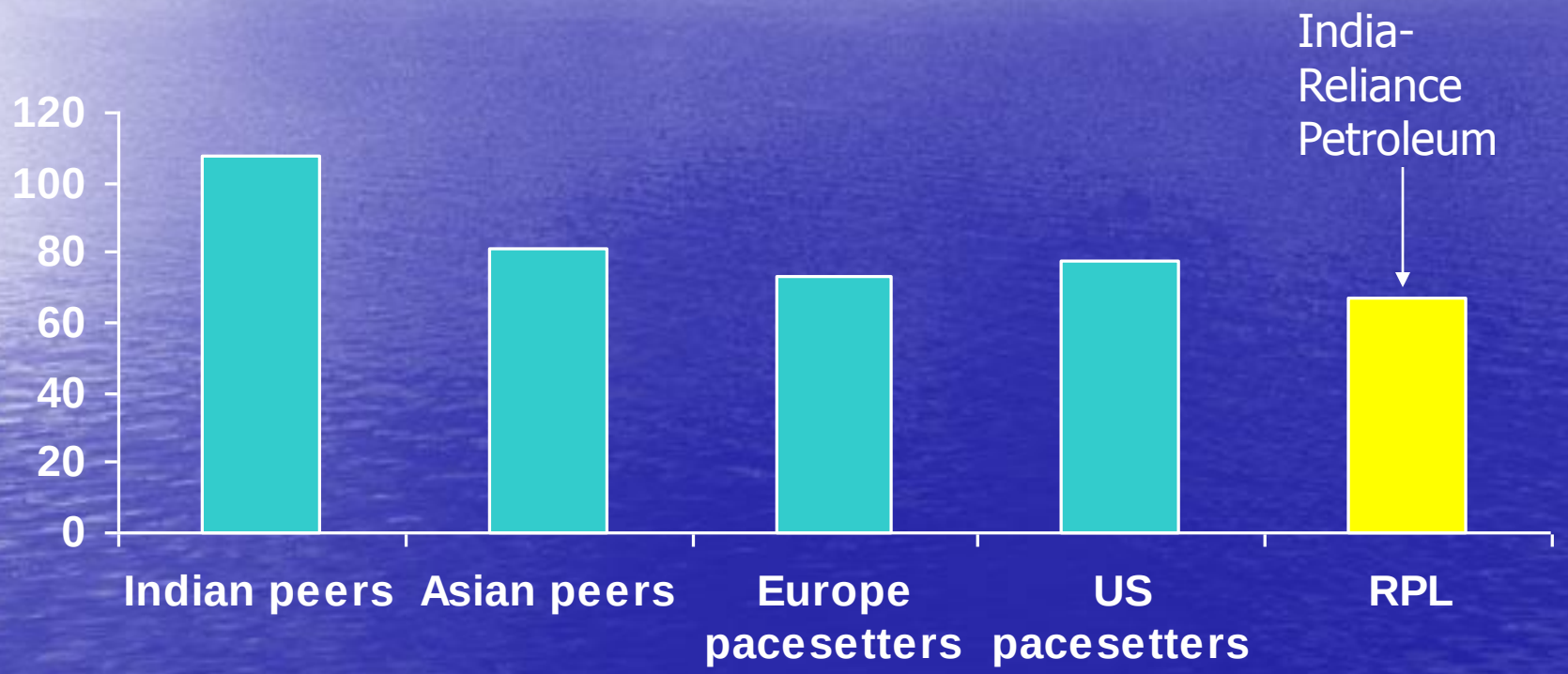
Policy Question

- Is it so unreasonable to demand that ALL coal based new power plants be high efficiency?
- If Japan can do it, why not the US and India and China?
- China and India are rapidly building new plants, China 88GW this year (more power than exists in the UK) -mostly coal fired-but they are not efficient!

Another example-refineries

- Refineries use a lot of energy, 7.5% of total US energy consumption! Largest single industry in terms of energy consumption
- Not all refineries are equal in terms of their energy intensity index-variations by factors of ~2

Example: Solomon Energy Intensity Index



World's most efficient and largest (1.2 mbpd) refinery is in India!

Energy & Loss Performance - CEL 2003

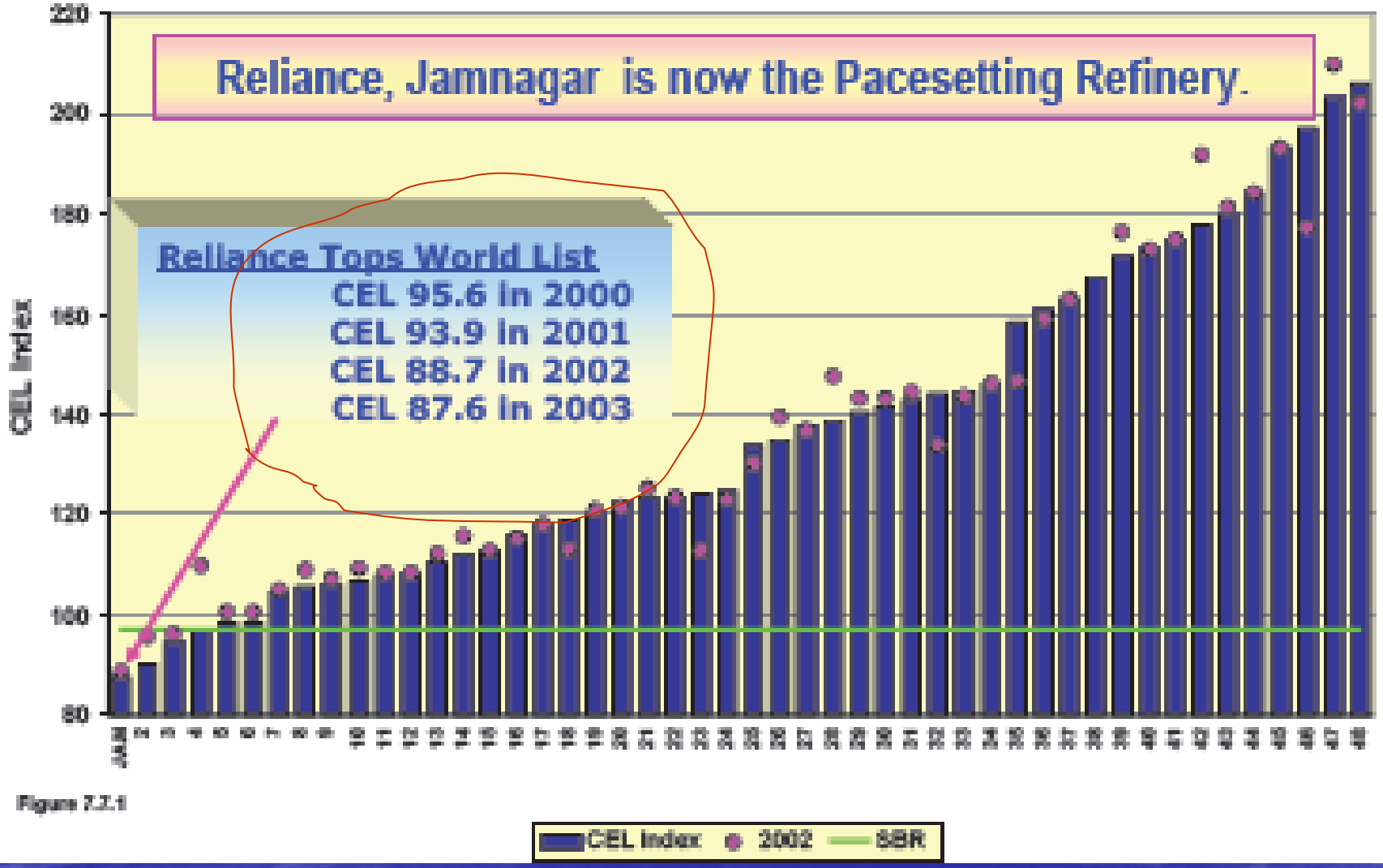
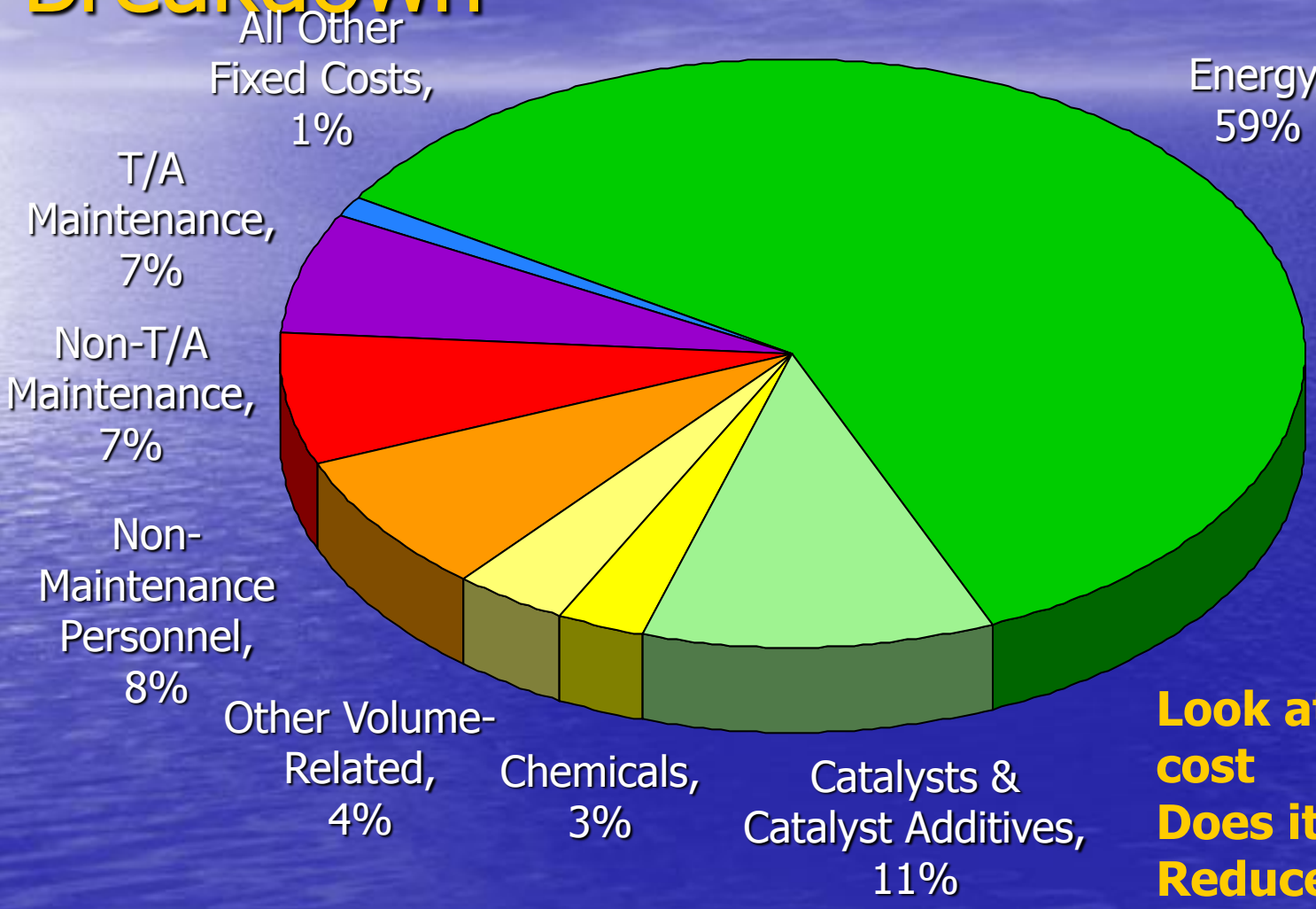


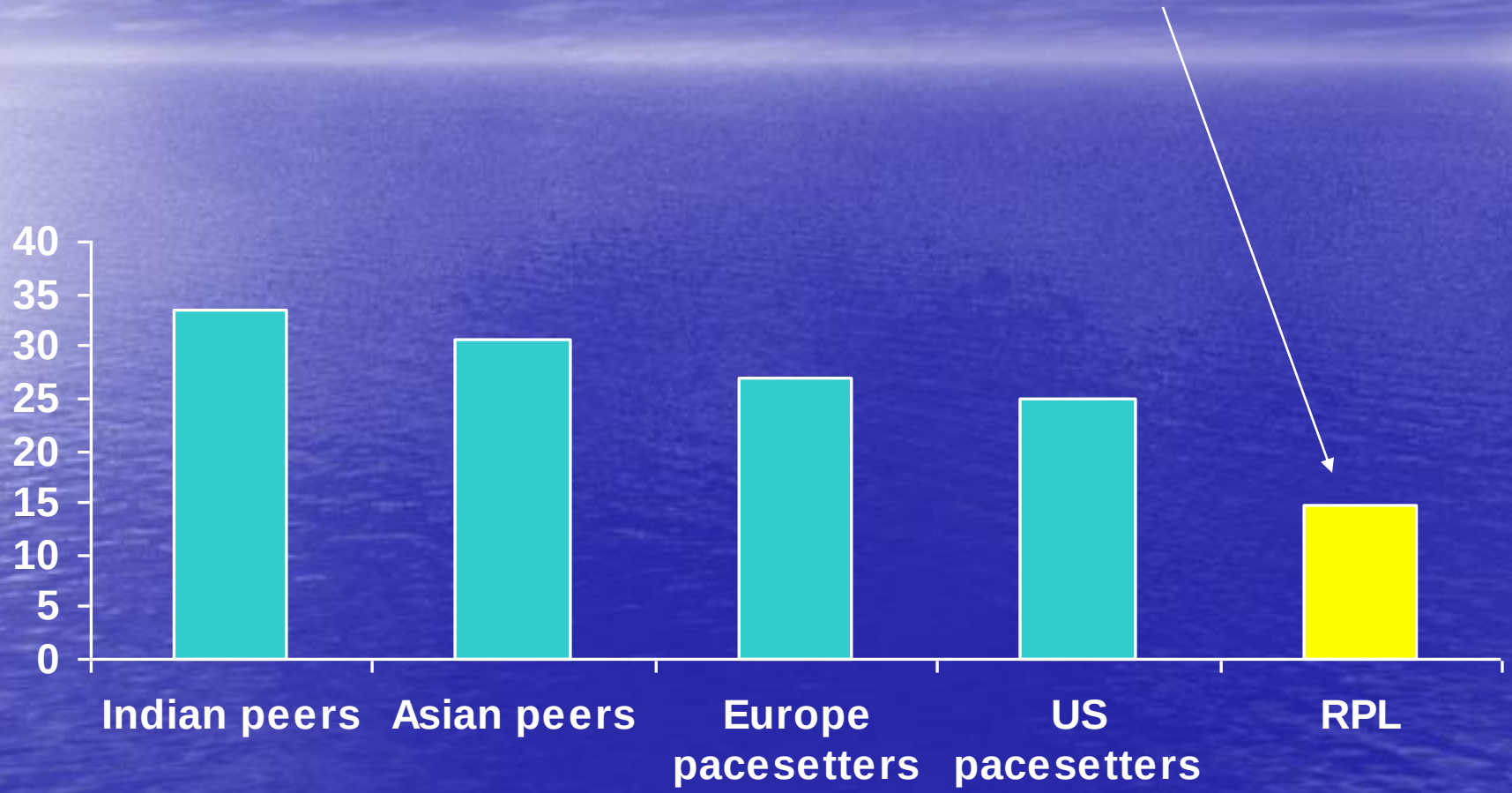
Figure 7.7.1

Refineries: Operating Expense Breakdown



Look at the energy cost
Does it not pay to Reduce it?

Operating costs do reduce!

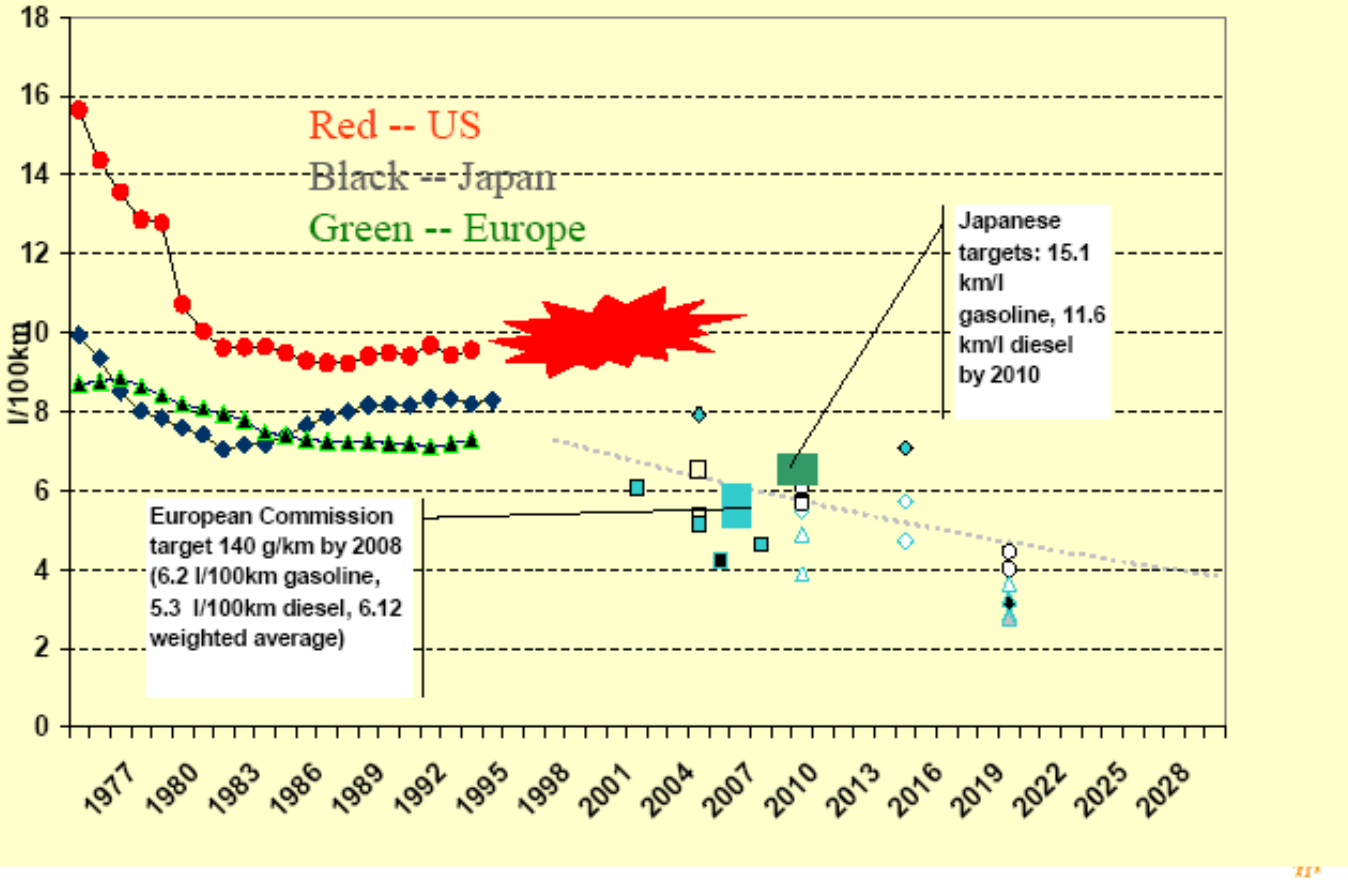


Does it surprise you that Reliance's Market Cap is ~$100 billion? And Mr. Ambani (Chairman) is worth ~$ 50 B? Efficiency pays rich dividends!

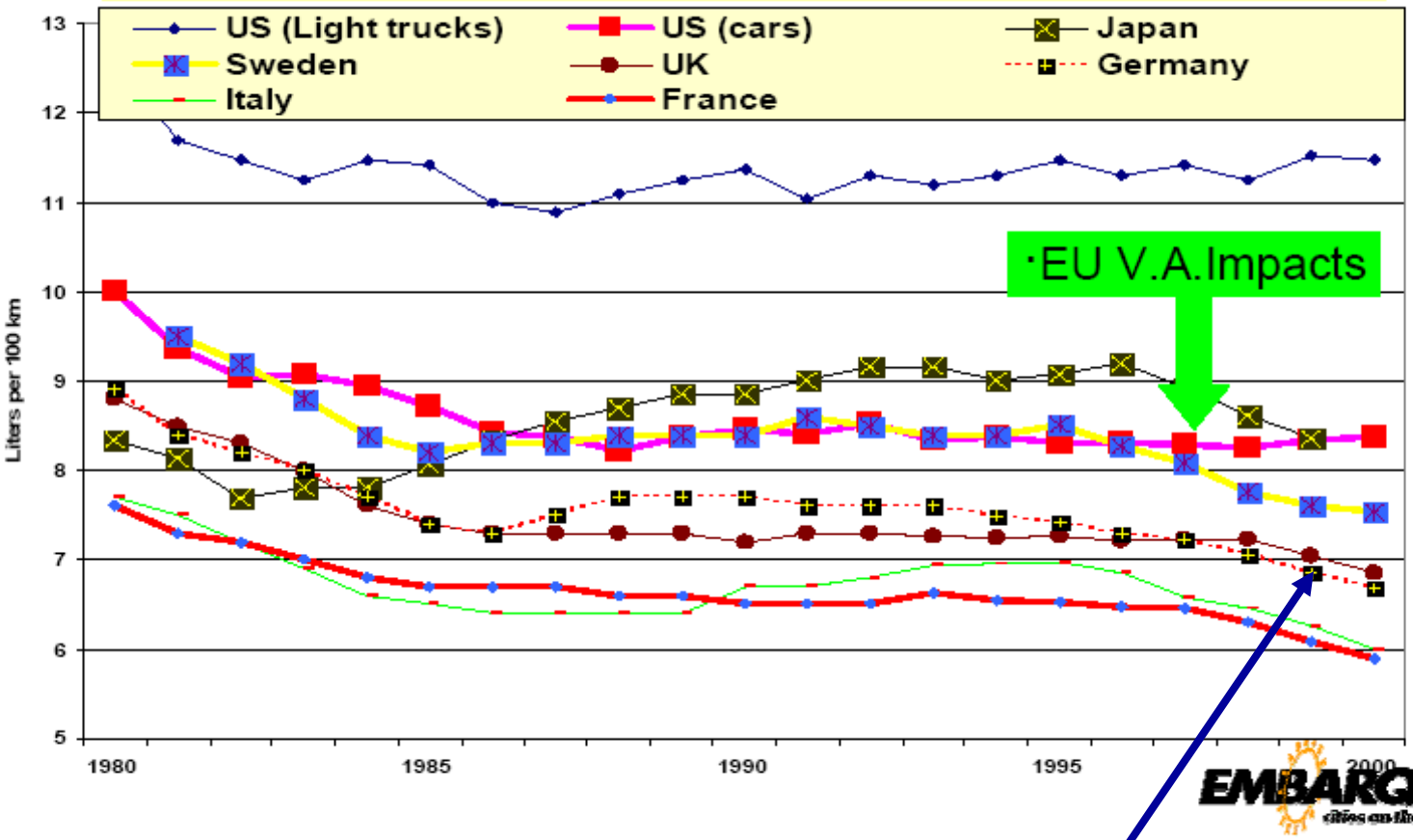
How about transportation?

- Automobiles-classic example

NEW CAR FUEL INTENSITIES: Trends, Targets, and "Best Practices"



Trends in New Car Fuel Intensity



Germany is decreasing, US is not

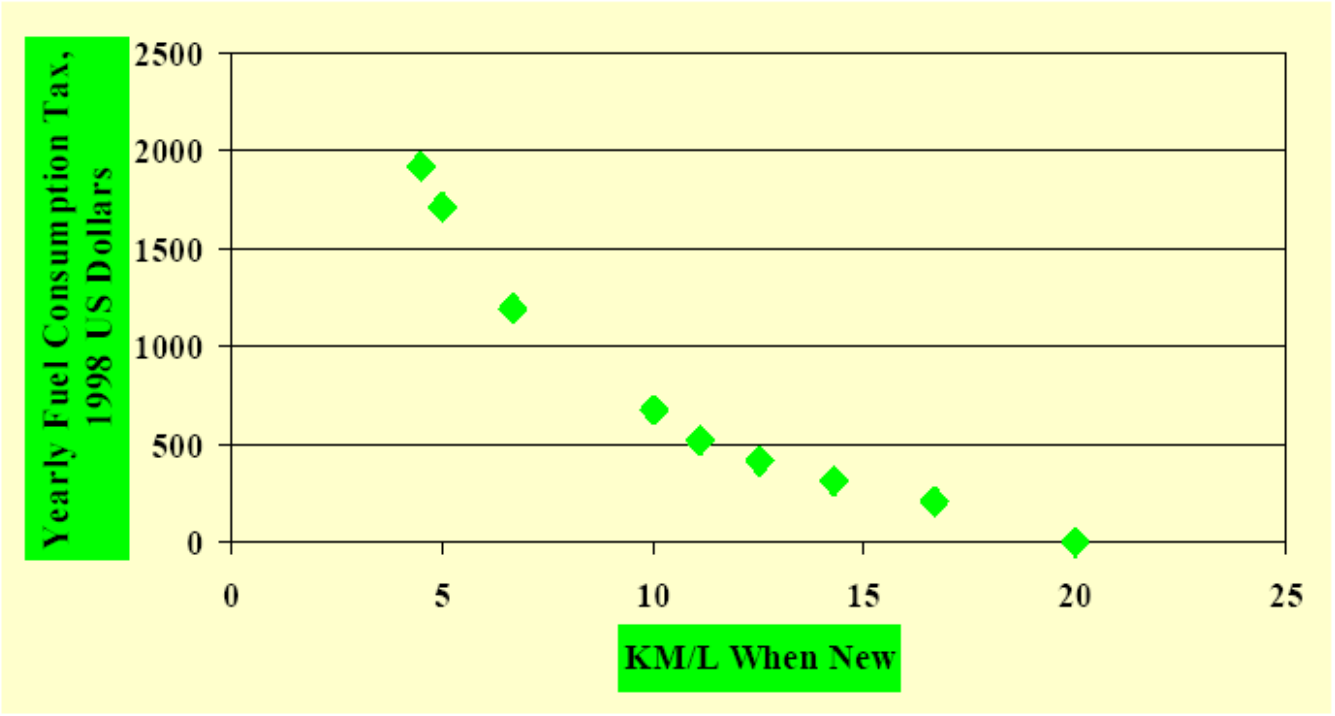
Automobiles

- If every car or SUV was a hybrid, we would reduce fuel consumption by 30-40%
  [If all of US arable land was used to produce ethanol, substitute 35% of gasoline]
- How do we get there?
- By taxing expected gas consumption at the time of purchase!
- Do differential taxes work?
- YES!

Compare!

Denmark!

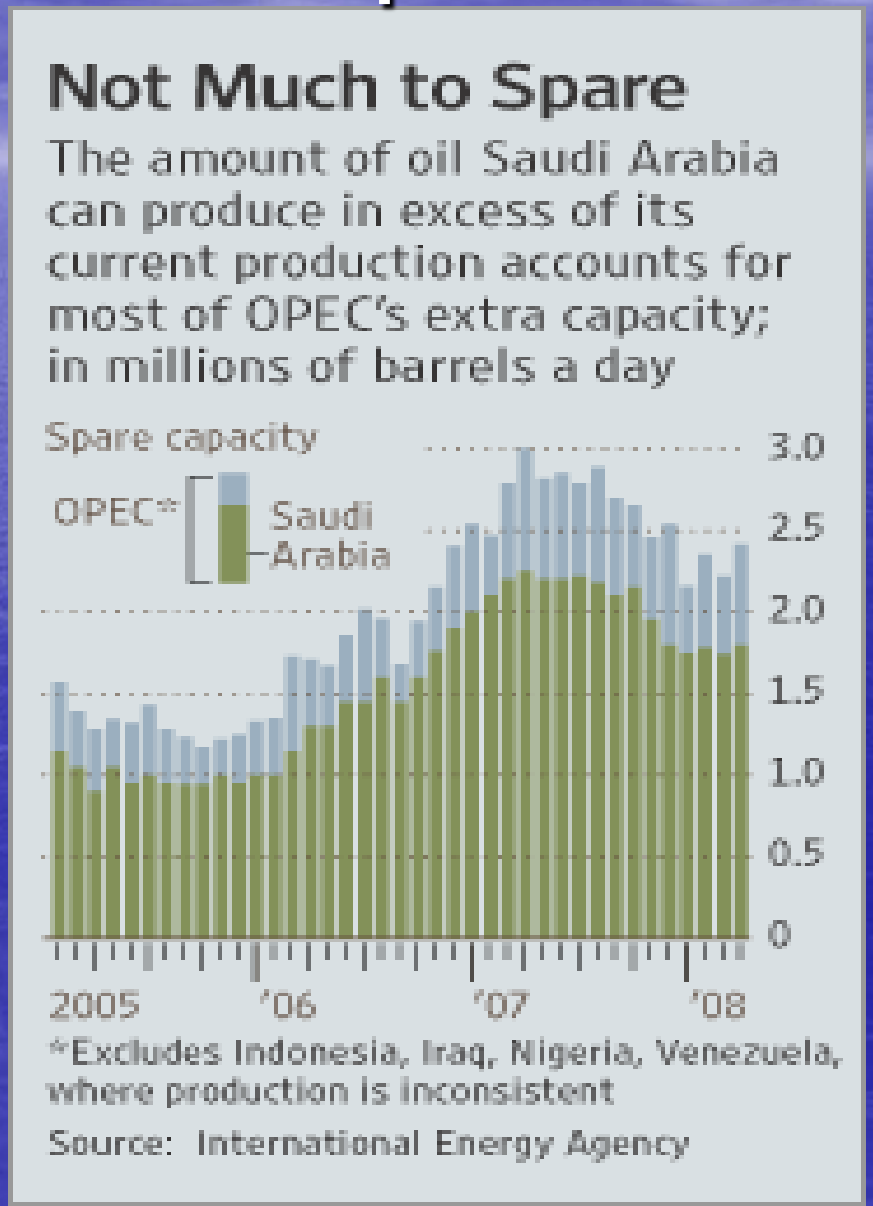
DANISH YEARLY "GREEN OWNER FEE" TAX SHIFT



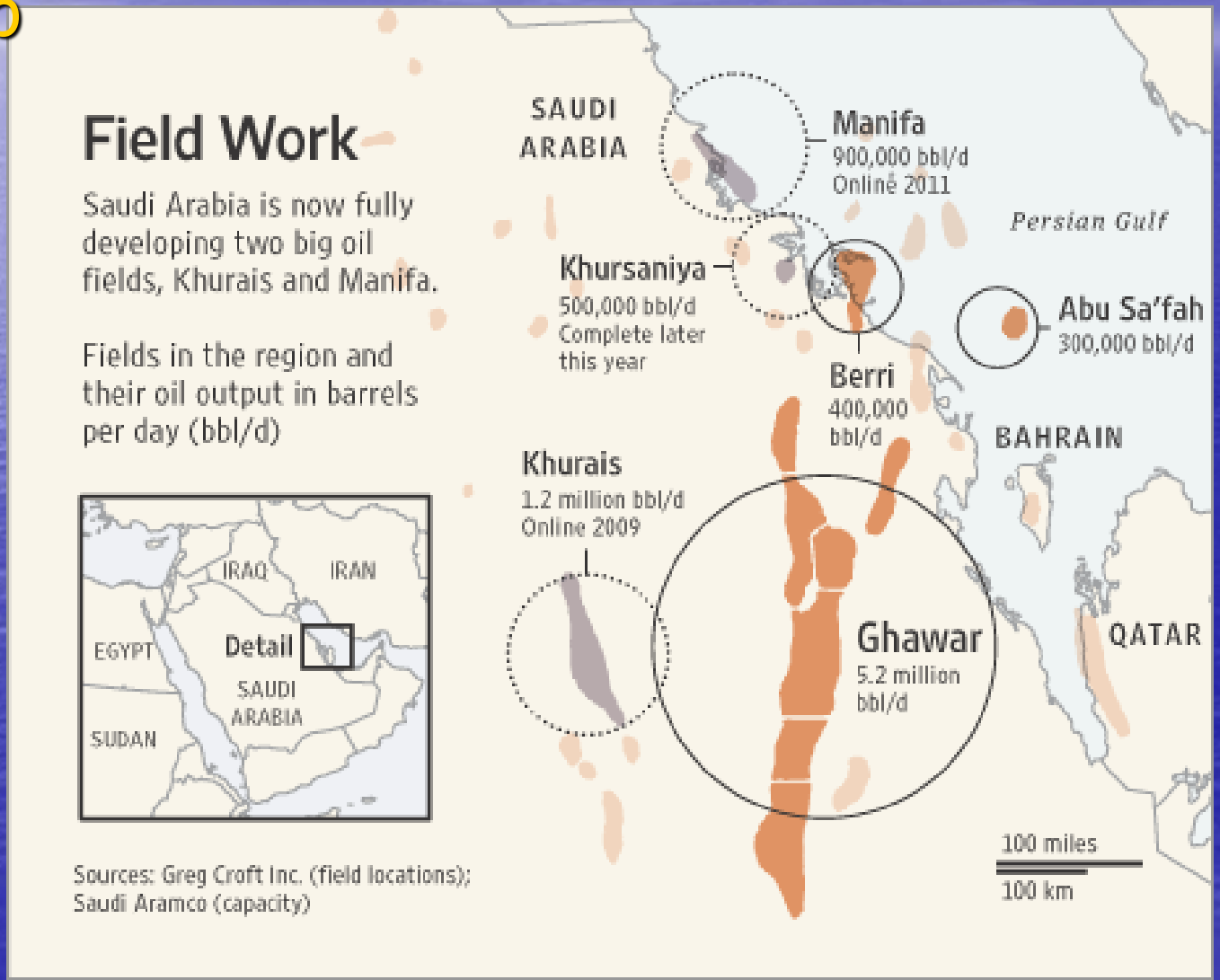
Change in the Yearly Fee Based on New-Car Km/L

EMBARQ
cities on the move

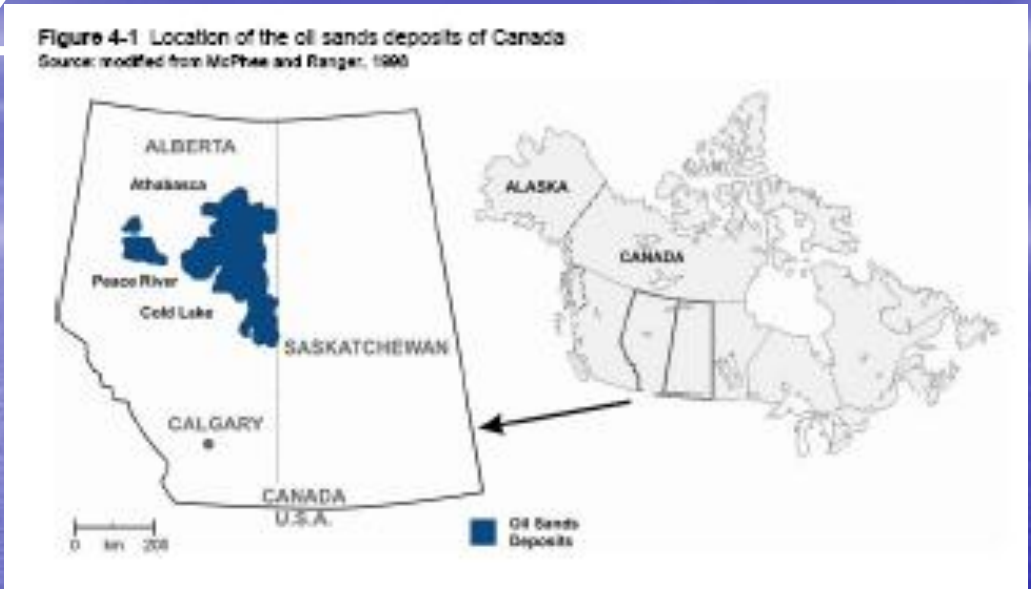
Why is oil so expensive?



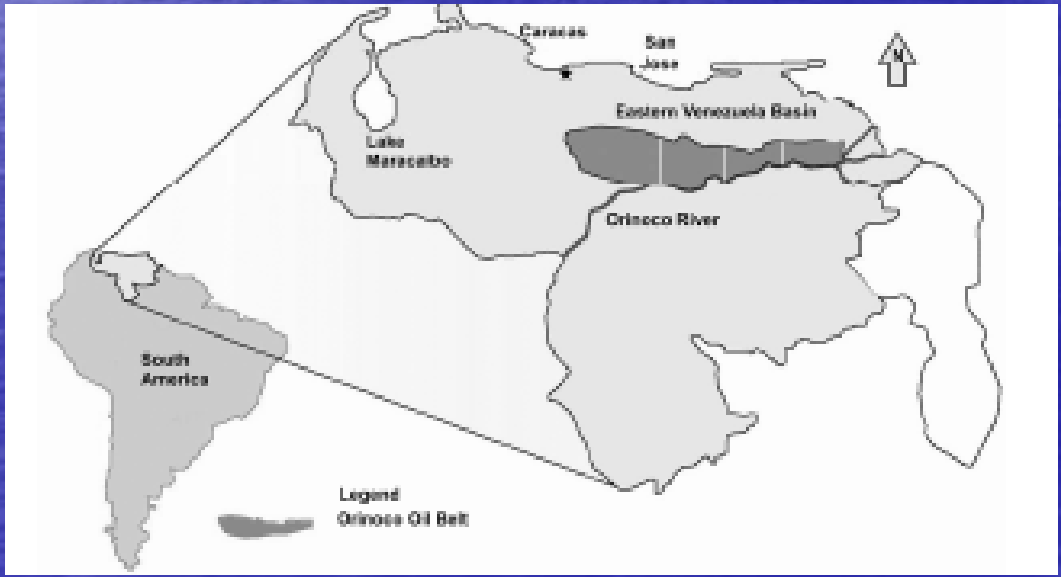
Saudi field is tapped out-needs secondary recovery-there is no simple to extract oil left-except in Venezuela-Chavez has screwed that up



Heavy oil-in two places,CANADA and VZ



Canada:
352 B Tonnes



Venezuela:
349 B tonnes

Tar sand in Canada

Not cheap. About $ 80/BBl for profitable extraction.

Fundamental law of economics: Price = marginal cost
If alternatives cost ~$ 80, the oil will sell at $80

What do we need to bring that oil to the US?

Keystone Pipeline – big controversy

Conclusions on Efficiency

- There is no other choice-MUST reduce energy consumption NOW
- The opportunities for increasing energy efficiency are HUGE – at least a 30-50% reduction in energy use possible per $ of GDP in the US-
- Much more so in places like China and India- they are not using the most efficient technology
- Need to implement the best technologies-both government regulation and tax policy are needed- as also new technologies!

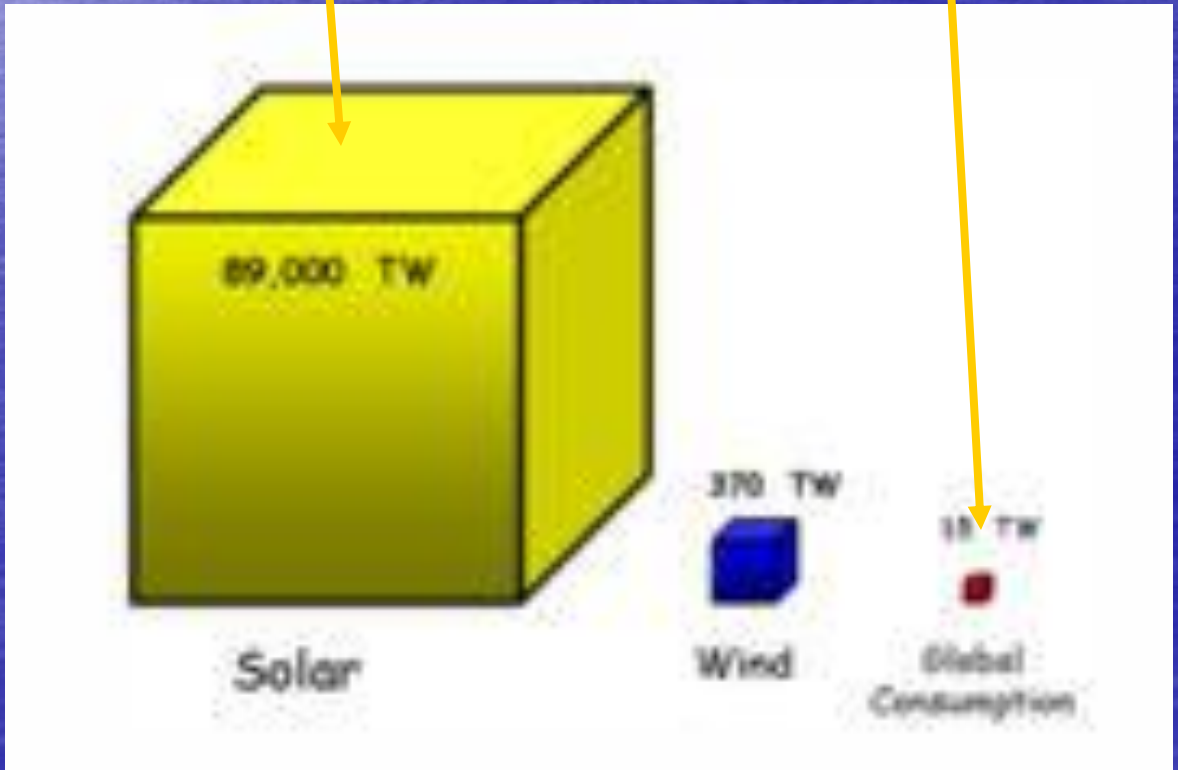
Example of India-How NOT to do things

- India's recently announced NANO car ($2500 cost) is NOT a hybrid-going to be a disaster for India's pollution and gas consumption
- Traffic is stop and go in most big cities
- Hybrids are the obvious solution-but not being implemented as of now

How about renewables?-Solar is a GIANT source compared to what we use

Potential
69k Terawatts

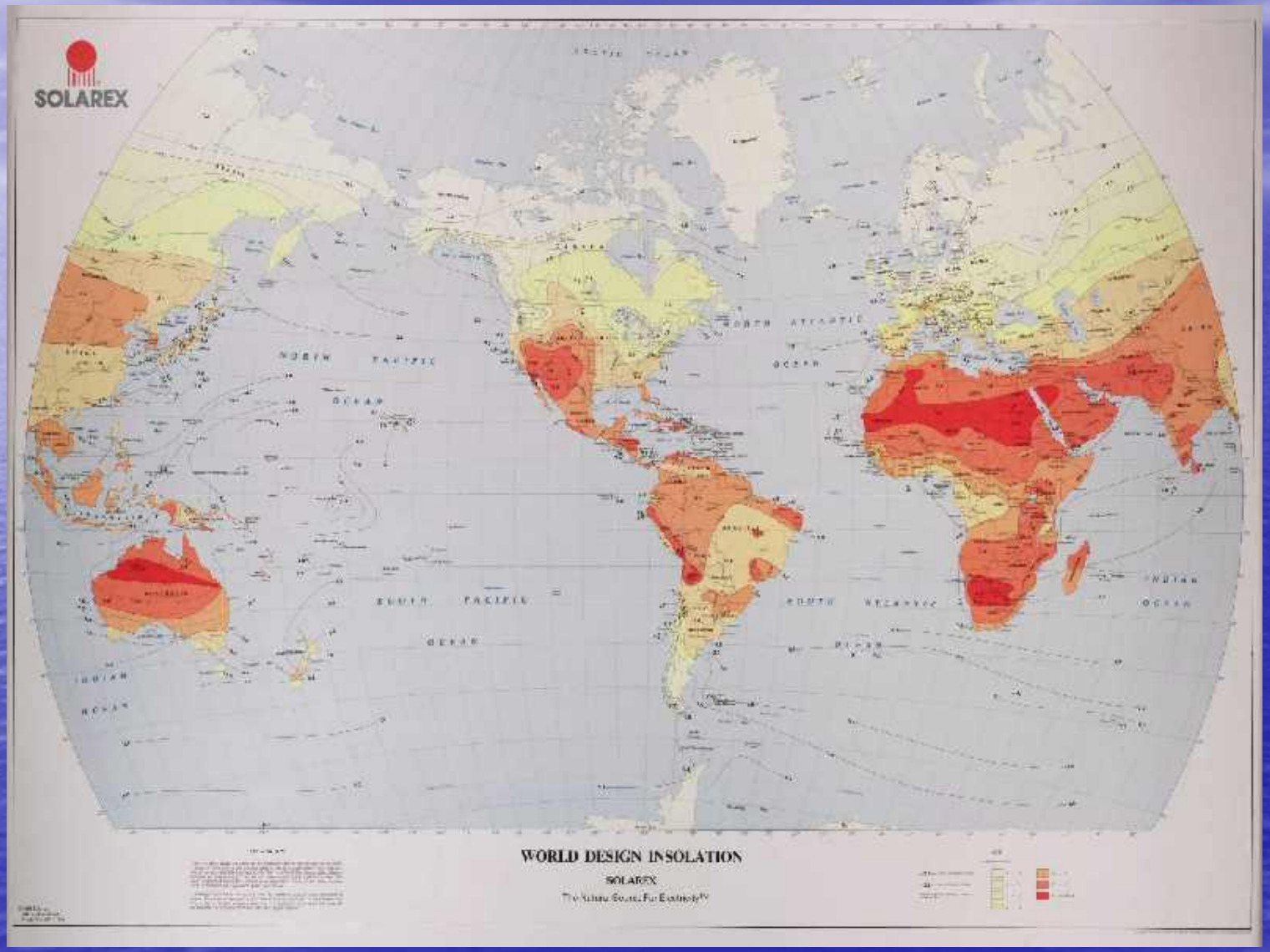
Use=17 TW



Solar intensity

- 1 kW/m^2 on a clear day
- About 1800- 2000 hours of sunlight
- Much more in Southwest, India, China, Middle East, Australia, Africa
- In the US, 1 sq meter = ~2000 kWh per year
- In parts of India, Africa, Australia,Iran : 1 sq.meter=~3000 kWh per year

Solar energy atlas of the world



What about efficiency of solar use?

- Direct Electric conversion, current ~15%
- Future (~10-15 years) , likely to be 25%
- For heating homes-very efficient and practical TODAY
- Photosynthesis? Very poor today, 0.5-1%
- Solar-electric, averaged over year, has a 60:1 advantage over photo-synthesis in terms of area used

What about corn-ethanol?

- Very poor conversion efficiency~0.5%
- 1 J input leads to ~1.4 J output
- Corn based ethanol will NOT solve our problems- **good for reducing pollution**, **bad for solving global warming problems**
- **Major moral hazard! Impact on fertilizer and food prices is horrific**
- **Food prices have doubled everywhere**
- **in the world-Rice, 150%, Wheat, 135%, corn 100%**
- **Poor are starving!**
- Waste to ethanol – **yes** if handled carefully in terms of replenishing the soil

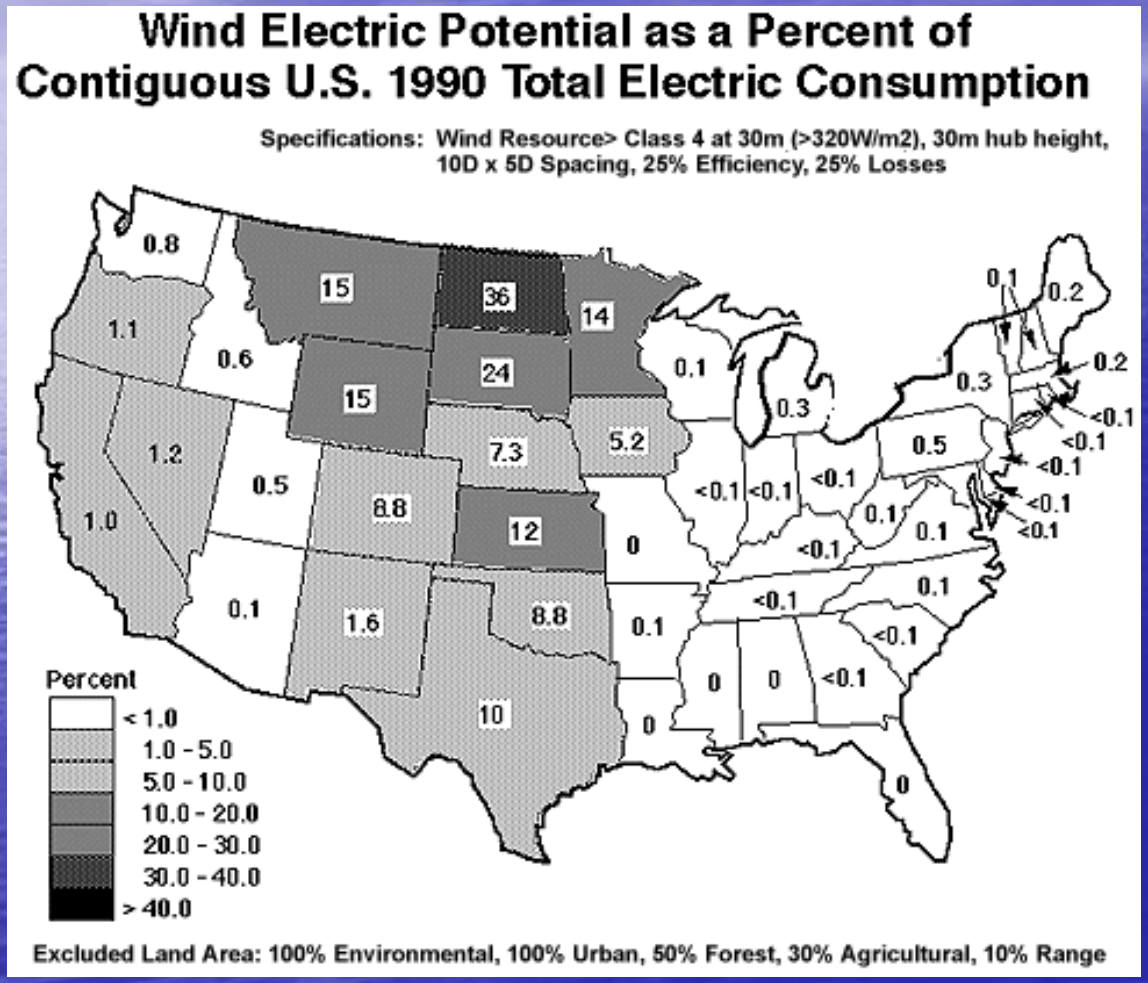
What about other bio-fuels

- Synthetic biology-to significantly increase photo-synthetic efficiency
- Bacteria directly convert water and nutrients into cellulose and alcohol (Super algae)
- This is the focus of the $500 million BP supported program at UC-Berkeley
- **That is the future of biofuels- that will most likely work**

Wind?

- 370 TW of wind available
- Great for the US Midwest and coastal areas

Electric Potential of Wind



In 1999, U.S consumed 3.45 trillion kW-hr of Electricity = 0.39 TW

What is wrong with wind?

Wind

- Power proportional to (velocity) ^{3}
- A 1000 MW power plant becomes 125 MW if wind speed drops by 2X
- How do we make up such a large loss?
- Severe impacts on power system stability

What do utilities do to handle large wind installations?

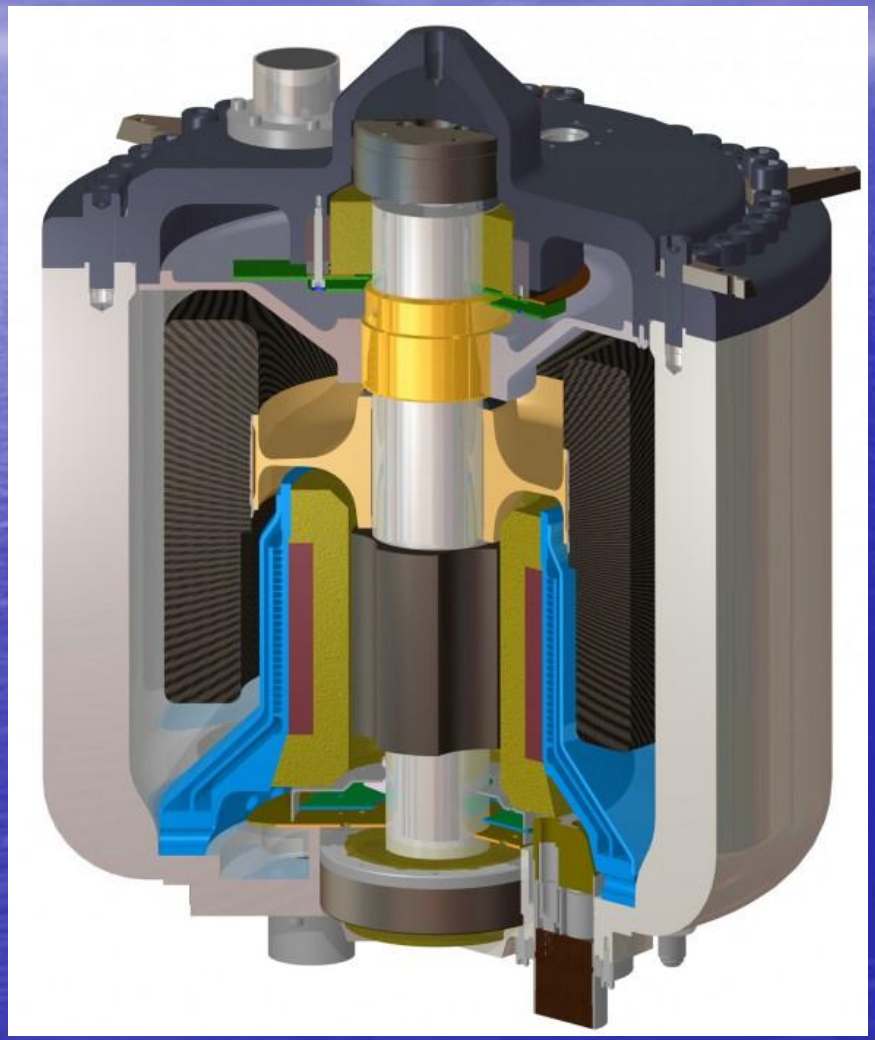
Utilities and wind

- By adding gas turbines to wind power stations
- Or-by using batteries or what else?

What else

- Flywheels-great for short term storage

flywheel storage –in vacuum



Beacon, NY Flywheel power plant (now in bankruptcy)

What about storage? Solar and wind are not continuous

- Many methods
- Batteries will not work for very long storage-but may be Ok for overnight
- Two other schemes will work for long term storage

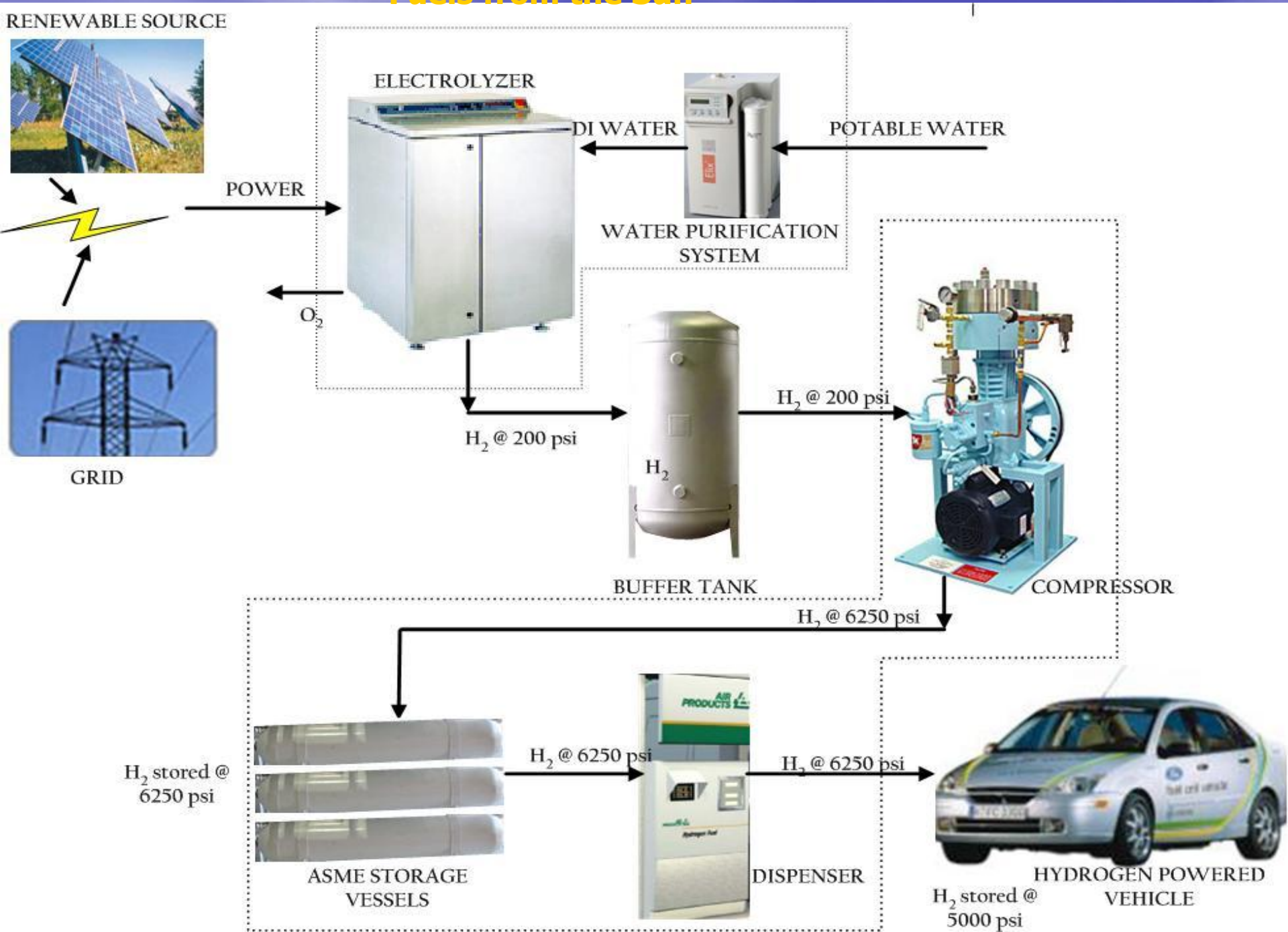
Pumped storage

- Solar/wind coupled with pumped storage hydroelectric plants
- Pump water uphill during day using solar, flow it downhill to generate electricity
- Very efficient – but needs water- may be a problem in many geographic locations-but not in California or India or parts of Africa

Chemical conversion

- Solar/Wind electricity into electrolyzer- **produce hydrogen** from water
- Store hydrogen, use in fuel cells for regenerating electricity
- Or, **make ammonia**, use ammonia as fuel for fuel cells
- **Why ammonia-** can be liquified very easily, (~8 atmospheres)-Liquids hold a lot more energy per liter than gases

Fuels from the Sun



What about cost of solar-electric?

- Today, costs about 15-20 c/kWh
- Compare with coal ~ 6-7 c/kWh[That is why the server parks(Google, IBM) are locating in Iowa]
- Compare with natural gas, ~10-12 c/kWh
- In places like California and New York, with higher tariffs during peak demand (daytime), price can be >50 c/kWh
- Solar competes for peak power, but not base-load coal

How do we get the costs down?

- By R&D on thin films-use lot less material, by a factor of 200
- Automated processing
- Within 5 years, we will be producing at <15 c/kWh, and within 10, <10 c/kWh
- Huge industry-currently $11 billion/year, producing 2 GW/year-likely to be $100 billion/year in 10 years
- Compare-no nukes built in the US in 25 years

Solar Heat: Archimedes burning Roman Fleet in Syracuse harbor: Why not power from heat?

Painting From Galleria Uffizi, Florence

Solar Thermal-Electric – US leads – about 1GW under construction or operating

World's largest solar-electric plant 64 MW (in Nevada)-solar thermal electric

Each shiny tube is a linear parabolic trough focusing sunlight on a tube-
heat up water to produce steam-run a turbine

Nevada Solar One Plant-inside of parabolic reflector being constructed

Tubing to Carry steam

Mirrors will be mounted on the truss

Conclusions

- Increasing energy utilization and production efficiency is not only feasible but imperative, and economical
- We need to educate our politicians- they are total idiots
- Sun and wind are both feasible, and can provide ALL of our energy needs
- A solar- fuel cycle is a critical R&D need
- Synthetic biology is another critical R&D need
- Decreasing cost of solar power is a third critical R&D need-National Academies of Sciences and Engineering called it the most important challenge of the 21st century
- We will discuss all of these