Meeting the energy and climate challenge: A Tale of Two Countries

Tsinghua University

15 July, 2009

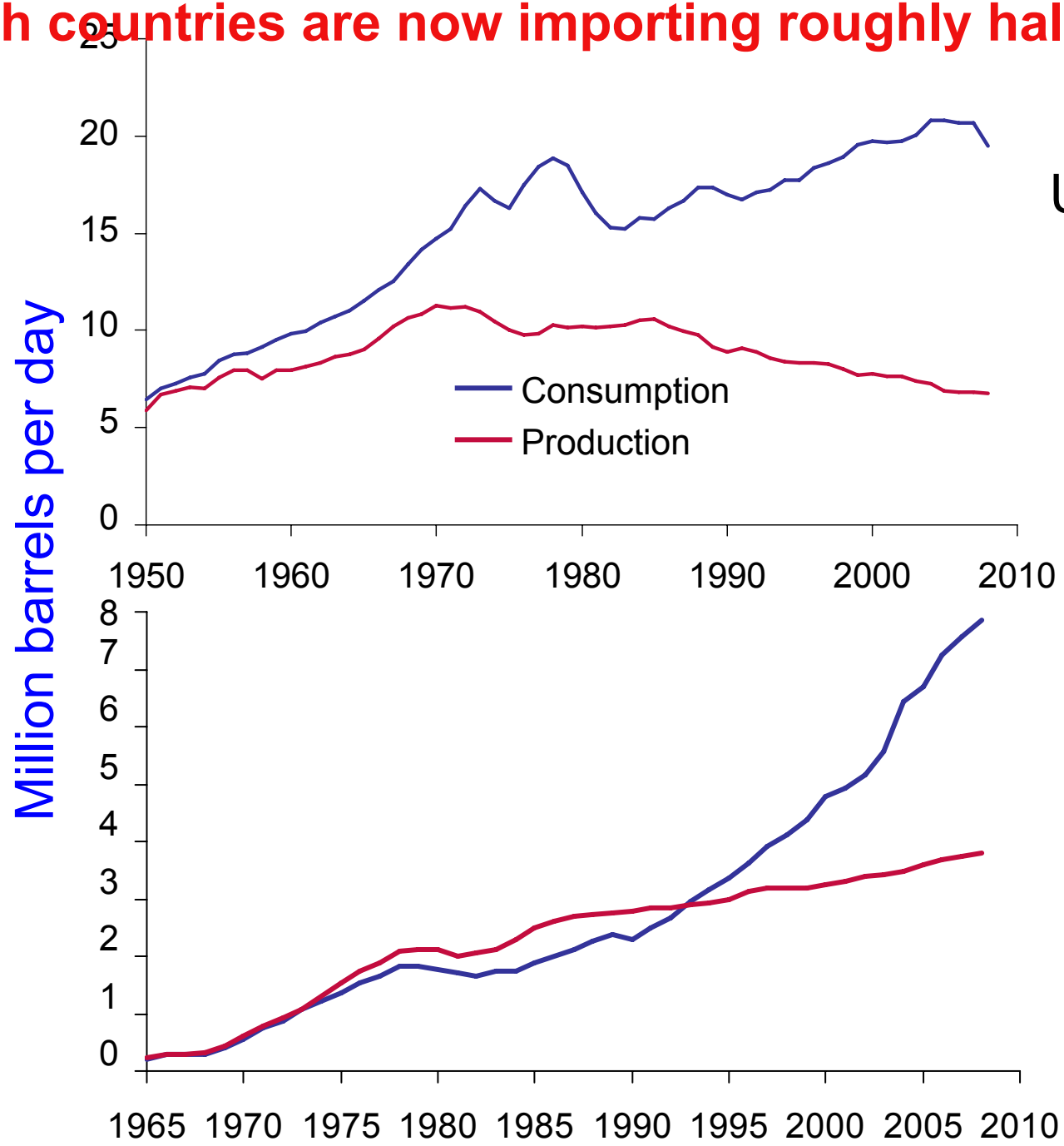
Energy Challenge

(1) There is growing competition and anxiety over access to energy resources.

(2) Our long-term economic prosperity is tied to the sustainable use of energy.

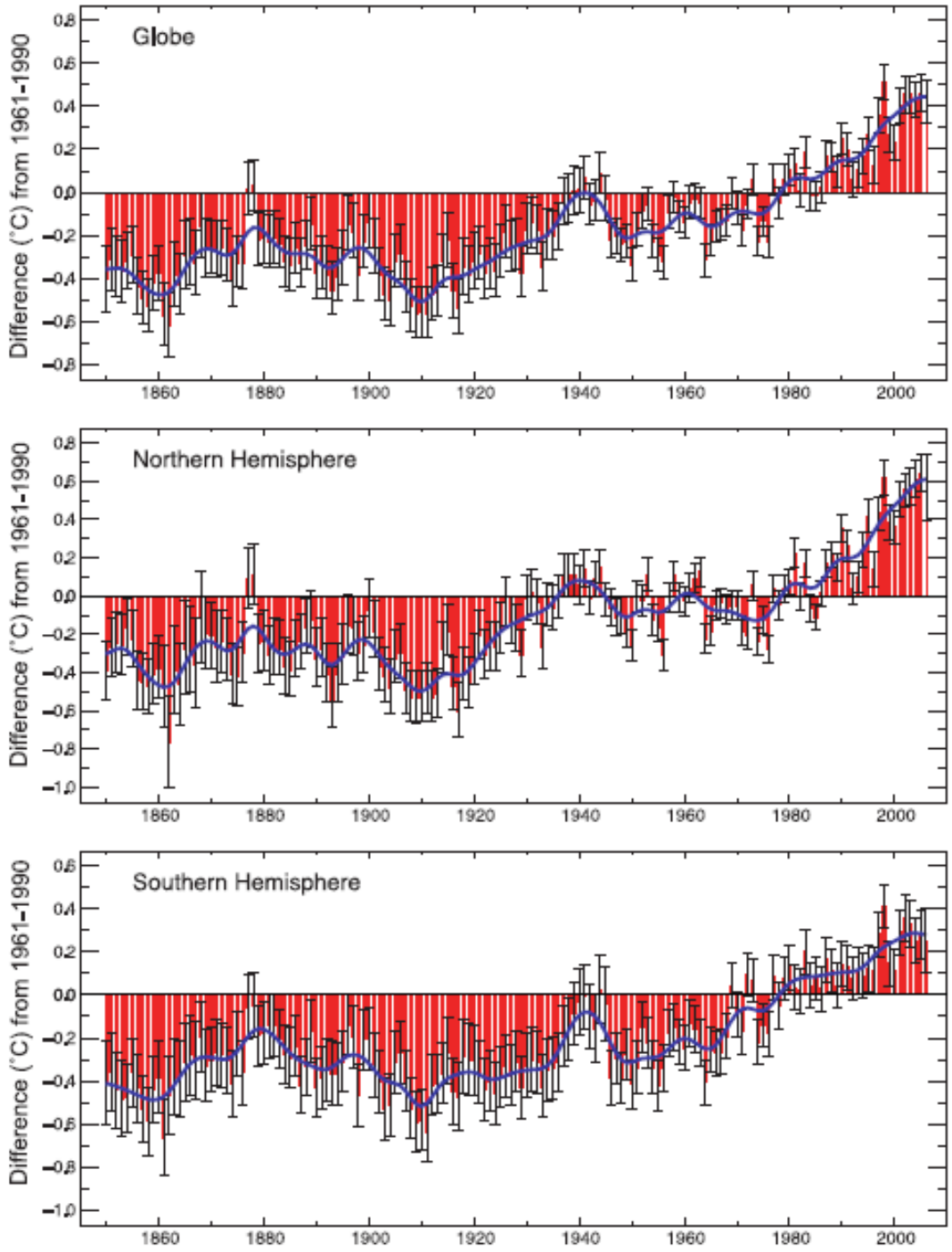
(3) There are risks of adverse climate change for both countries.

Both countries are now importing roughly half of their oil



US became a net oil importer in the 1940s

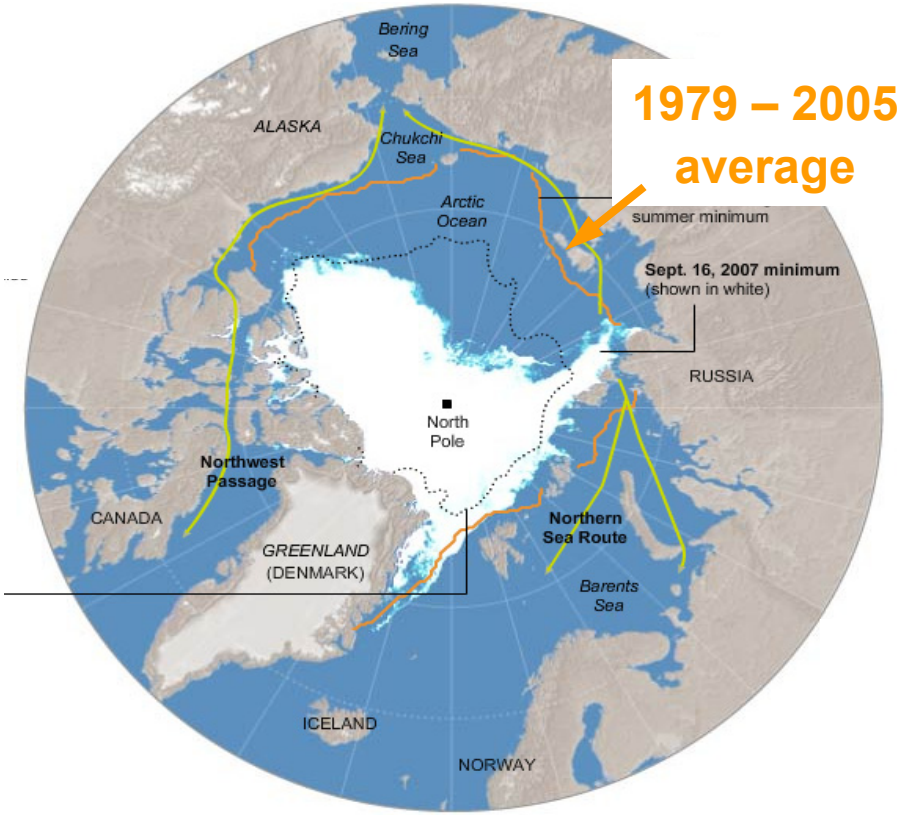
China became a net oil importer in the 1990s



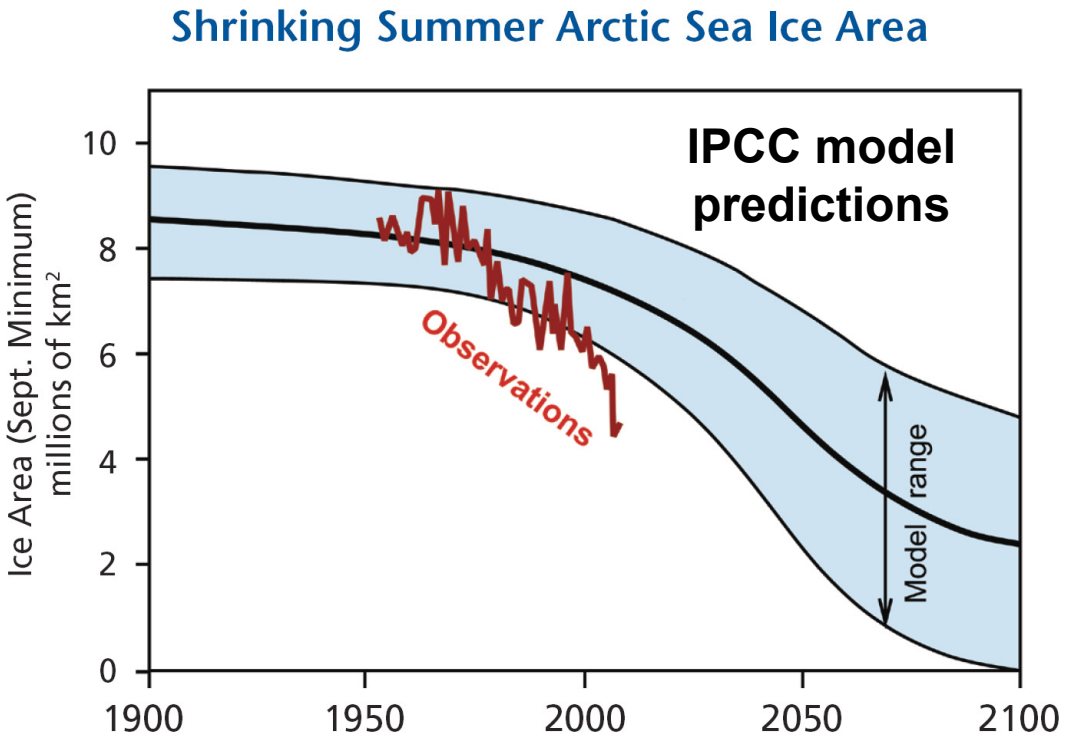
Temperature Record

1850 – 2006

IPCC 4th climate assessment (2007)

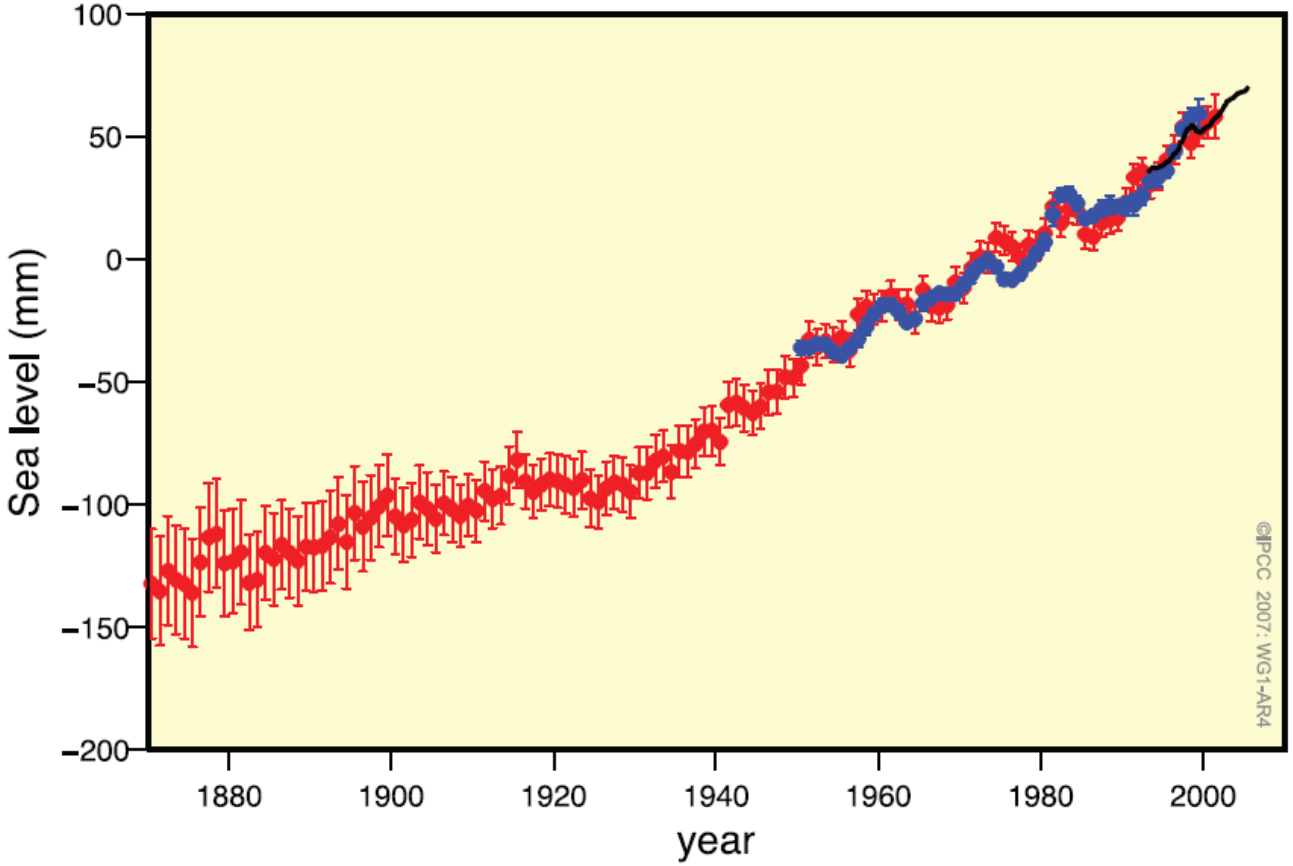


The Polar Ice Cap is melting much faster than predicted



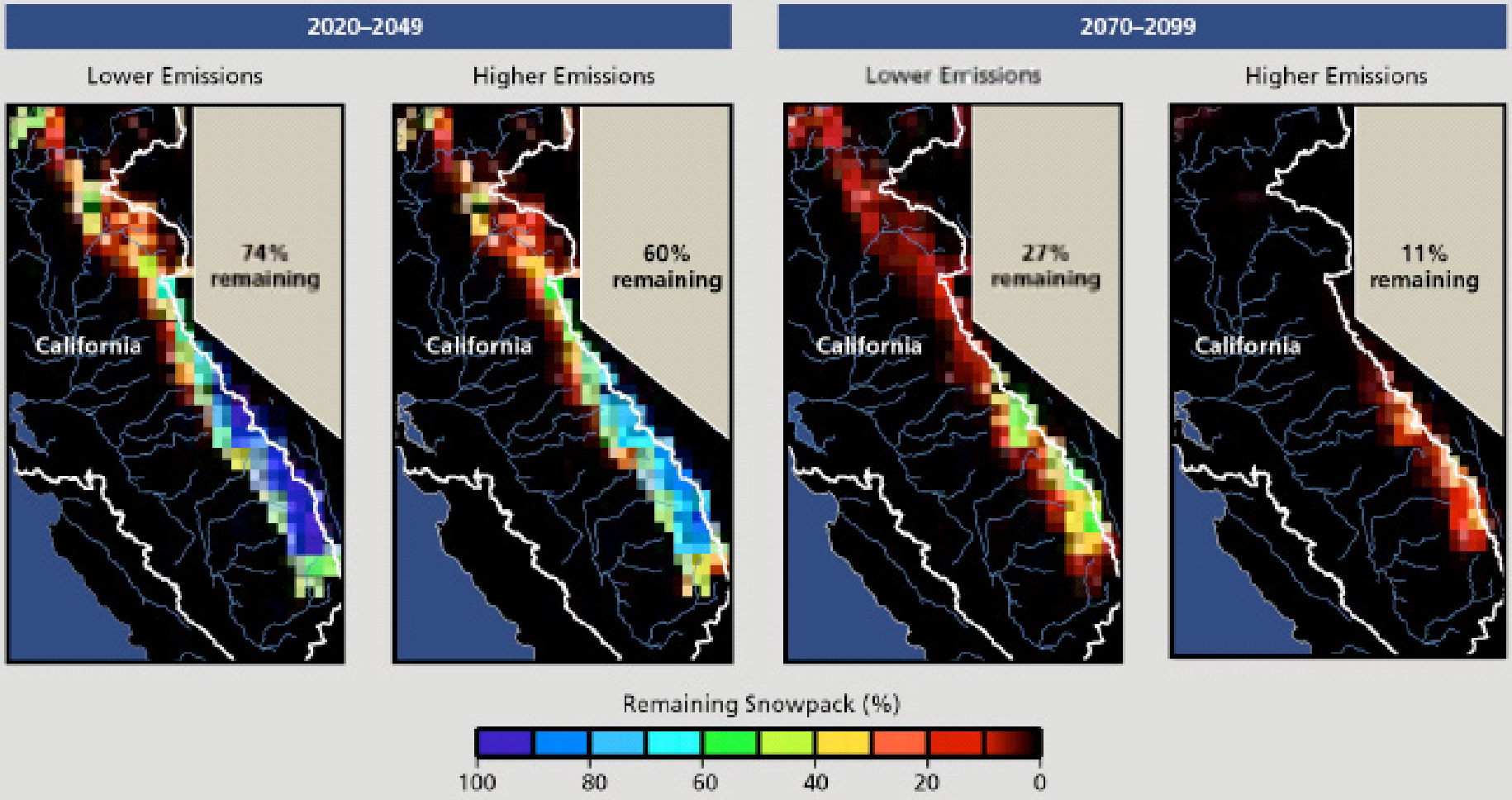
Source: Stroeve et al. 2007 and updated by Dirk Notz Hamburg

Global Sea Level: 2007 IPCC Technical Summary

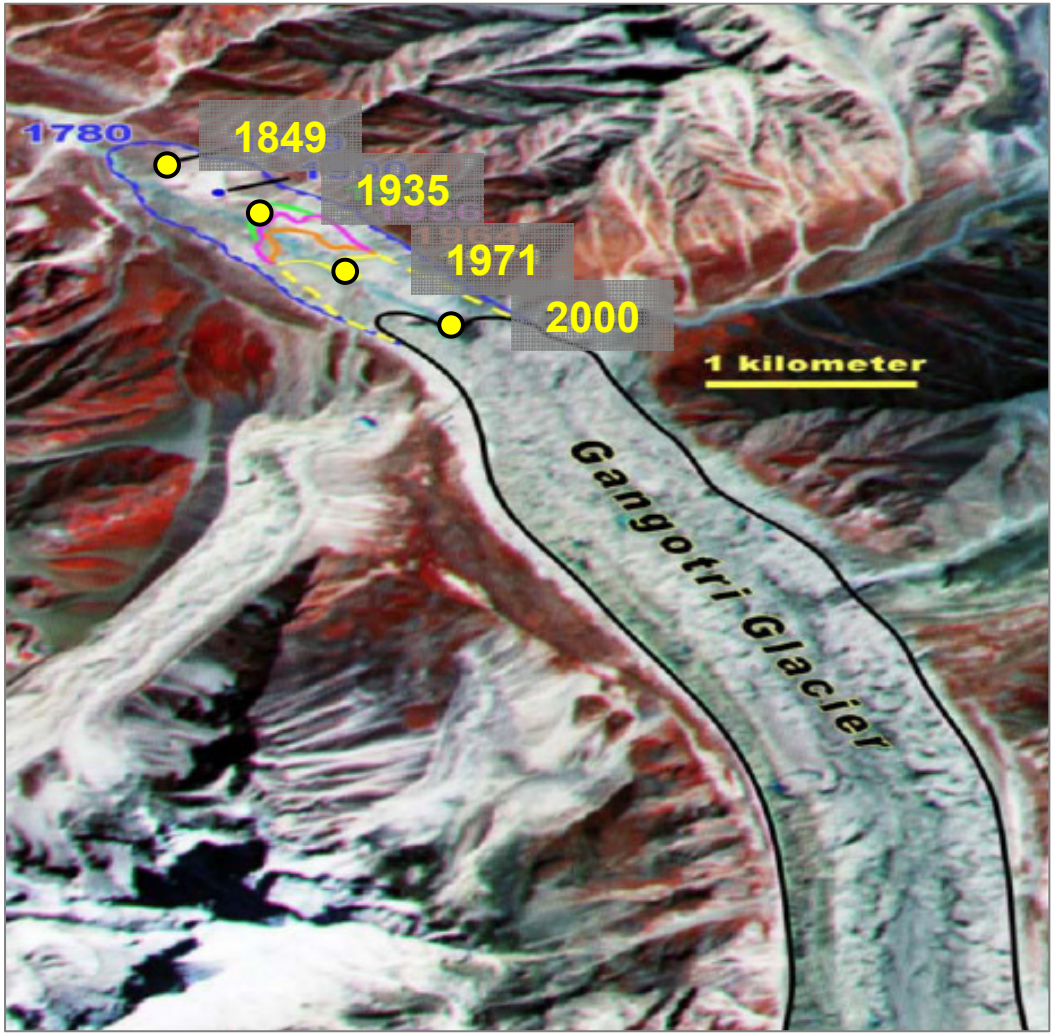


Past 2000 years:	0.0 - .02 mm/year
1870 – 1890:	0.6 mm/year
1990 – 2008:	3.0mm/year (including recent satellite data)

Projections of Sierra snow-pack and implications for water



China's glaciers are receding rapidly



Gangotri Glacier, Himalayas near China

In the past 50 years the glaciers in northwest China have shrunk by 21%, and are receding at a rate of 10-15 meters per year.

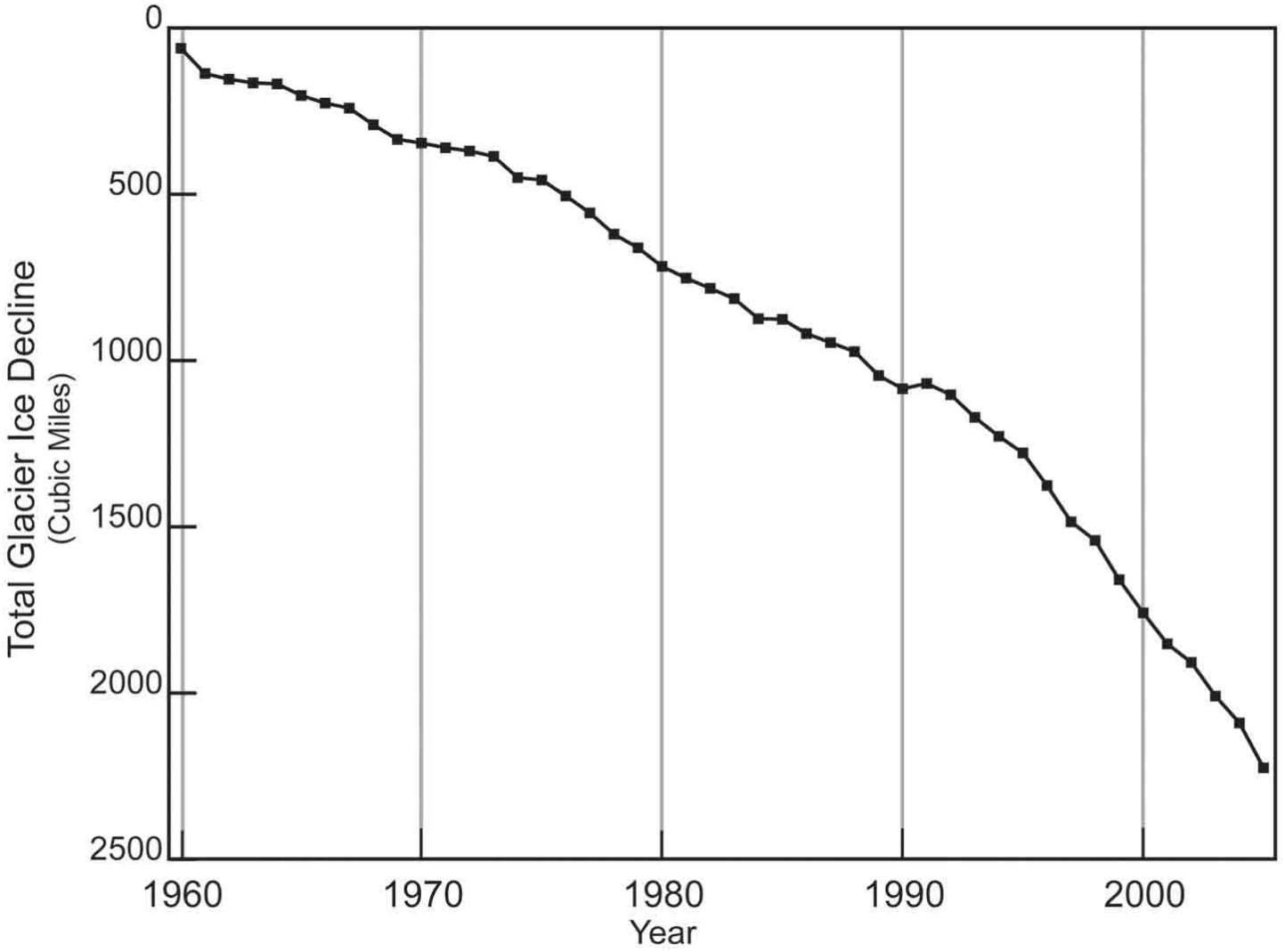
By 2050 China's western glaciers are projected to decrease by 27%.

Meltwater from glaciers supplies the majority of freshwater in Asia

China's National Assessment Report on Climate Change (II): Climate change impacts and adaptation. 2007

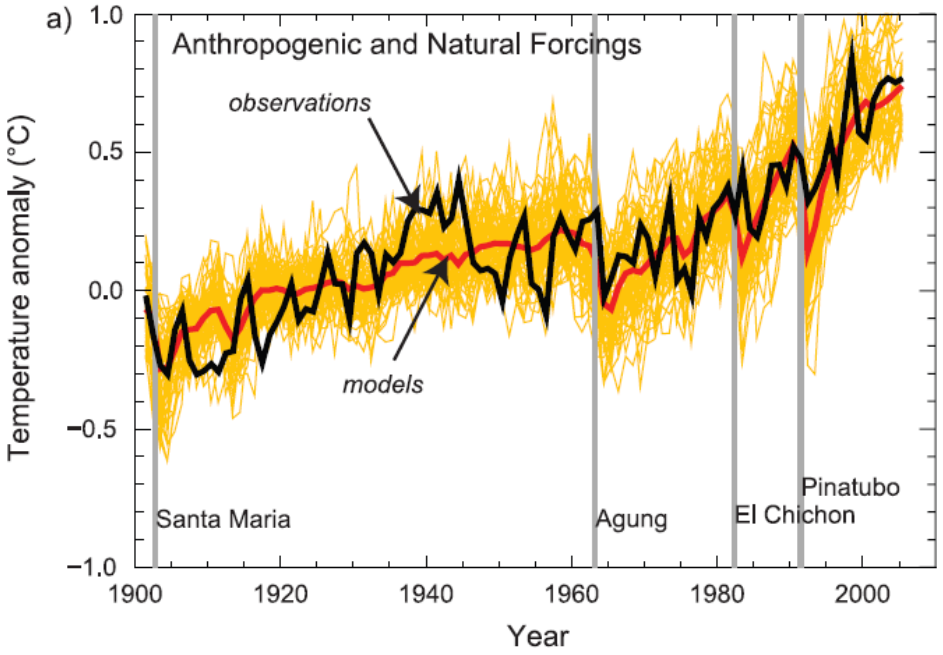
Cumulative Glacier Ice Melt

In 45 years, we have lost over 9,000 cubic km of ice.

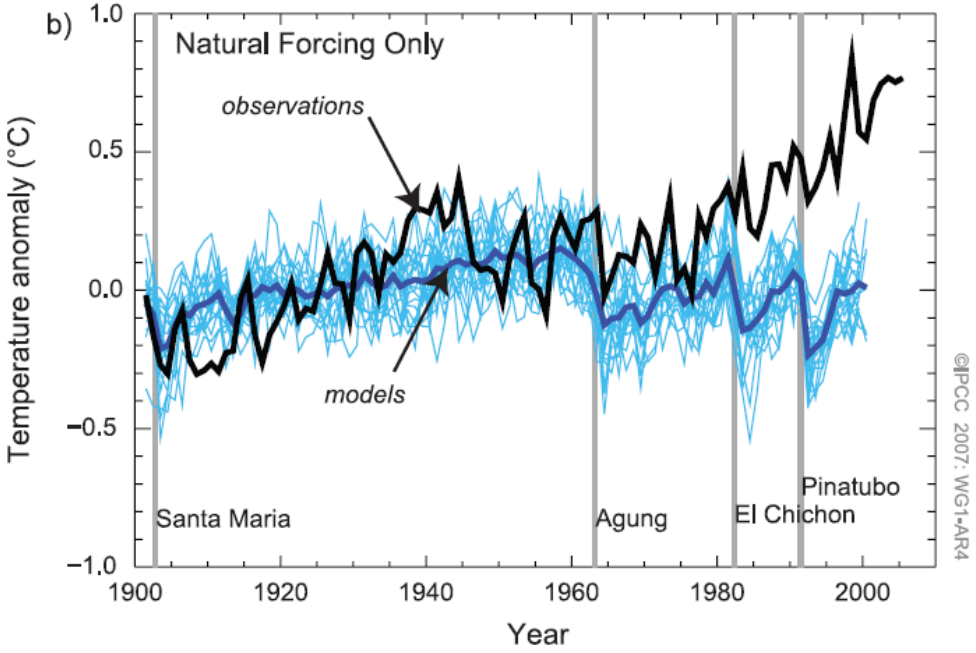


Meier *et al.*[27]

2007 IPCC Technical Summary

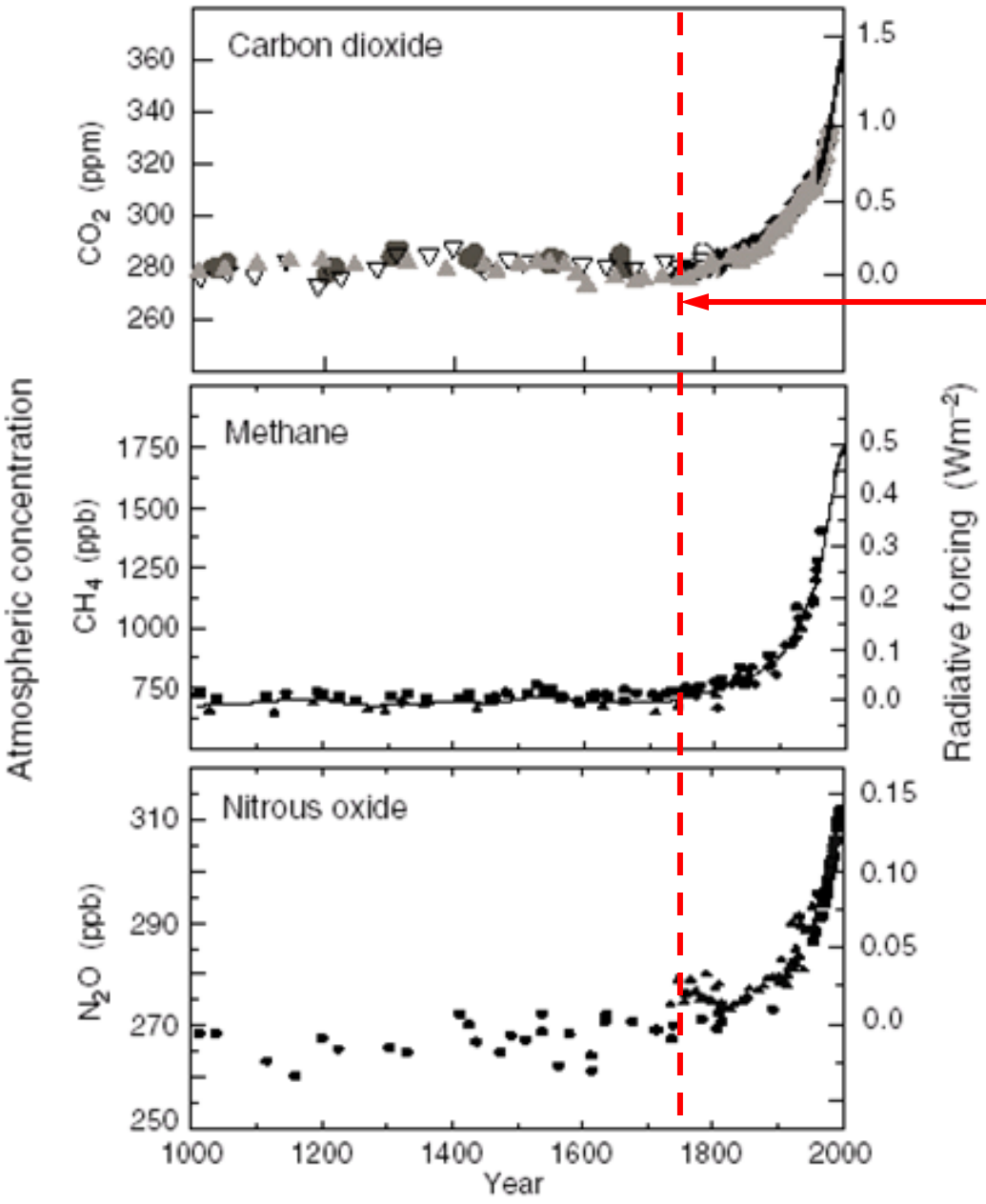


Atmospheric model **(red)** with natural variations and human greenhouse gas and observations **(black)**



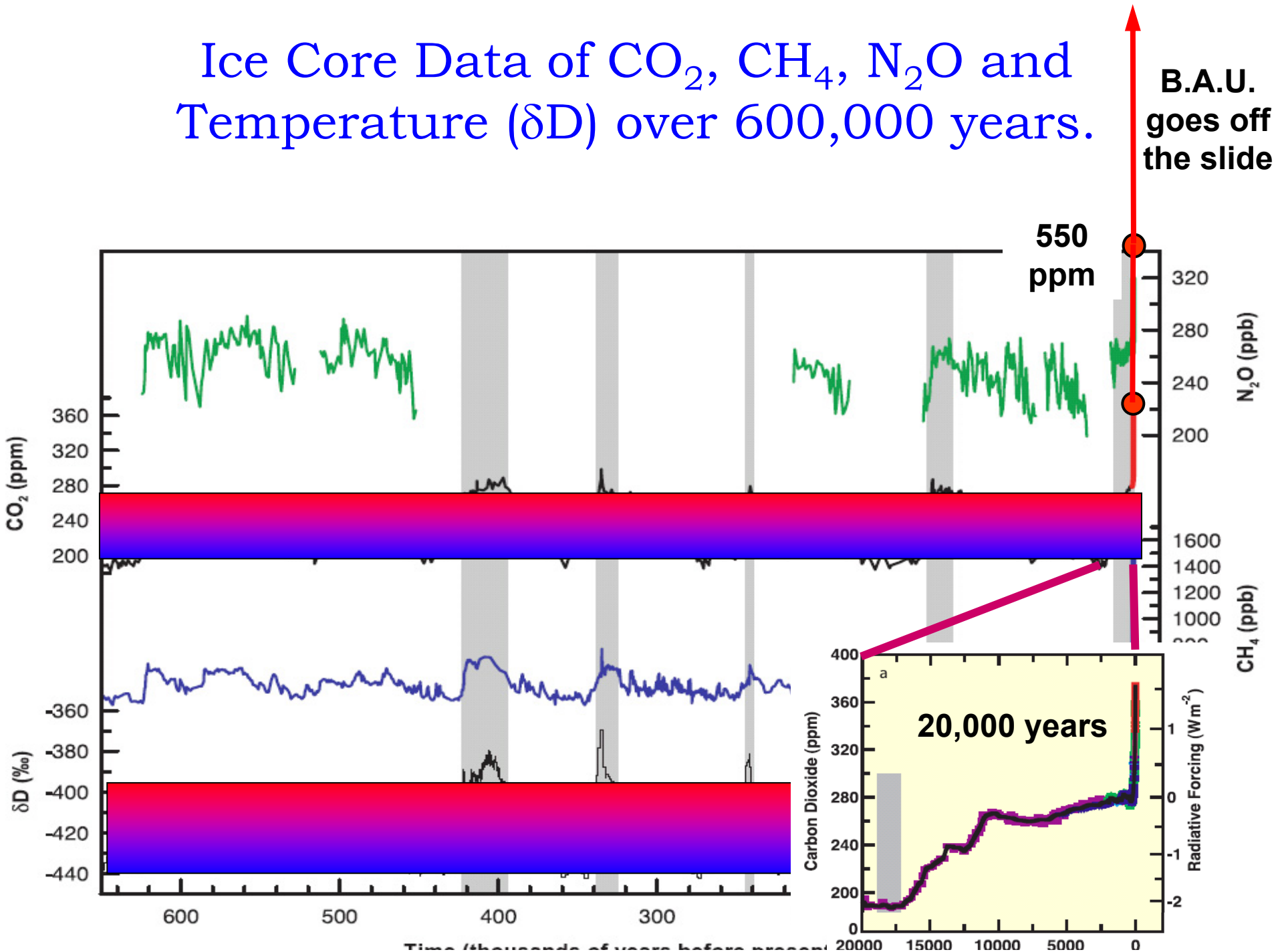
Atmospheric model **(blue)** with only natural variations and observations **(black)**

The change is caused by emission of greenhouse gases

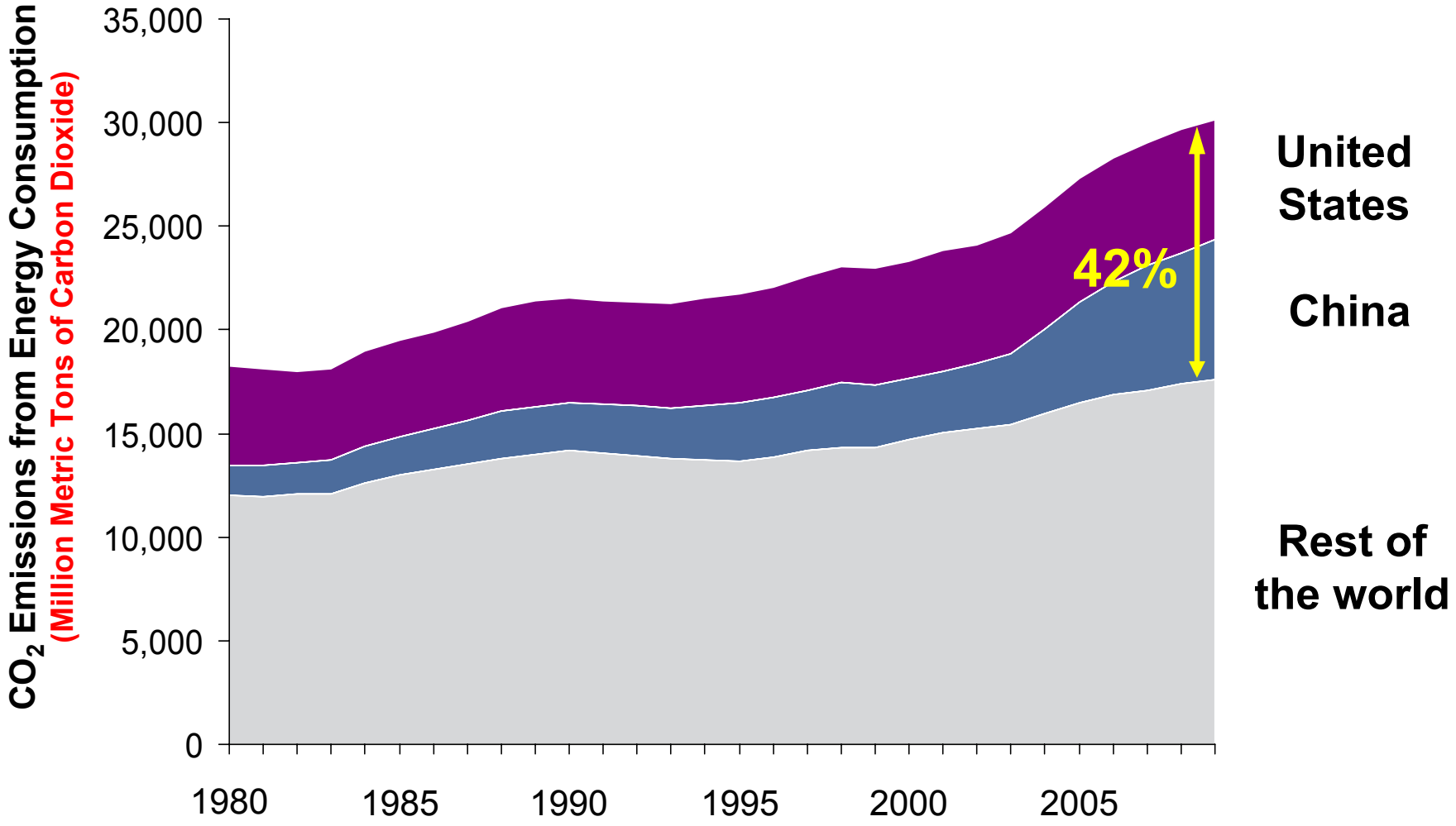


1750, the beginning of the industrial revolution

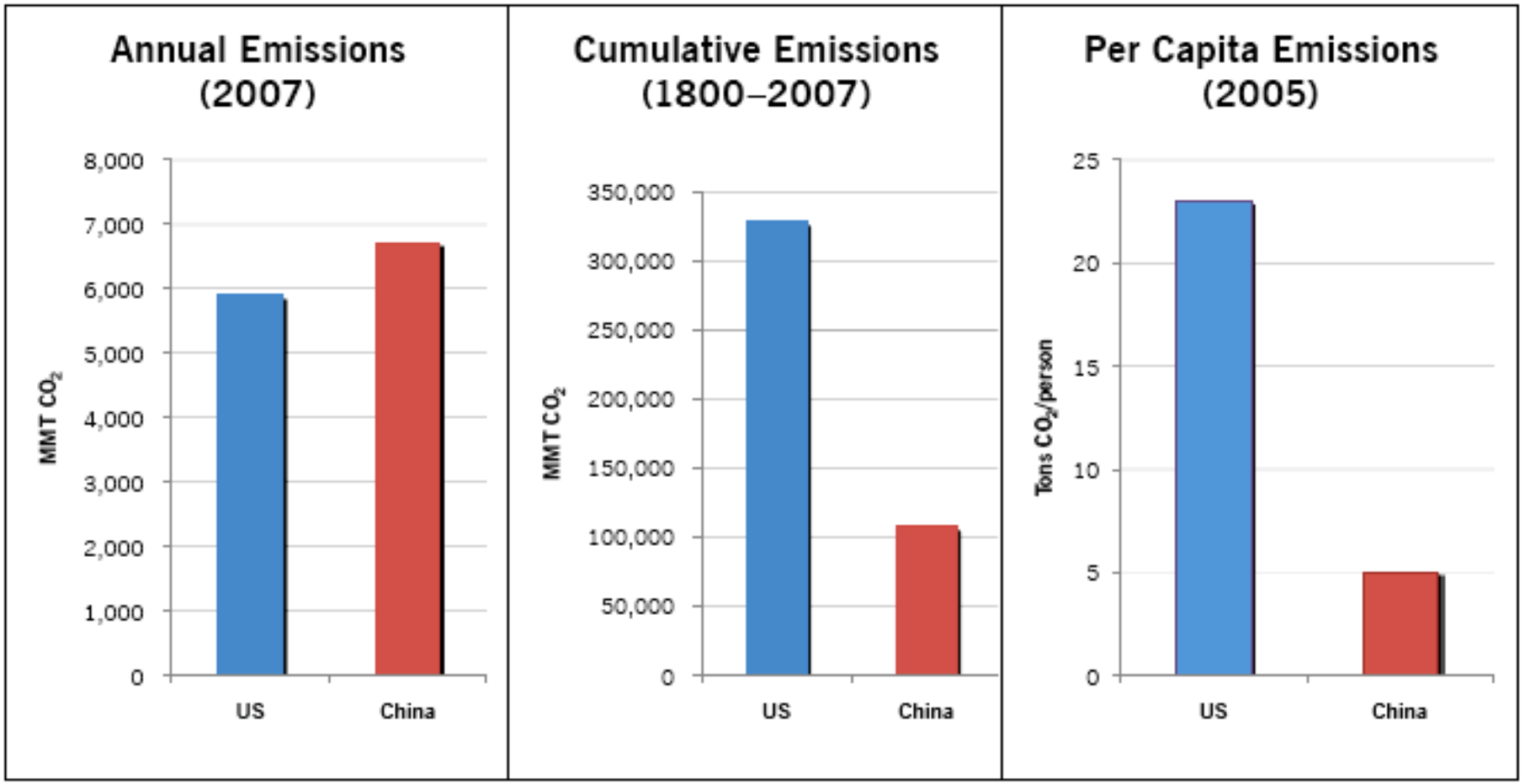
Ice Core Data of CO_2, CH_4, N_2O and Temperature (δD) over 600,000 years.



U.S. and China CO_2 Emissions: 42% of World Total



Comparison of U.S. and China Energy-Related Emissions – Three Perspectives

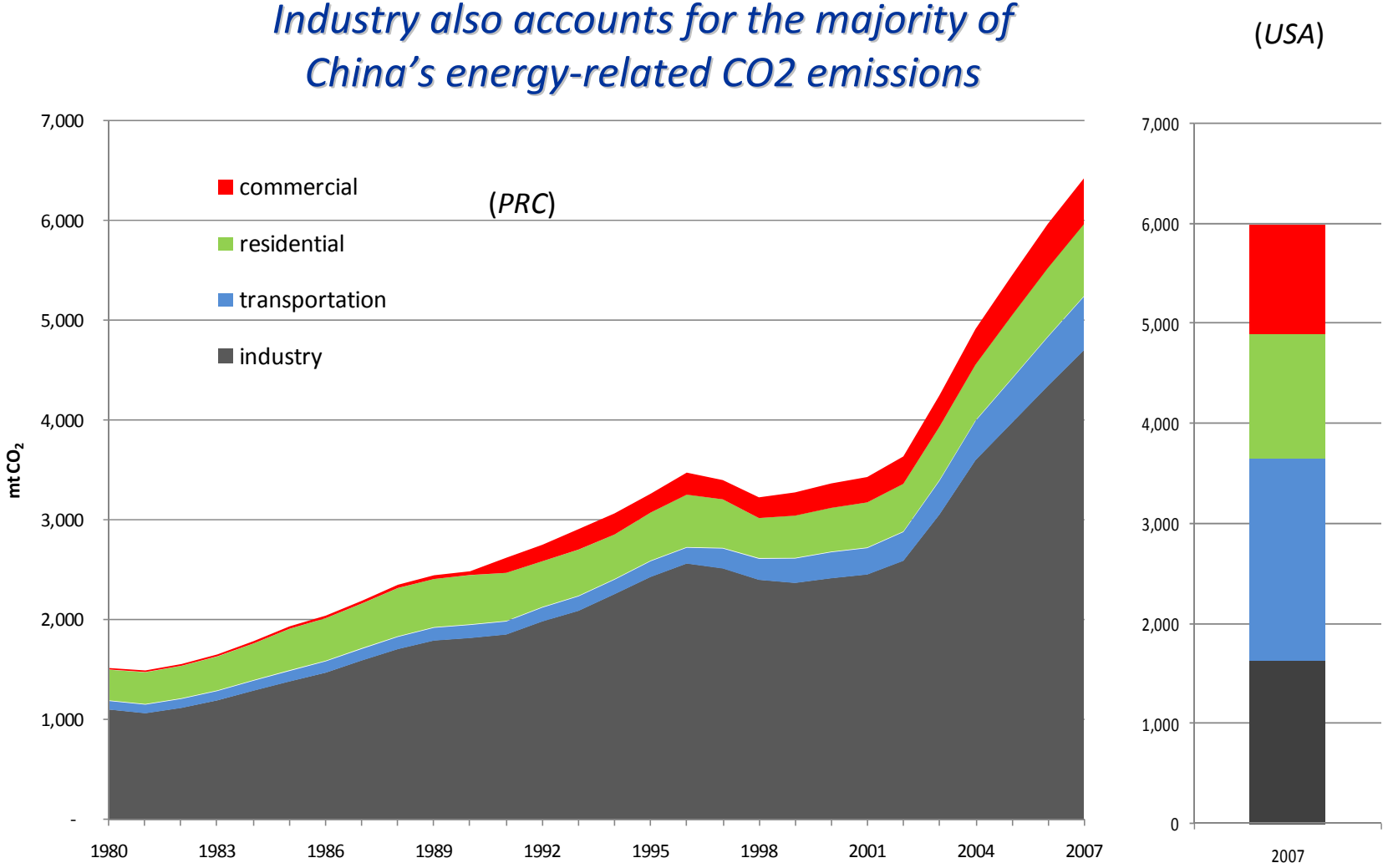


Source: Asia Society, 2008. *Common Challenge, Collaborative Response: A Roadmap for U.S.-China Cooperation on Energy and Climate Change*. http://www.asiasociety.org/taskforces/climateroadmap/US_China_Roadmap_on_Climate_Change.pdf

[25] Data sources: "CO_2 Emissions From Fossil Fuels," Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center (CDIAC), 2007; The Netherlands Environmental Assessment Agency (MNP), 2007; Statistical Review of World Energy, BP; IEA, 2007; World Bank database (population data), 2007; CDIAC-ORNL, MNP, BP, USGS (cement), IEA, World Bank.

Energy Use in China and the U.S.

Industry also accounts for the majority of China's energy-related CO2 emissions



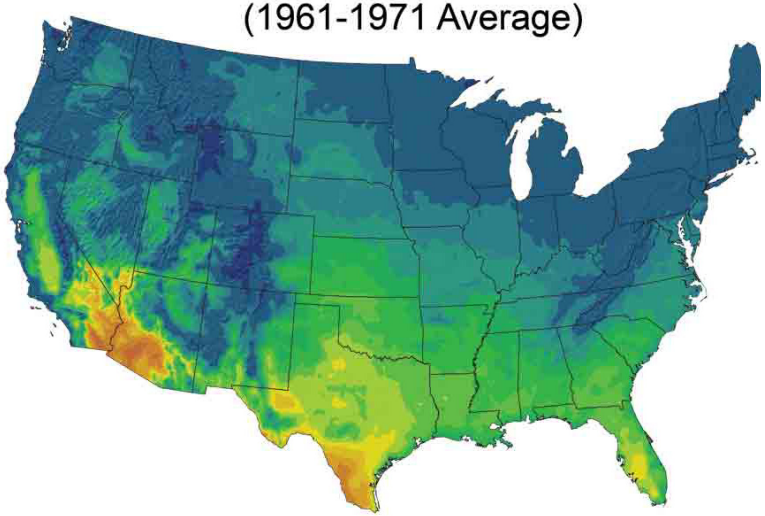
Source: EIA, 2008, Emissions of Greenhouse Gases Report, available at: http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html; China emissions calculated using 1996 revision of IPCC default carbon emission factors; commercial fuels only, not including biomass.

15

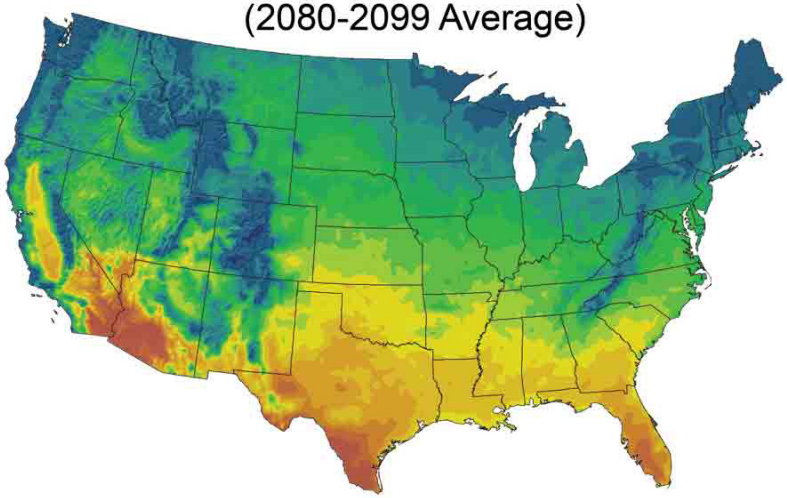
If the world follows a “Business-as-usual” path, what do climate models predict will happen?

Days above 90 degrees F

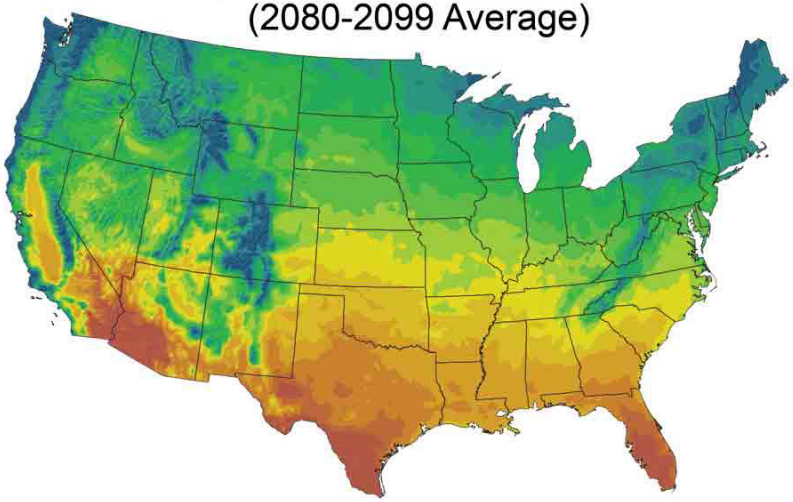
Recent Past
(1961-1971 Average)



Projected End-of-Century under
Lower Emissions Scenario[91]
(2080-2099 Average)



Projected End-of-Century under
Higher Emissions Scenario[91]
(2080-2099 Average)



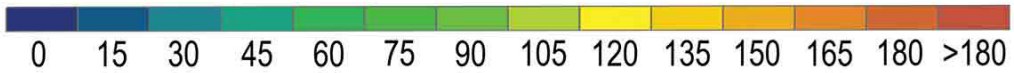
Chicago:

~ 10 days to 75 -90 days greater than 90° F

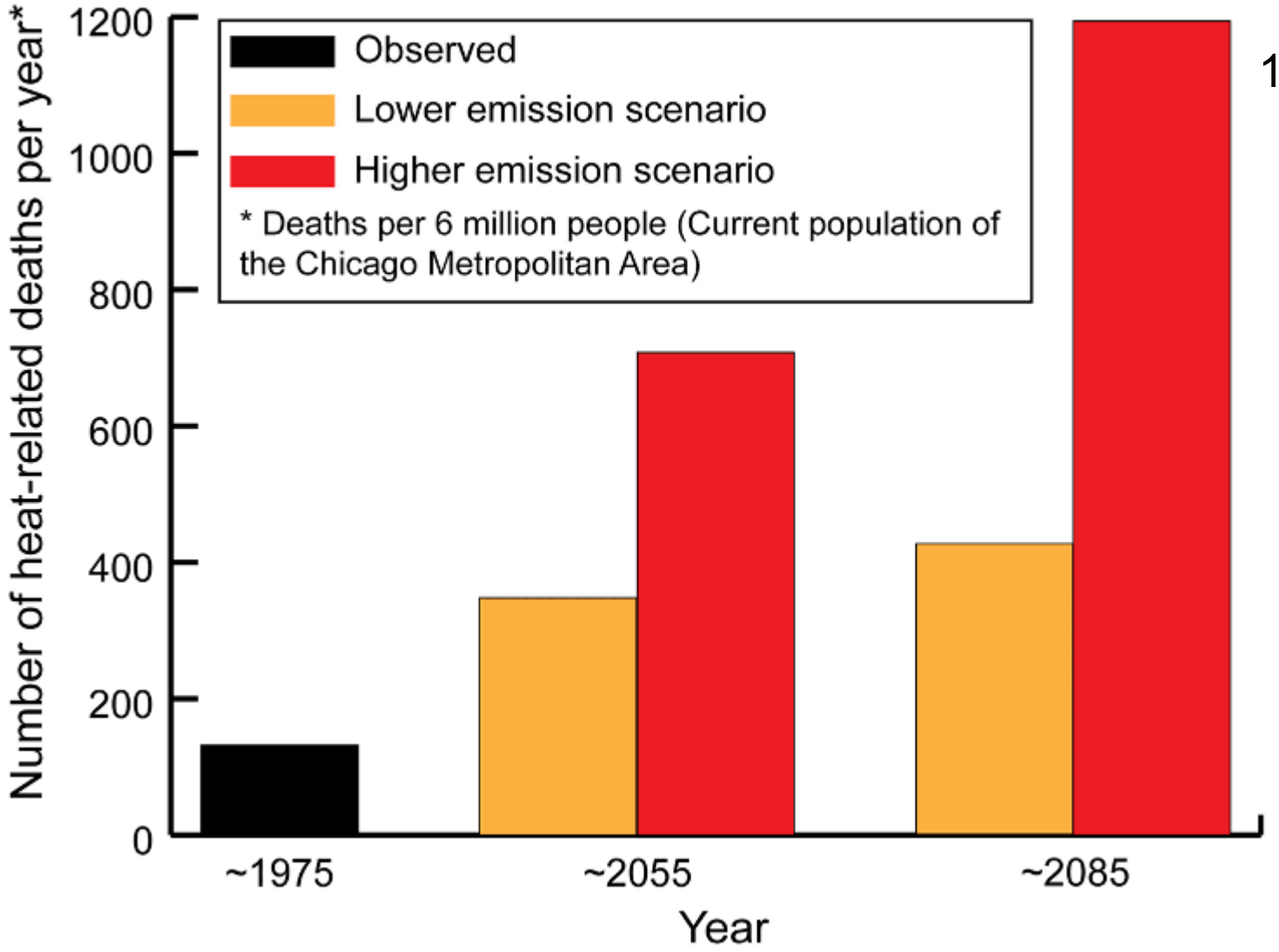
St. Louis:

~ 45 days to ~ 120 days (1/3 of the year)

Number of Days per Year

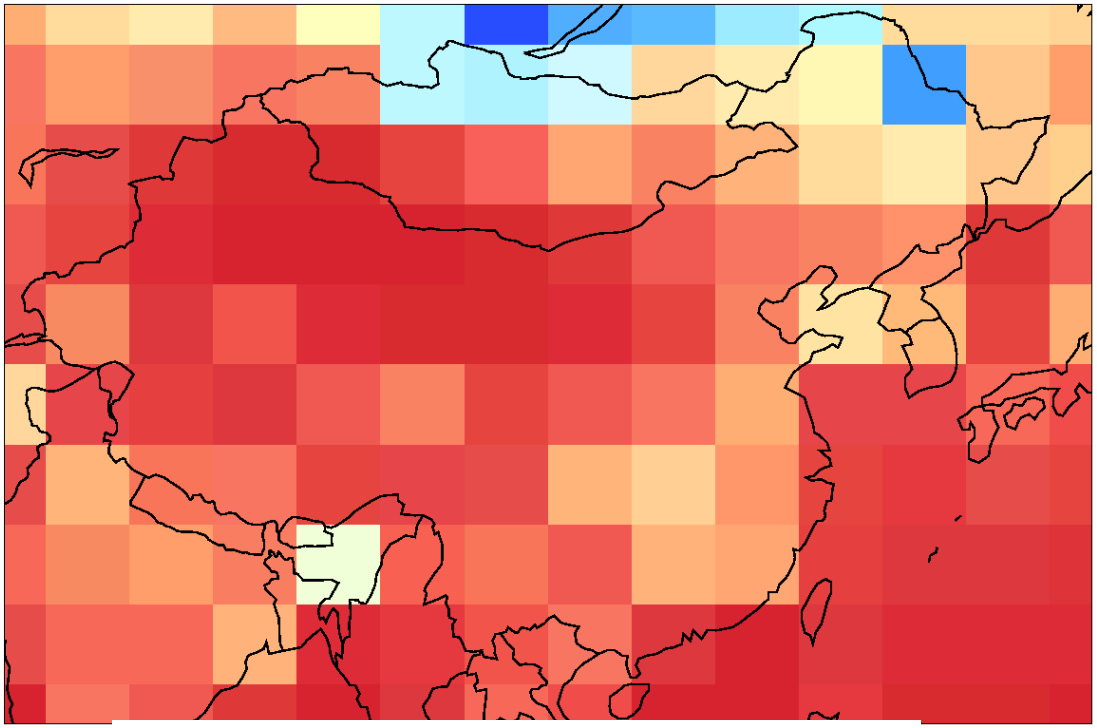


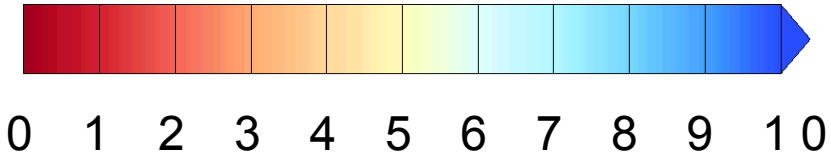
Projected Increase in Heat-Related Deaths in Chicago



10x increase in heat - related deaths

Extreme heat waves will become common in China

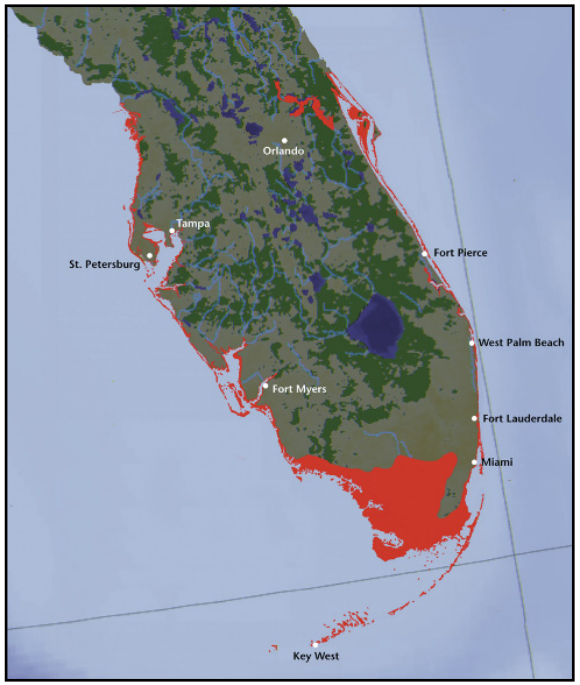




Number of years between extreme heat waves by 2100 under business-as-usual scenario

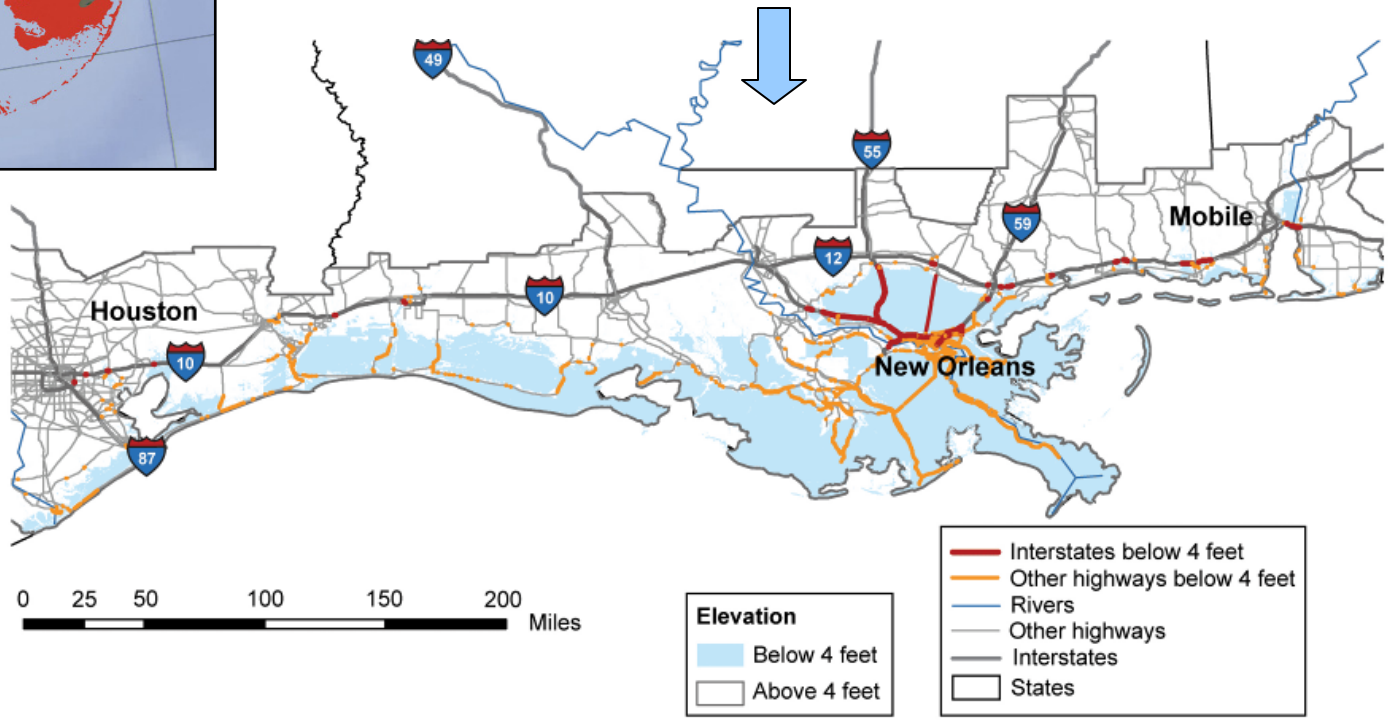
Extreme heat waves that currently happen every 20 years would occur every other year in much of China

U.S. coastal areas at risk from sea-level rise

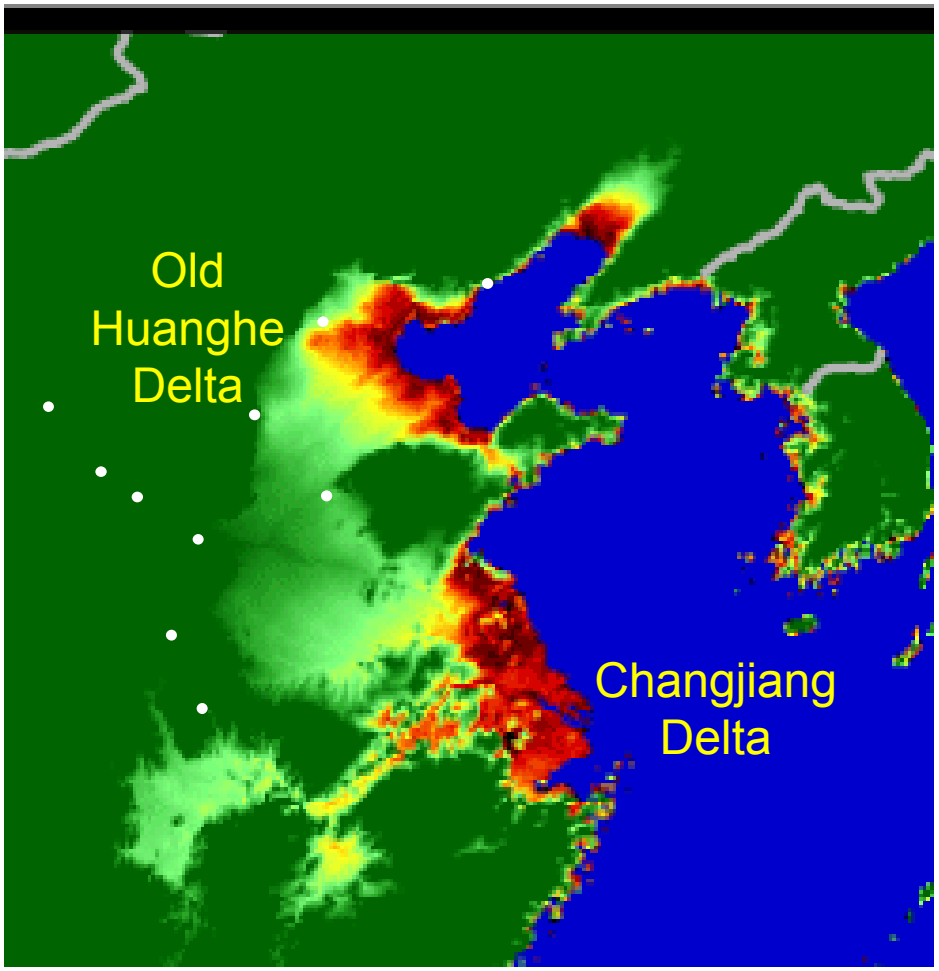


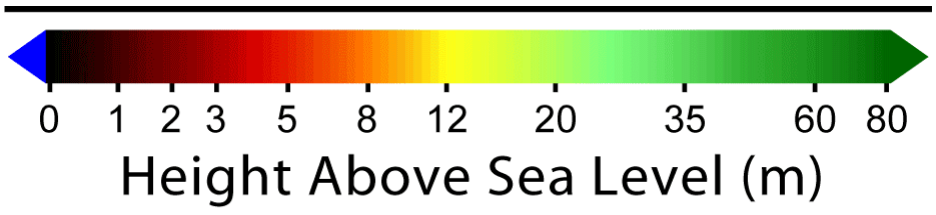
Areas in red would be under water with a 1 meter rise in sea level, projected for this century

Areas in blue below 4 feet



China at Risk of Sea Level Rise

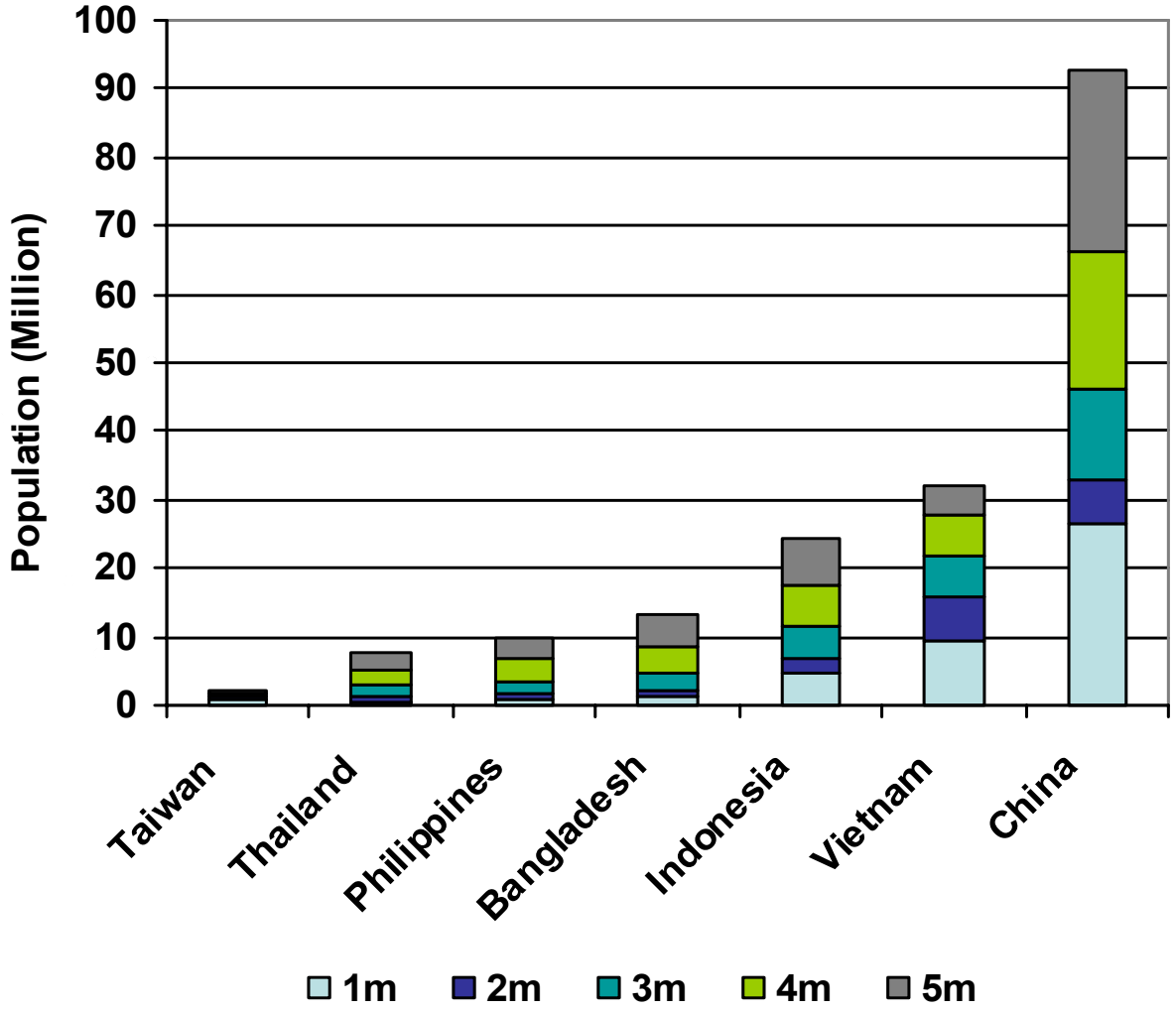




IPCC: “In China, a 30 cm sea-level rise would inundate 81,348 km^2 of coastal lowland”

Rising sea levels increase risk of flooding, storm surges, and coastal erosion

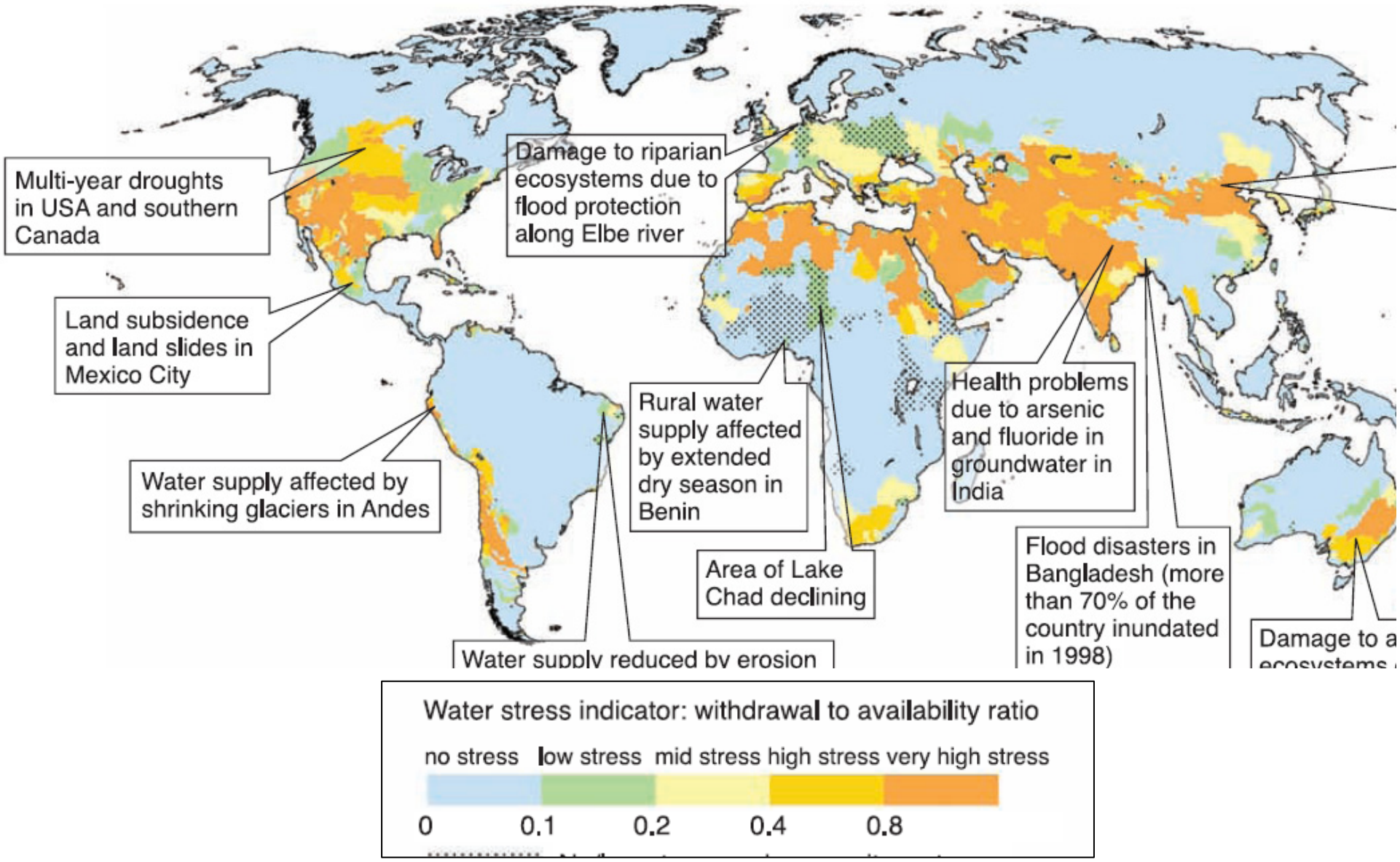
With densely-populated coastal cities, China is particularly vulnerable to sea level rise



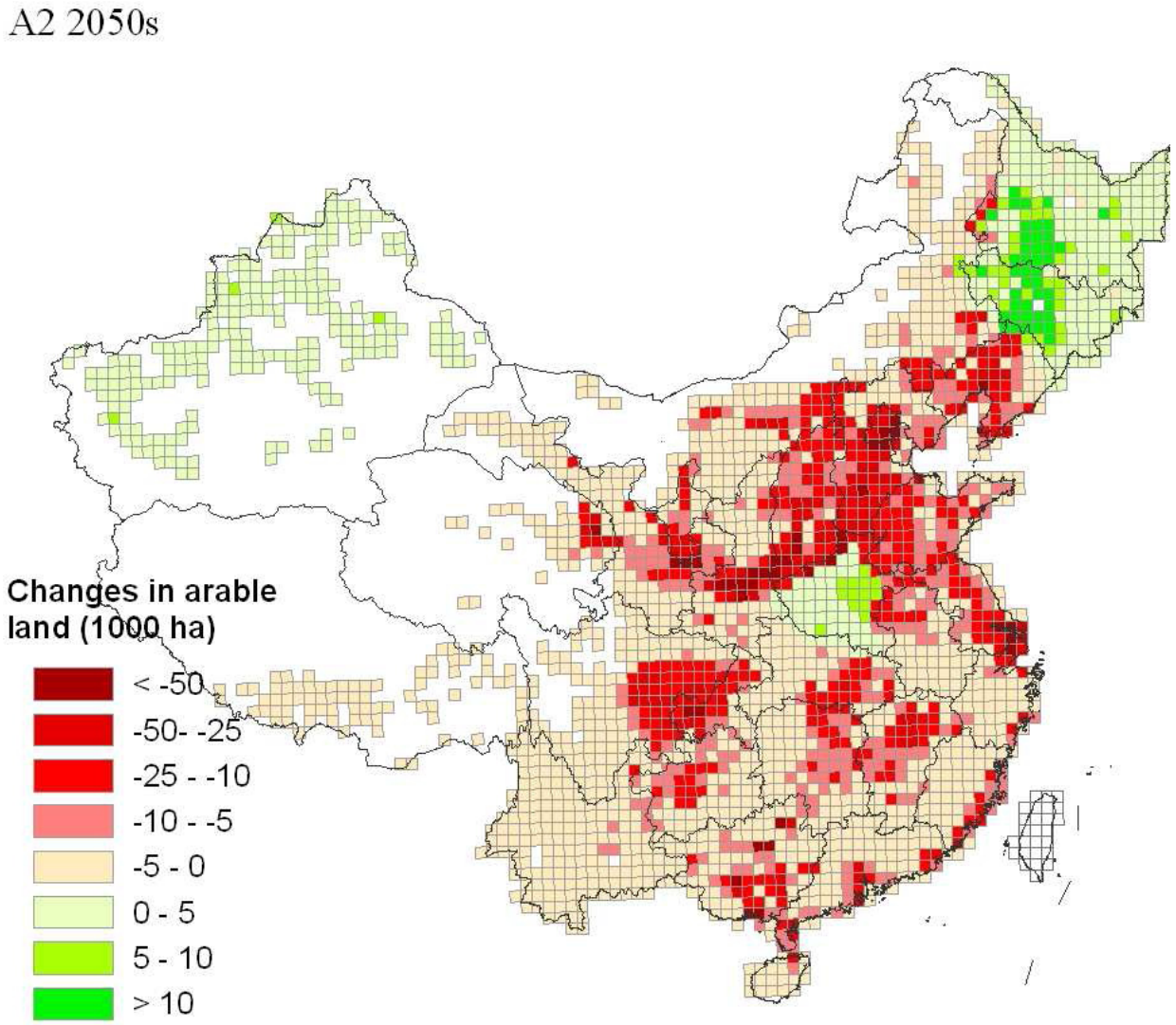
Population Impacted by Sea Level Rise (1m – 5m)

Source: Working Group II, IPCC 4th Assessment Report; UN Human Development Report 07/08; "Heating up the planet', Lowy Institute; World Bank" The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis"

Predicted water stress areas around the world



Changes in arable land in 2050 in A2 emissions scenario



By 2030, crop productivity in China could decrease by 5 – 10%.

By 2050 – 2100, rice, maize, and wheat yields could decline by 37%

Sources: “The Impacts of Climate Change on Chinese Agriculture - Phase II”; funded by the UK Government, in partnership with China's Ministry of Science and Technology; October 2008; and China’s National Assessment Report on Climate Change

The permafrost is beginning to thaw

Zimov et al., 2006. Science. 312:1612-1613

Science has unambiguously shown that we are altering the destiny of our planet.

The consequences of what we are doing today will not be fully realized for at least a hundred years.

What will be our legacy to our children and grandchildren?

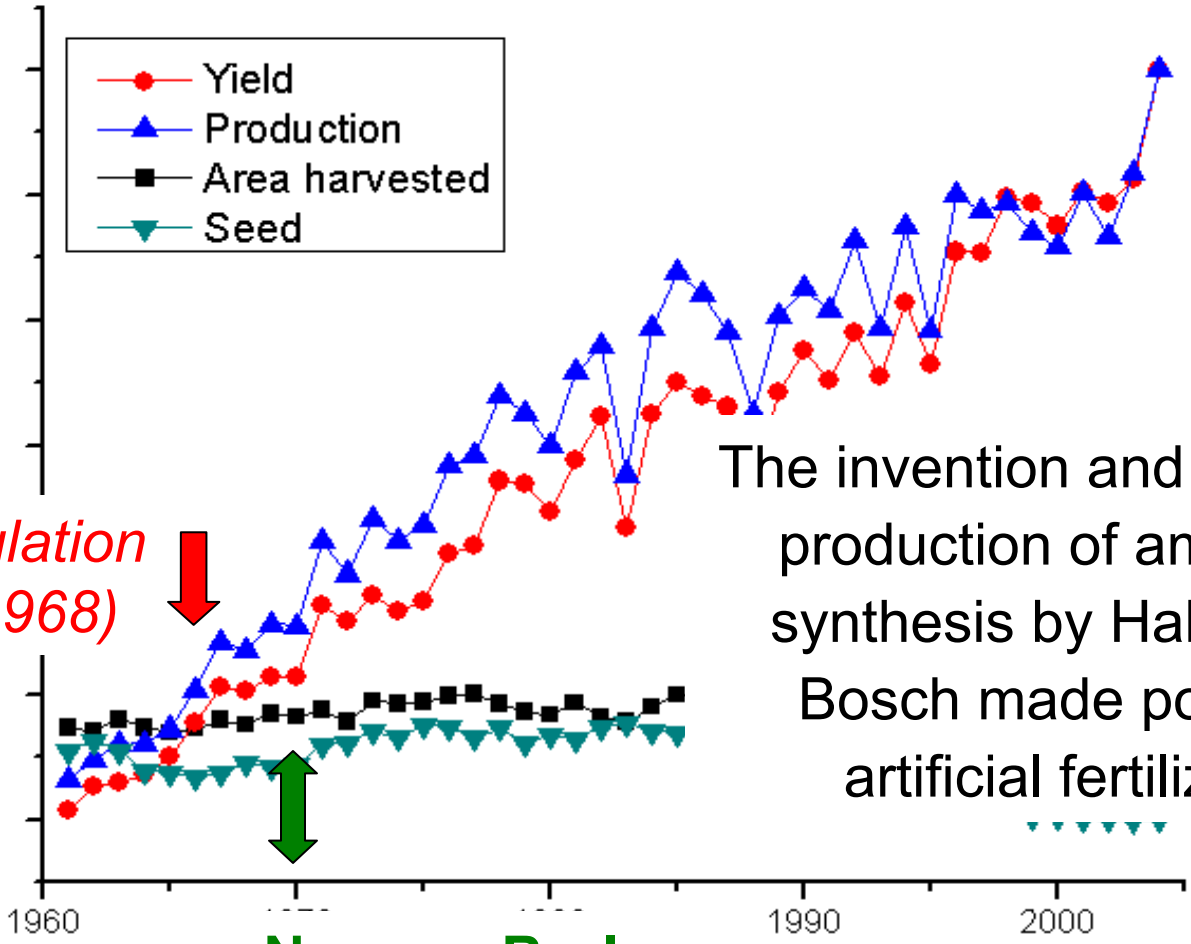
Denial will not change our destiny.

Our message is not one of doom and gloom, but of optimism and opportunity.

Science and Technology has given us solutions in the past.

With the right government policies, it will come to our aid in the future.

World Production of Grain (1961 – 2004)



The Population Bomb (1968)

The invention and industrial production of ammonia synthesis by Haber and Bosch made possible artificial fertilizers.

1960: Population = 3 B

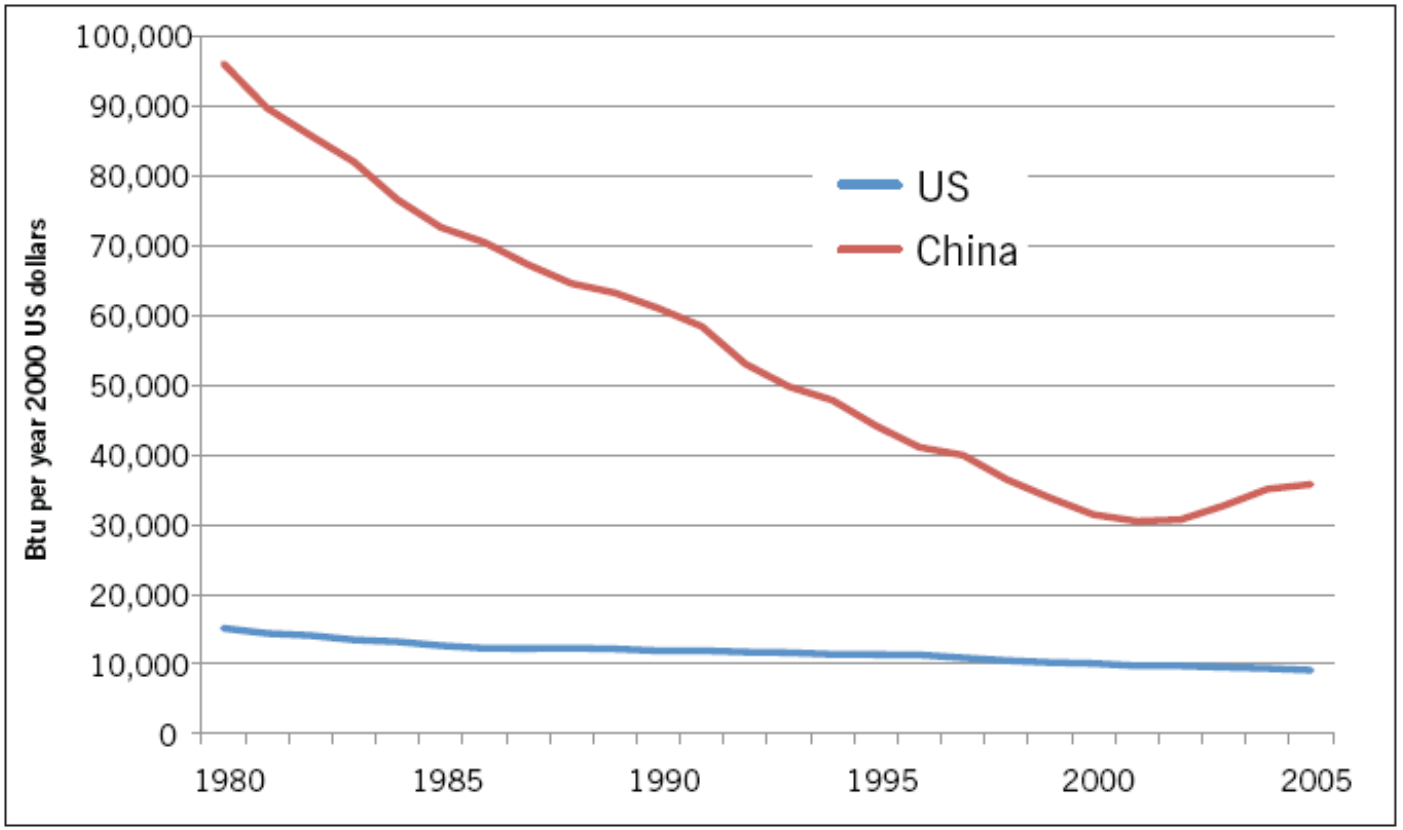
Norman Borlaug awarded Nobel Prize

2005: Population = 6.5 B

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

China's Energy Intensity Compared to the U.S.

Comparison is based on current market exchange rates and thus not reflective of physical energy intensities



Source: Asia Society, 2008. *Common Challenge, Collaborative Response: A Roadmap for U.S.-China Cooperation on Energy and Climate Change*. http://www.asiasociety.org/taskforces/climateroadmap/US_China_Roadmap_on_Climate_Change.pdf

Data source: "International Energy Outlook, 2007," Energy Information Administration, U.S. Department of Energy.

In 2005, China Adopted an Energy Intensity Reduction Target

- November 2005: Premier Wen Jiabao at the Plenary of the Communist Party: "Energy use per unit of GDP must be reduced by 20% from 2006 to 2010"
- March 2006: Statement reiterated by the National Peoples Congress
- China's 11th Five Year Plan (2006-2010): outlined goal of reducing energy consumption per unit of GDP by 20% between 2006 and 2010
- Depending upon the GDP growth rate - 2010 energy
  - 5-year savings of about 700 Mtce (19.5 Quads)

Key Energy-Efficiency Policies and Programs

Energy Policies	Date Effective
Fuel Consumption Limits For Passenger Cars	2004
Medium and Long-Term Plan for Energy Conservation	2005
Renewable Energy Law	2005
Government Procurement Program	2005
National Energy Efficient Design Standard for Public Buildings	2005
Eleventh Five-Year Plan	2006
The State Council Decision on Strengthening Energy Conservation	2006
Revised Consumption Tax for Larger, Energy-Inefficient Vehicles	2006
Reduced Export Tax Rebates for Many Low-Value-Added But High Energy-Consuming Products	2006
Top-1000 Energy-Consuming Enterprise Program	2006
"Green Purchasing" Program	2006
Revision of Energy Conservation Law	2007
Allocation of Funding on Energy Efficiency and Pollution Abatement	2007
China Energy Technology Policy Outline 2006	2007
Government Procurement Program	2007
National Phase III Vehicle Emission Standards	2007
Interim Administrative Method for Incentive Funds for Heating and Metering and Energy Efficiency Retrofit for Existing Residential Buildings in China's Northern Heating Area	2007
Law on Corporate Income Tax (preferential tax treatment for investment in energy-saving and environmentally-friendly projects and equipment)	2008
Allocation of Funding on Energy Efficiency and Pollution Abatement	2008
Appliance Standards and Labeling	Various Years

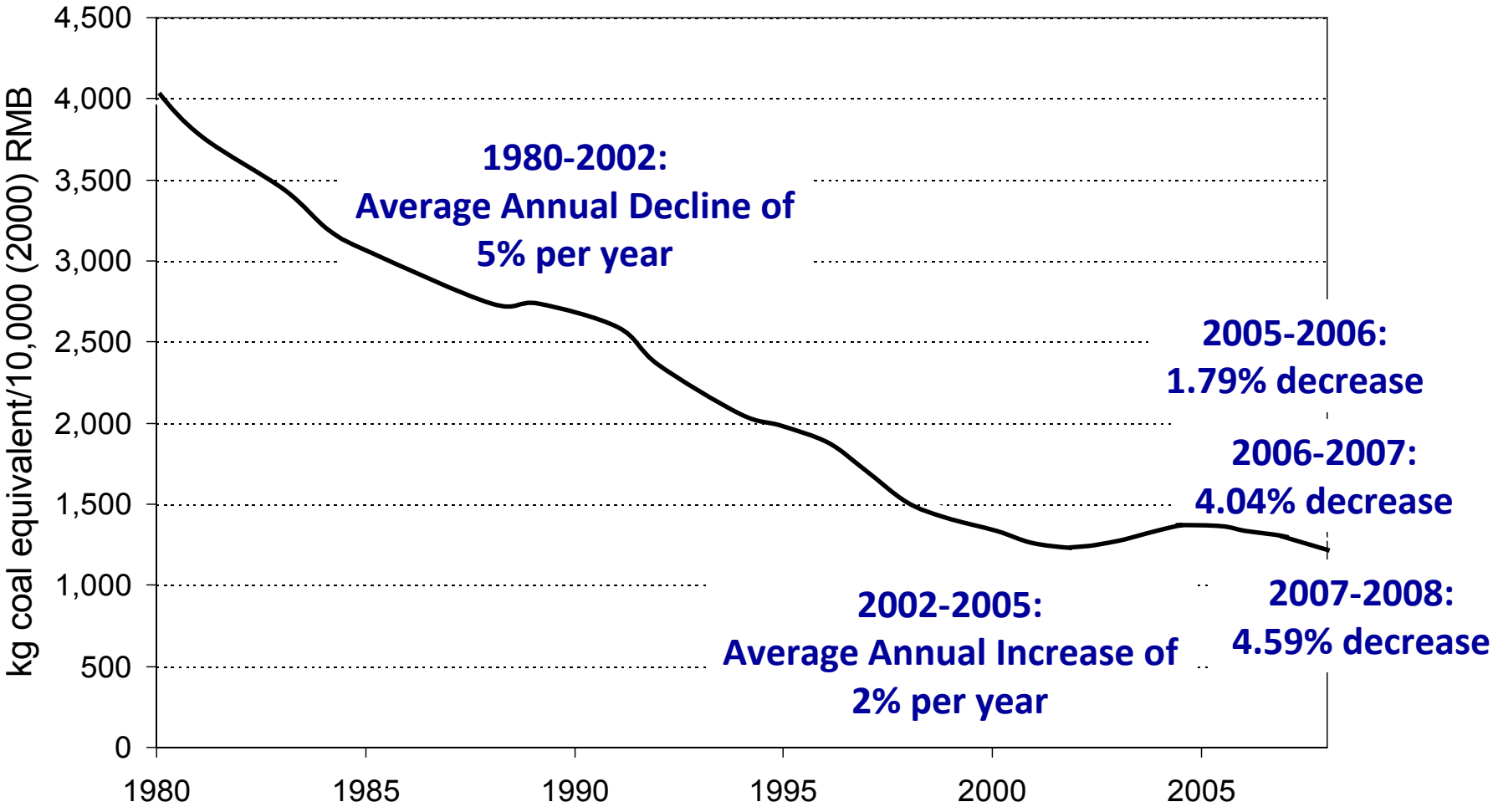
Ten Key Projects

Project	Expected Annual Savings
Energy efficiency and conservation in buildings	100 Mtce (2.8 Quads)
Oil conservation and substitution	38 Mt of oil = 54.3 Mtce (1.5 Quads)
Renovation of coal-fired industrial boilers	50 Mtce (1.4 Quads)
District level combined heat and power projects	35 Mtce (1 Quad)
Energy-efficient lighting	29 TWh = 3.56 Mtce (0.1 Quads)
Motor system energy efficiency	20 TWh = 2.46 Mtce (0.07 Quads)
Waste heat and pressure utilization	1.35 Mtce (0.04 Quads)
Energy systems optimization	Not specified
Government procurement of energy efficiency products	Not specified
Monitoring and evaluation systems	Not specified
Total	**>250 Mtce (6.9 Quads)**

Reducing Energy Use in the Industrial Sector

- China's national-level government established the Top-1000 Energy-Consuming Enterprises Program
- Provincial and local governments signed agreements with about 100,000 smaller companies
- All companies using more than a certain threshold level of energy annually agreed to develop energy conservation targets and action plans

Energy Use in China: Recent Trends



Source: National Bureau of Statistics, *China Statistical Abstract*, various years.

President Obama and U.S. Congress

Historic investments in energy efficiency, renewable energy, and transmission

Doubling federal investment in science

The House of Representatives has passed energy and climate change legislation that places a cap on carbon emissions that will reduce carbon emissions by more than 80% by 2050

“To protect our planet, now is the time to change the way that we use energy. Together, we must confront climate change by ending the world's dependence on fossil fuels, by tapping the power of new sources of energy like the wind and sun, and calling upon all nations to do their part.

And I pledge to you that, in this global effort, the United States is now ready to lead.”

President Barack Obama
Prague, Czech Republic
5 April, 2009

2009 is the 30th Anniversary of the U.S.-China Agreement on Cooperation in Science and Technology

"Science and technology also have played a critical part in the dramatic advances of our relationship with the People's Republic of China."

President Jimmy Carter
25 January, 1979

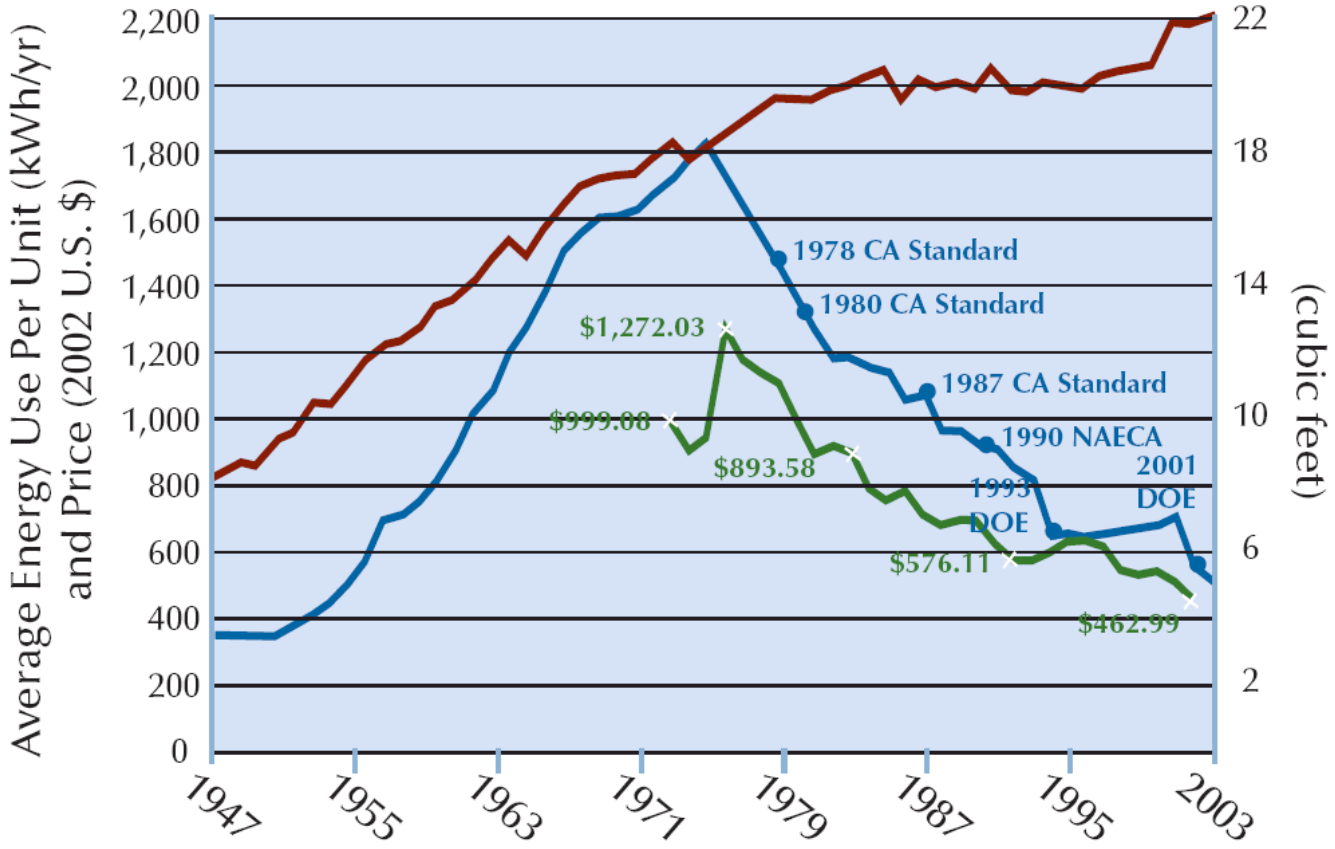
Longest-standing accord between our countries

Led to an era of robust government-to-government collaboration

We continue that tradition today

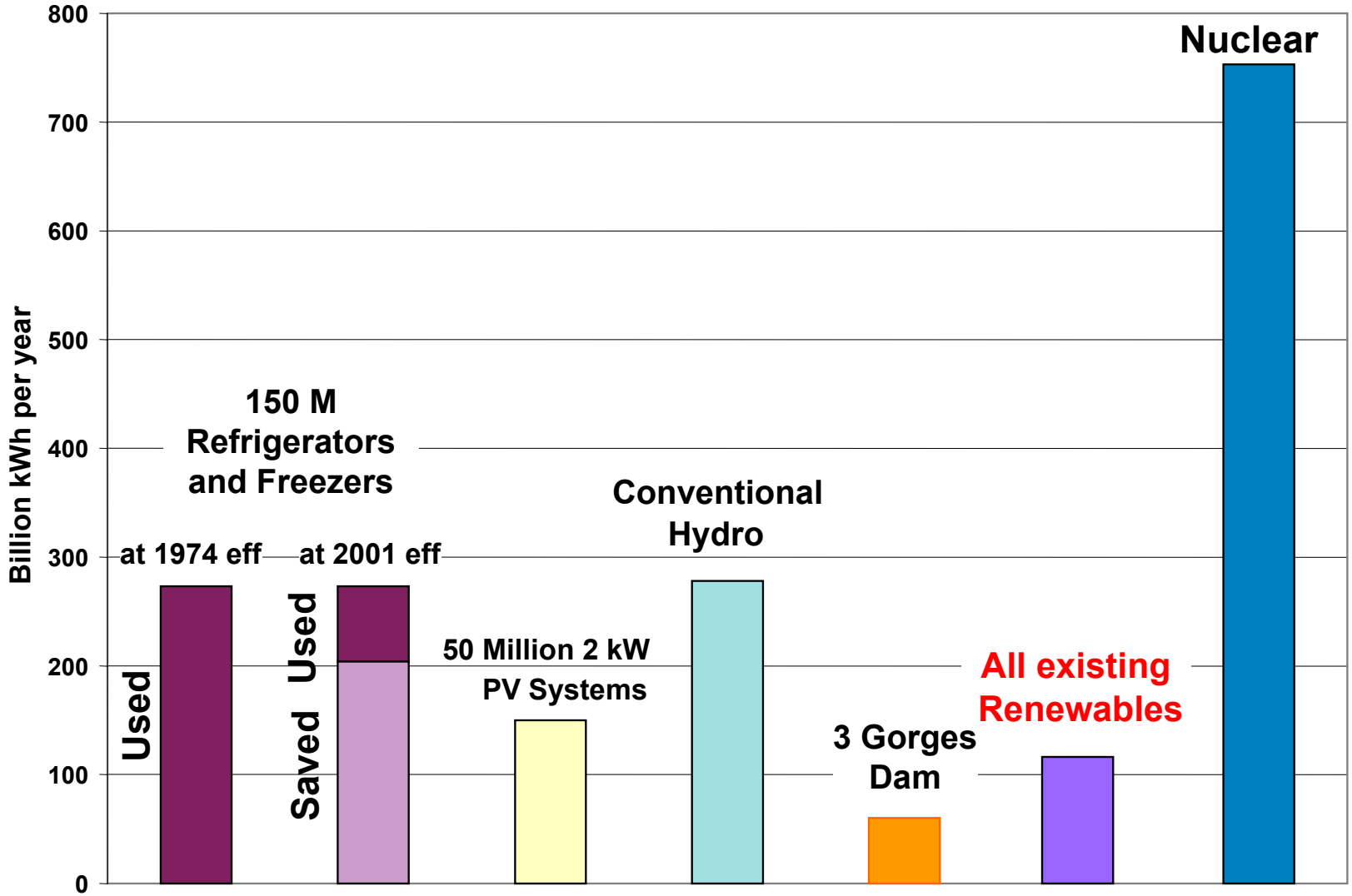
In the next few decades, energy efficiency and conservation will be the most effective mitigations tools.

Regulation stimulates technology: Refrigerator efficiency standards and performance.

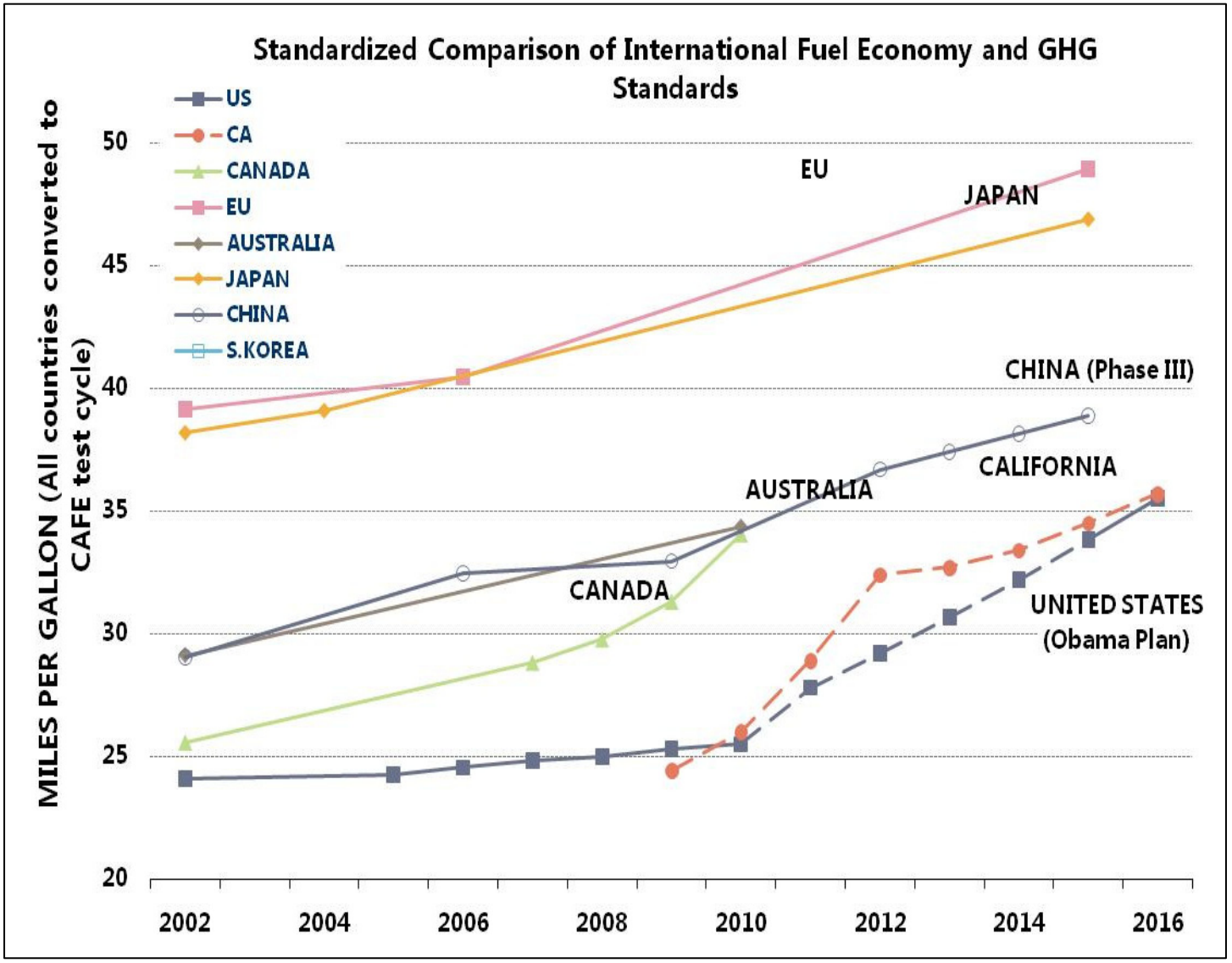


Energy savings is greater than ***all*** of US renewable energy. Regulation of consumer electronics and computers can save a similar amount of energy.

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

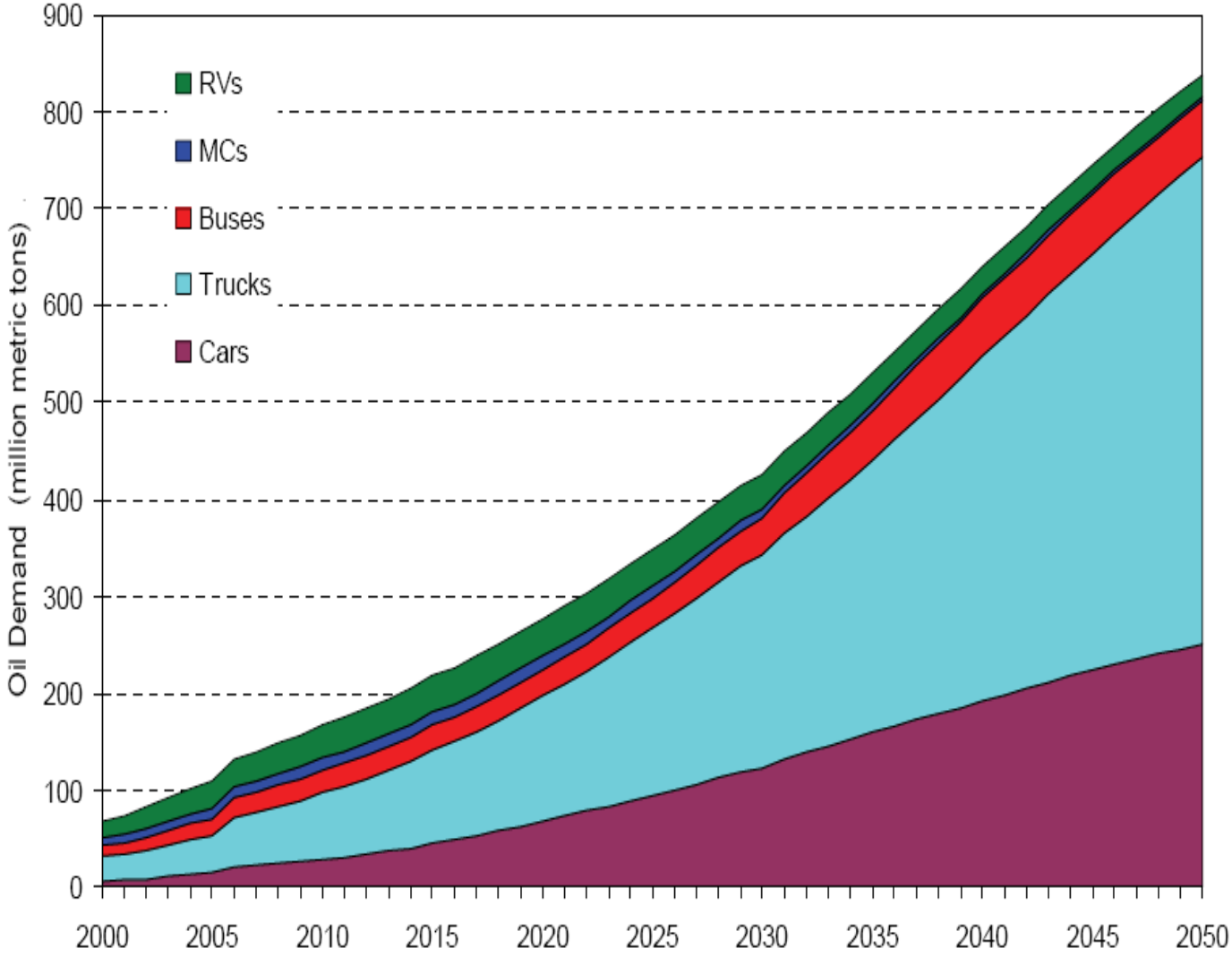


China has adopted aggressive fuel economy standards to curb oil demand growth



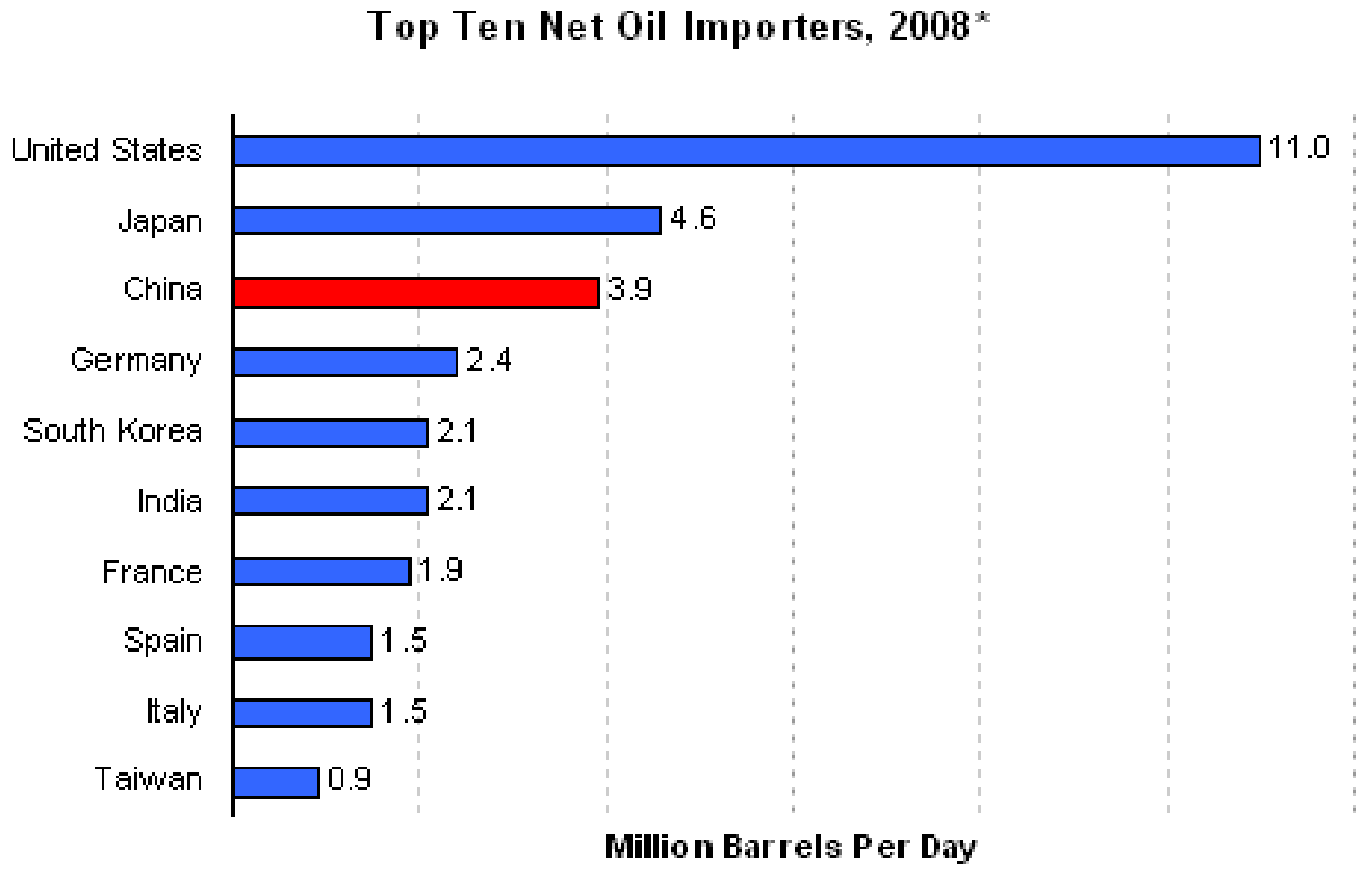
Source: Innovation Center for Energy and Transportation

Chinese vehicle fleet projected to grow rapidly through 2050, with a corresponding growth in oil demand



Source: “Projection of Chinese Motor Vehicle Growth, Oil Demand, and CO2 Emissions through 2050”, Argonne National Lab, 2006.

China is the third largest oil importing country after US and Japan



Source: EIA Short-Term Energy Outlook (July 2009)

*estimate

International collaborations that jointly develop new technologies

- Energy efficient and cost effective buildings

Dallas, Texas

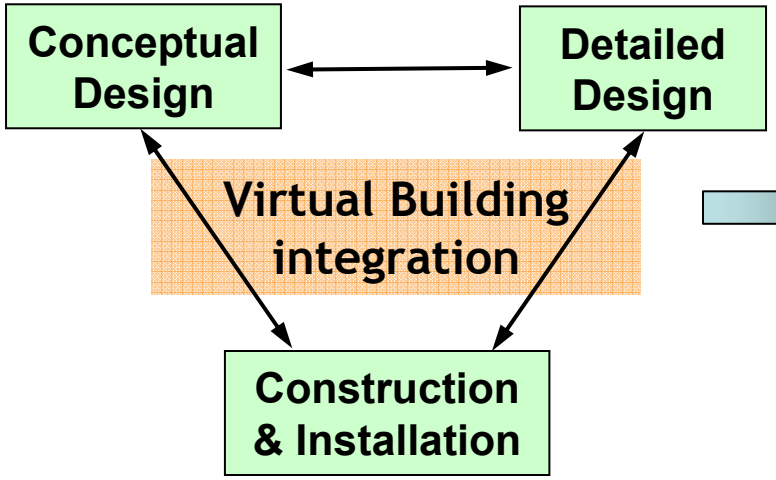
Retrofitting urban roofs and pavements with solar-reflective materials is equal to eliminating carbon emissions from all automobiles for 11 years.

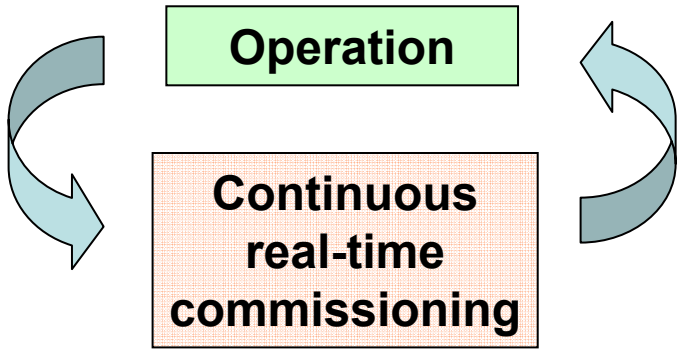
White roofed buildings:

Sunlight energy is reflected back into space rather than heating up buildings and homes in the summer.

Santorini, Greece

Buildings consume 40% of our energy:
A new way of designing and constructing buildings.

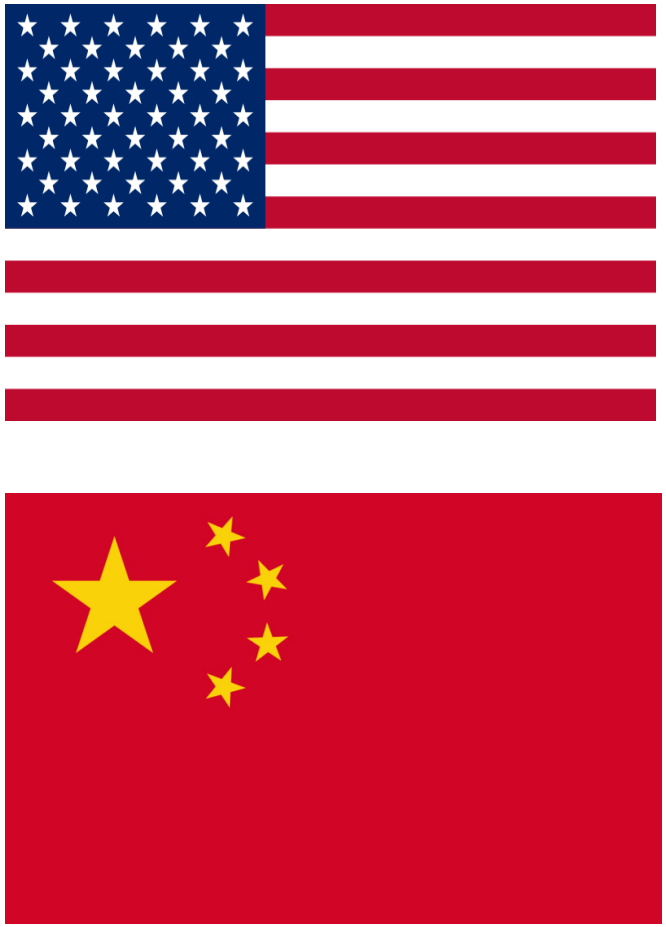




Computer-aided design tools with Embedded Energy Analysis

Computer-controlled operation with Sensors and Controls for Real-Time Optimization

- Oxygen sensor
- Air pressure sensor
- Air temperature sensor
- Engine temp. sensor
- Throttle position sensor
- Knock sensor



U.S. has roughly 300 billion square feet of real estate

China will add about 300 billion square feet of real estate within the next 15 years

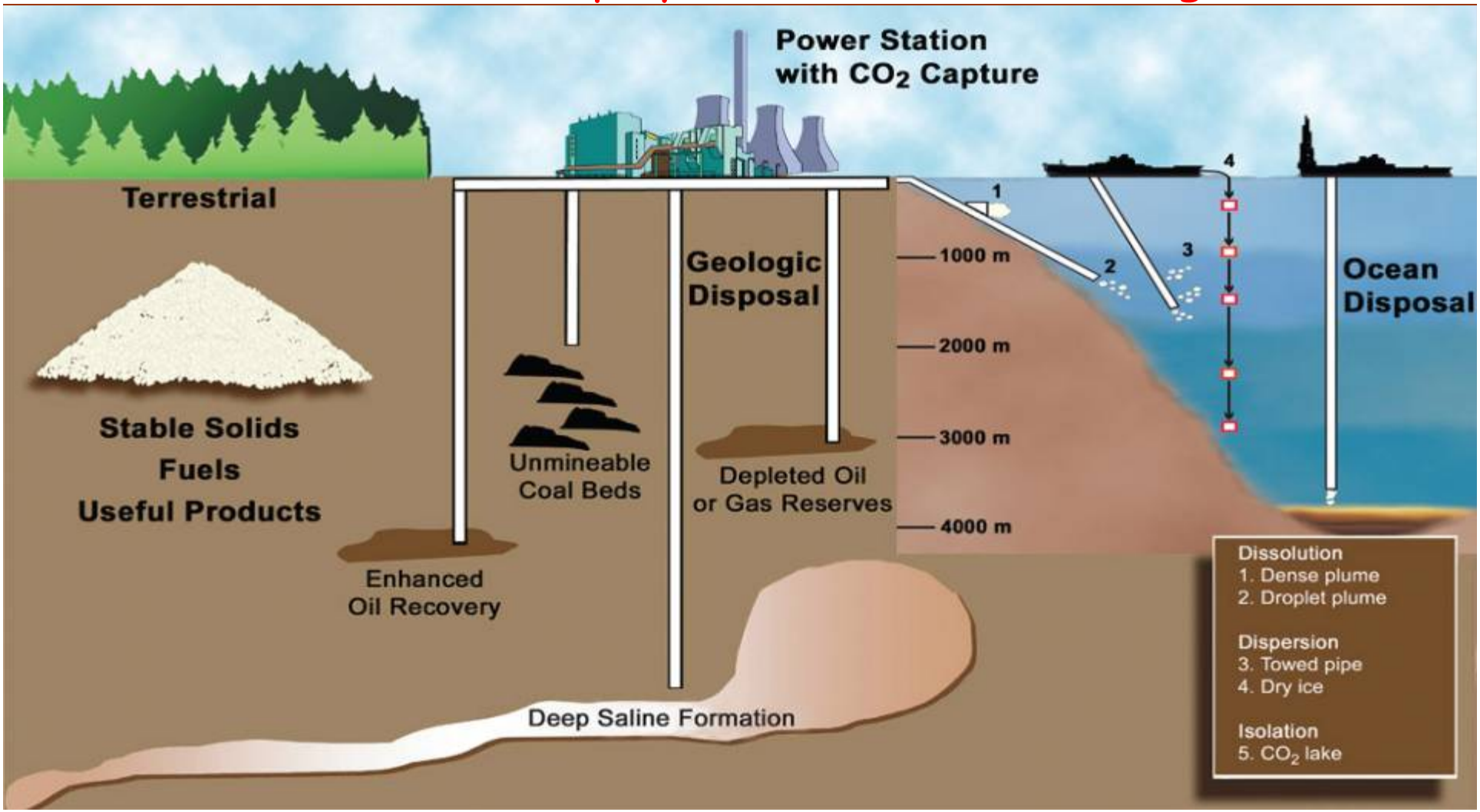
In a typical year, half of all new floor space in the world is built in China

International collaborations that jointly develop new technologies

- Energy efficient and cost effective buildings
- Carbon capture and sequestration, Nuclear Energy

US, China, Russia, and India have 2/3 of the world's known coal reserves.

International collaboration in carbon capture and storage will accelerate deployment of CCS technologies.

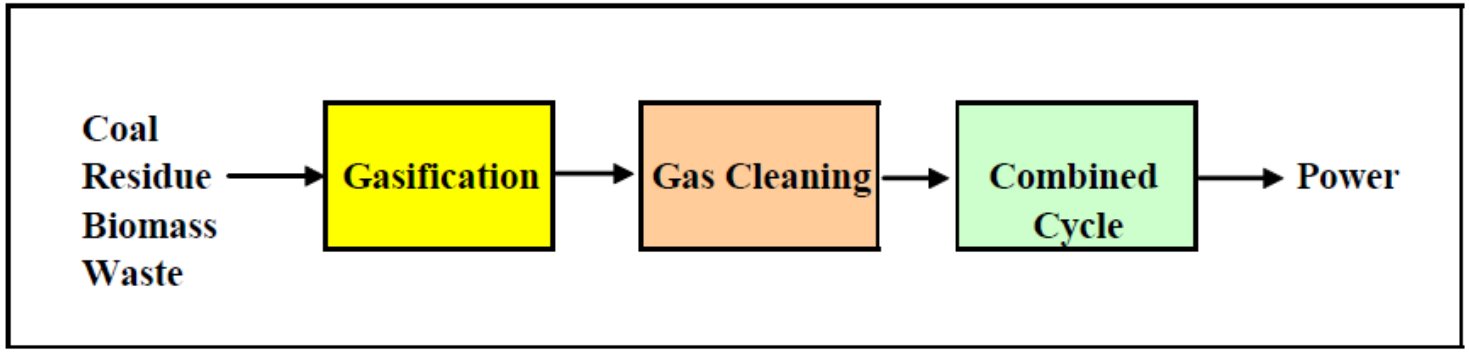


CO_2 capture and sequestration

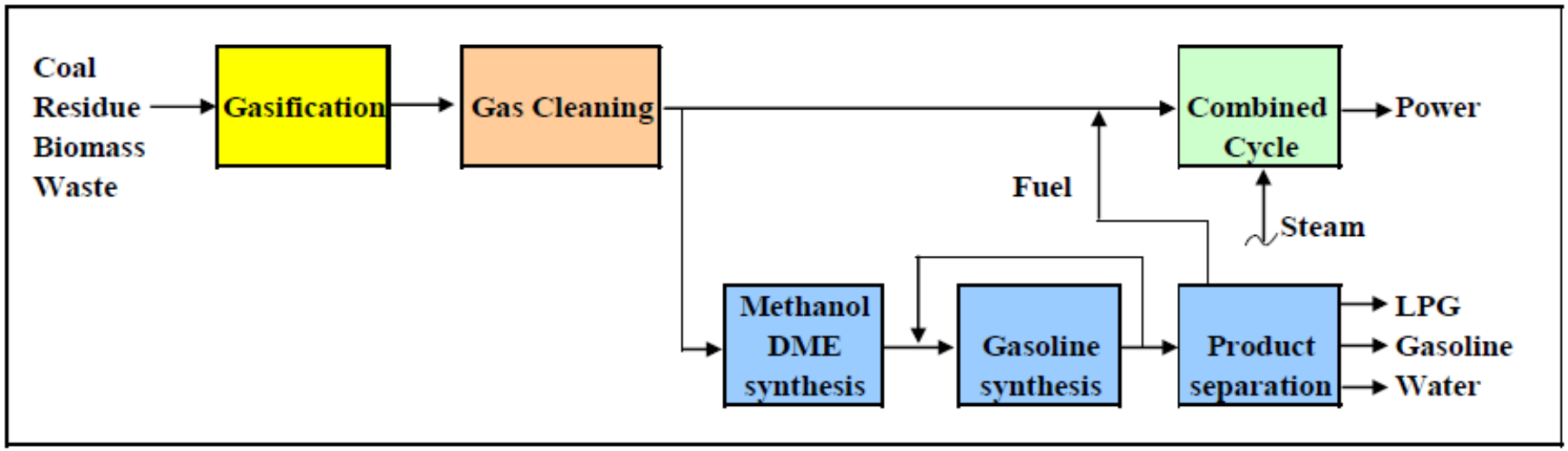
1. As with many countries, the US is pursuing both pre- (e.g. IGCC and oxy-burn) and post-combustion CO_2 capture methods.
2. Our goal is to have commercial deployment of CCS begin in 8 – 10 years.
3. Many new coal plants will be built before CCS is routinely deployed. We need an efficient capture technology from existing coal plants. DOE is supporting R&D in numerous avenues (membrane technologies, phase separation, catalytic capture).

Poly-generation of Power and Chemicals may justify higher IGCC investments

IGCC power plant



Integration of IGCC with chemical synthesis



Nuclear Fission provides carbon-free base-load power

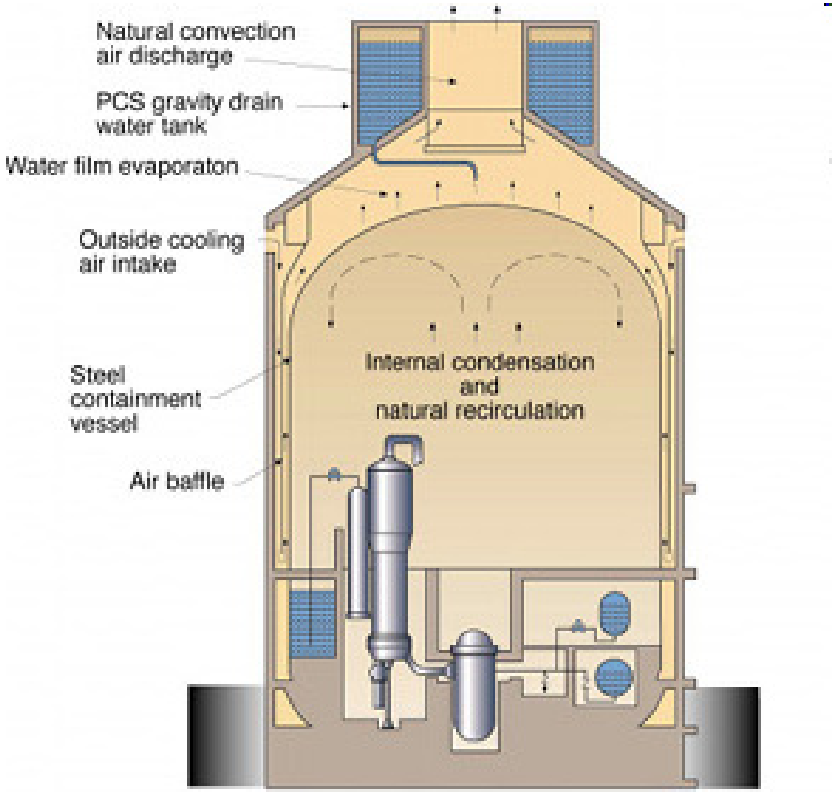


Figure 3. AP600 Passive Containment Cooling System

Gen III+ reactors (e.g. AP 1000):

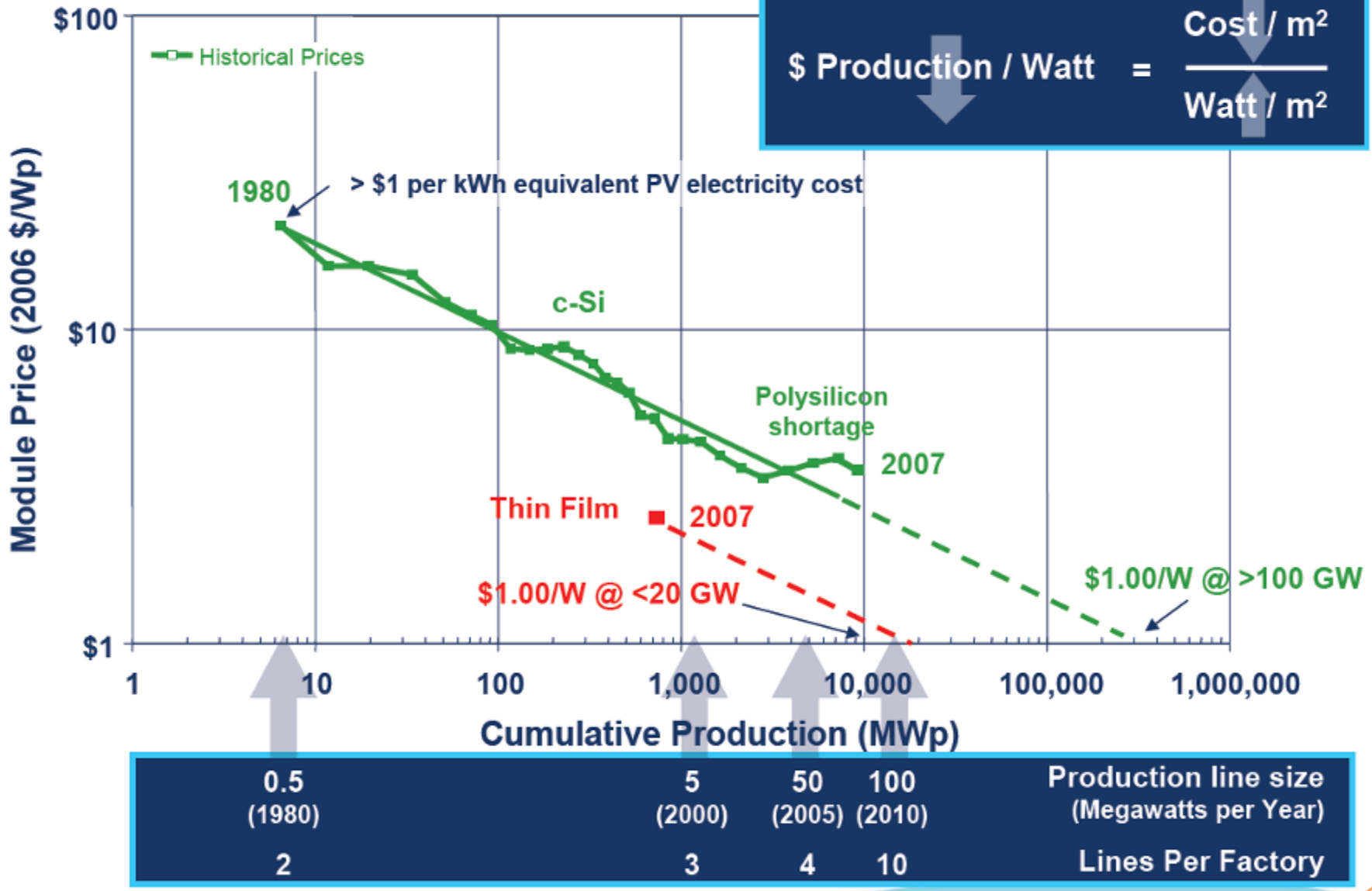
- Natural circulation
- Passive safety
- Decreased number of components means lower cost

- The nuclear waste issue is solvable.
- Nuclear proliferation is a concern and requires international cooperation.

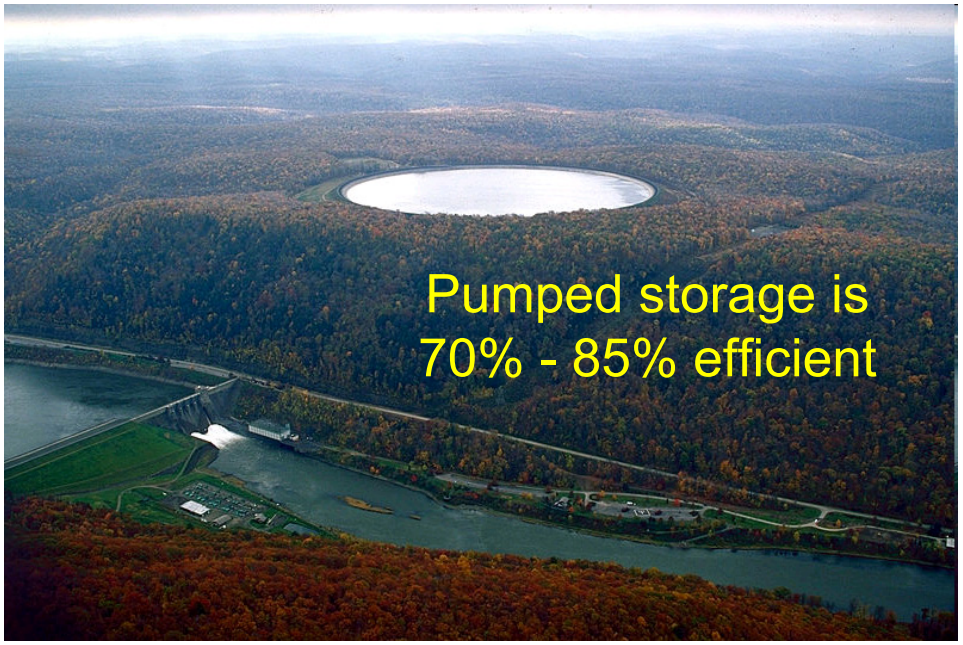
International collaborations that jointly develop new technologies

- Energy efficient and cost effective buildings
- Carbon capture and sequestration, Nuclear Energy
- Breakthroughs in renewable energy

Solar Learning Curve: Module Cost/Watt

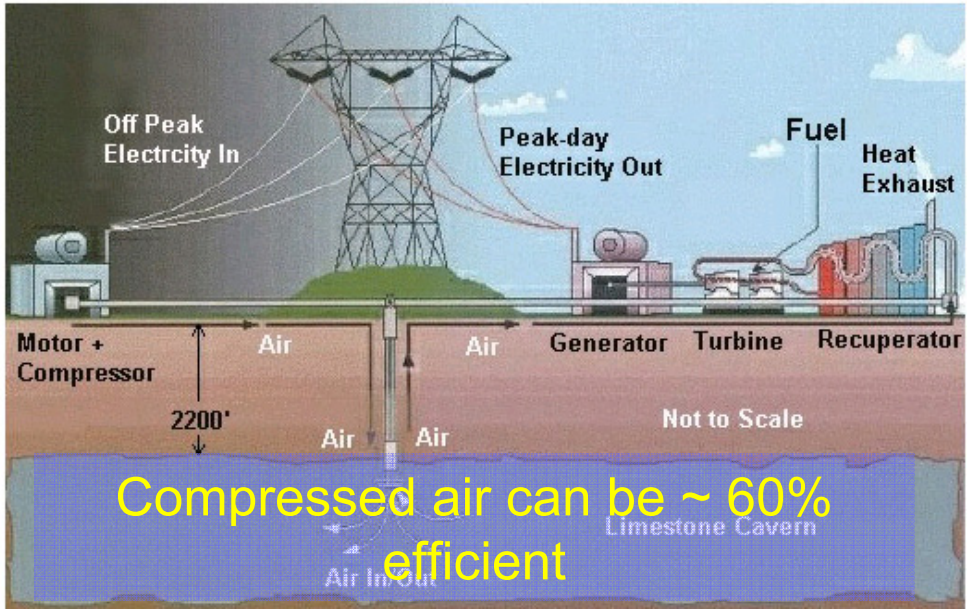


Source: Adapted from National Renewable Energy Laboratory

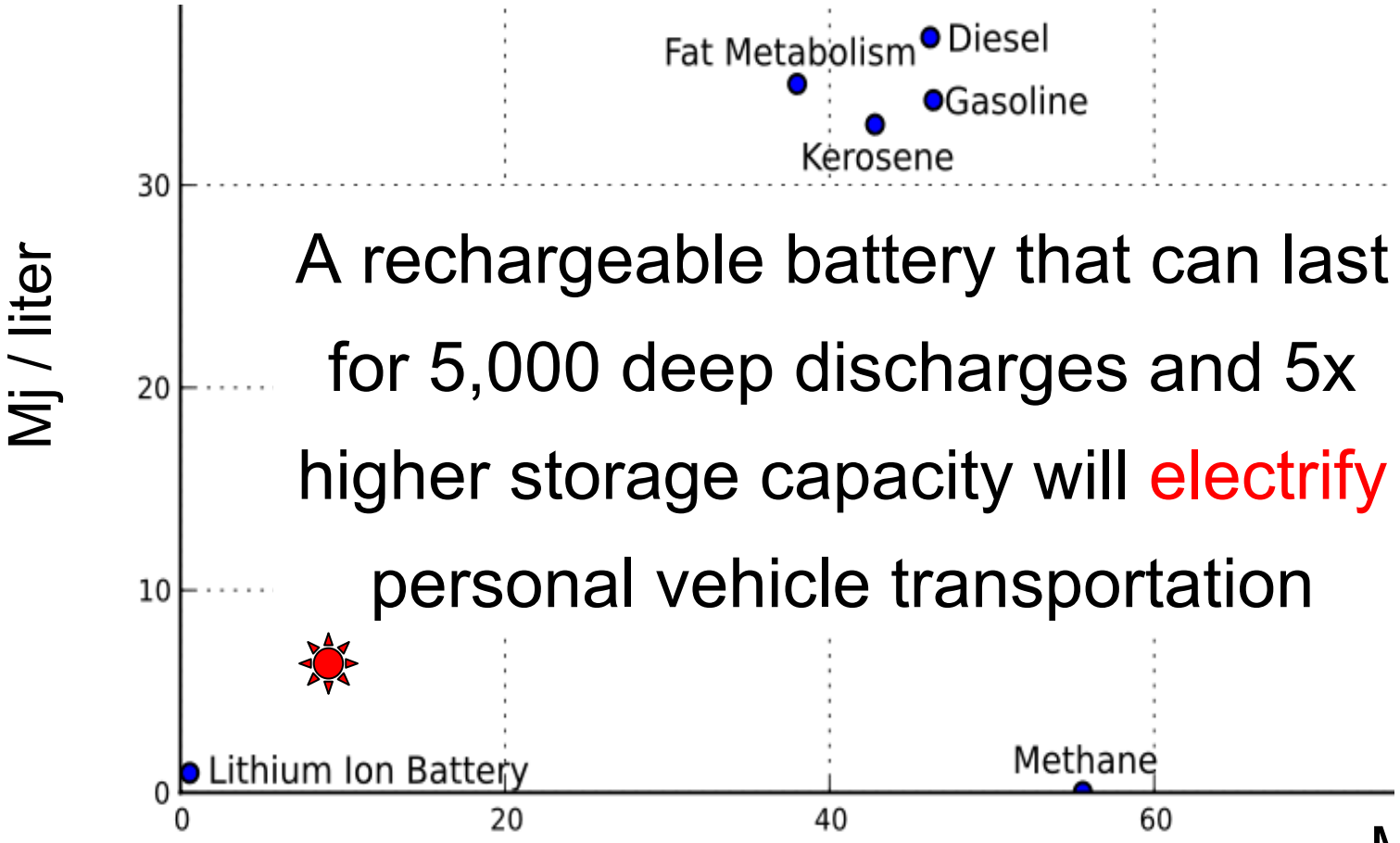


As wind and solar energy sources become a greater part of our electricity supply, we will need a smart grid to respond to variable generation.

Large scale energy storage will also be needed.



Energy densities of chemical fuels and the best commercial battery



A rechargeable battery that can last for 5,000 deep discharges and 5x higher storage capacity will electrify personal vehicle transportation

Body Fat	38 Mj/kg	35 Mj/liter
Kerosene, jet fuel	43 Mj/kg	32 Mj/liter
Lithium ion battery	0.54 Mj/kg	0.9 Mj/liter

Feedstock grasses such as *Miscanthus* can be energy crops.

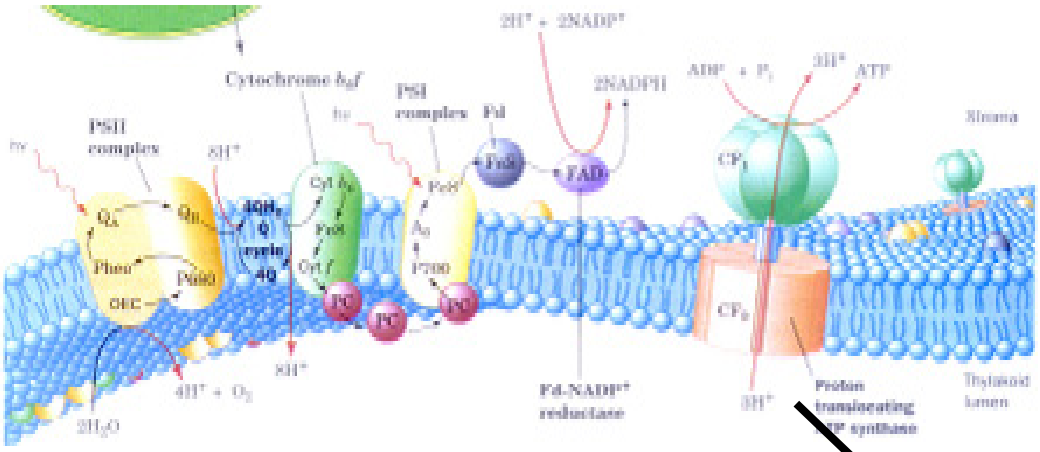
Non-fertilized, non-irrigated test field at U. Illinois yielded

15x more ethanol / acre than corn.

50 M acres of energy crops, plus agricultural and urban wastes can produce **1/2** of current US consumption of gasoline.

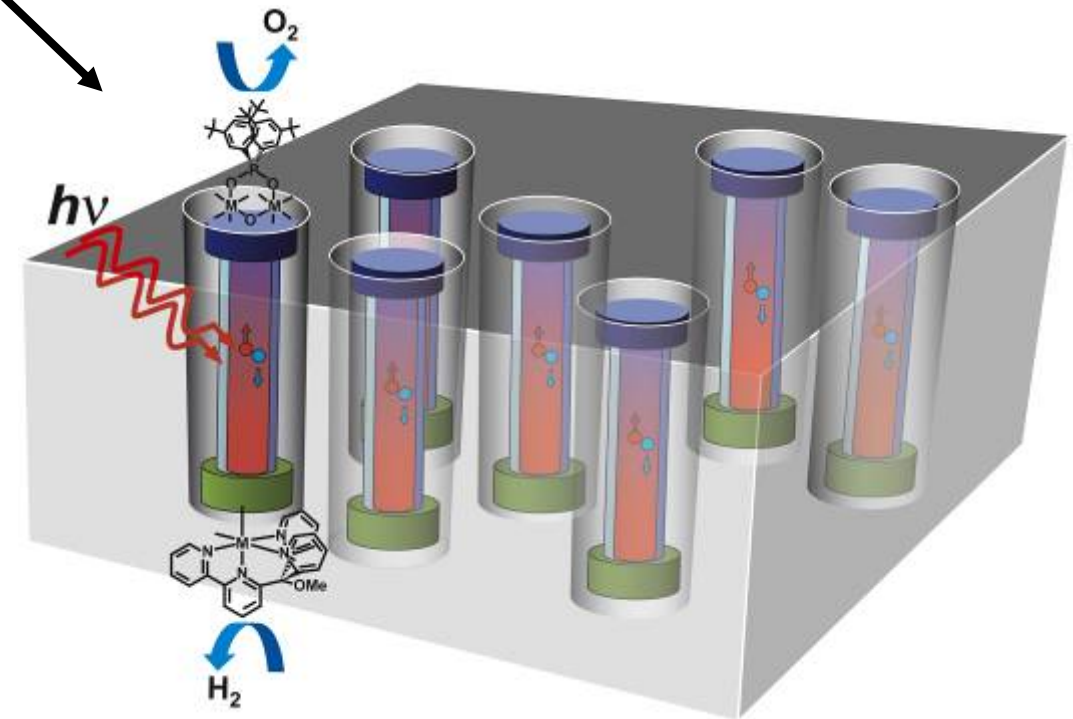
Entire metabolic pathways were introduced into yeast to produce gasoline and diesel-like fuels.

Artificial Photosynthesis

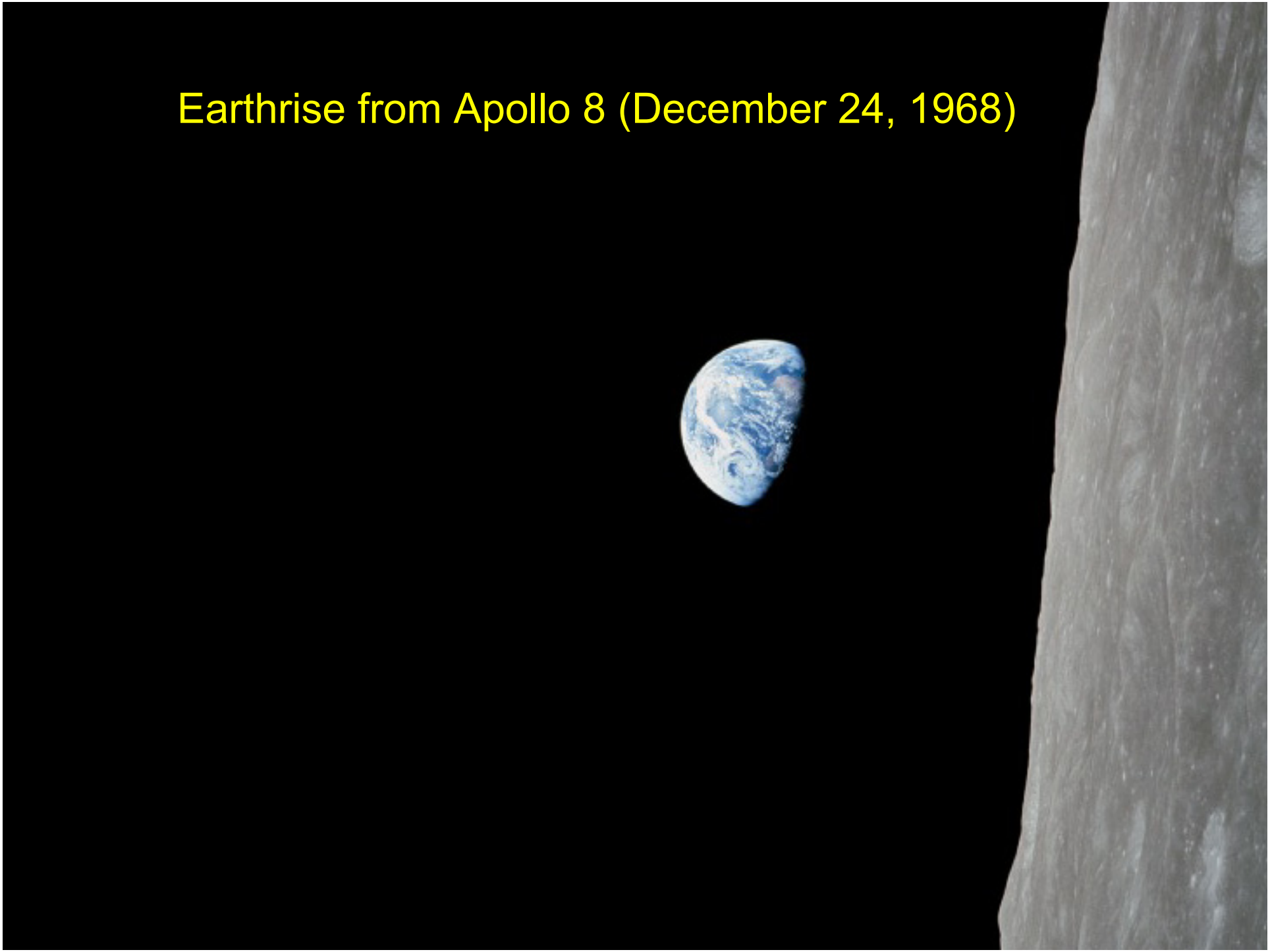


The first important step is to use sunlight to "split" water into oxygen and hydrogen.

$2H_2O$ + 4 photons → O_2 + 4H



Earthrise from Apollo 8 (December 24, 1968)



"We are now faced with the fact, my friends, that tomorrow is today. We are confronted with the fierce urgency of now. In this unfolding conundrum of life and history, there is such a thing as being too late."

Martin Luther King, 1967