The Motivation for Cleaner Coal Technologies

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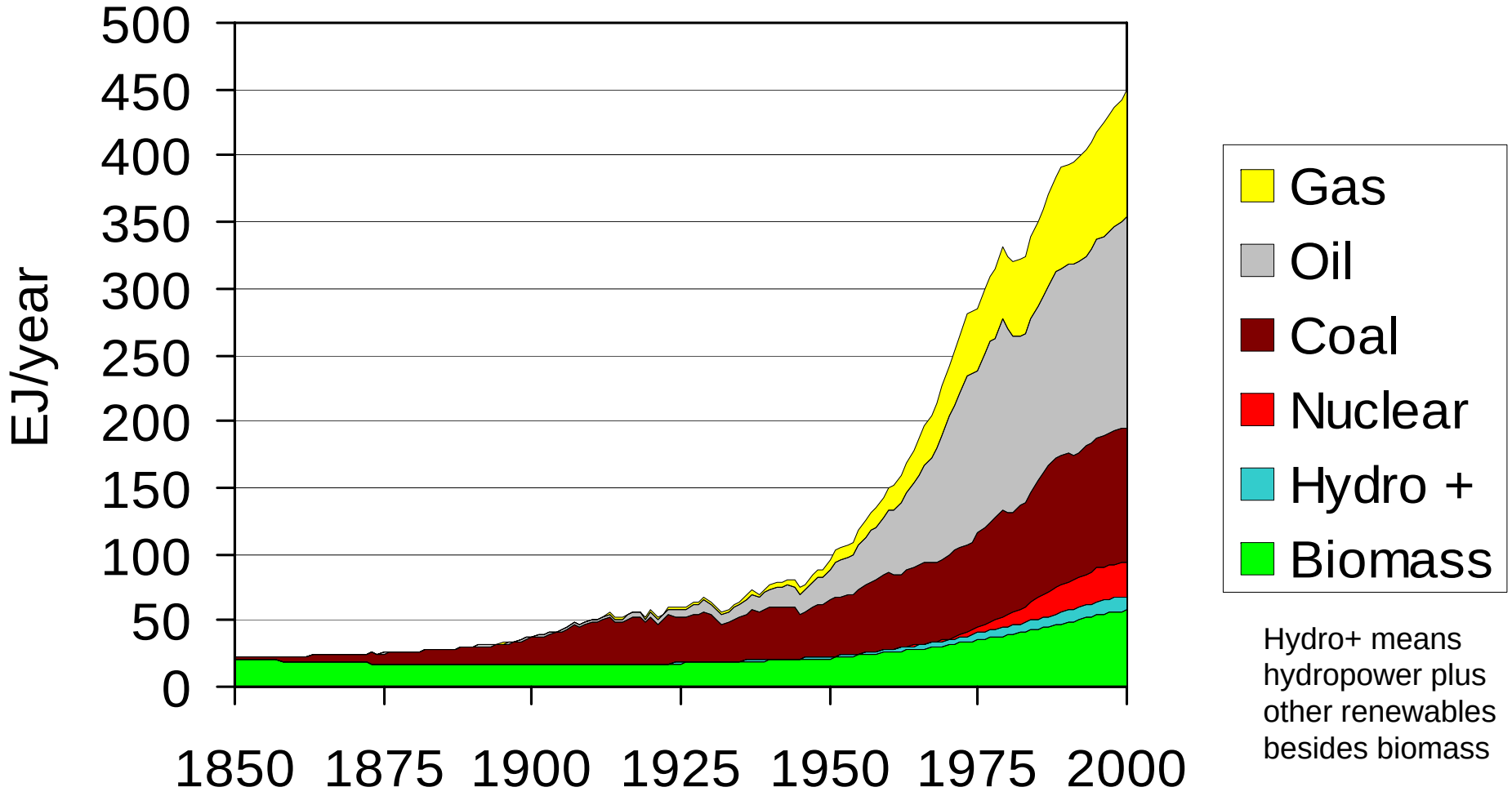
Coal, oil, & gas have fueled world energy growth for 150 years



Hydro+ means hydropower plus other renewables besides biomass

Energy supply grew 20-fold between 1850 and 2000.

Fossil fuels continued to dominate in 2005

		World	USA	China
Primary Energy (exajoules)		**514**	**106**	**80**
of which…	Oil	34%	40%	18%
	Natural Gas	21%	24%	2%
	Coal	26%	25%	62%
	Nuclear Energy	6%	8%	0.6%
	Hydropower	2%	1%	2%
	Biomass and Other	11%	3%	15%

Fossil-fuel dependence was 81% for the world, 82% for China, 88% for the United States

China & USA are biggest consumers and emitters

2005	*USA*	*China*	*India*
Population, millions	297	1306	1100
GDP/pers, 2005$ (ppp)	42000	7300	3700
Total energy supply, EJ	106	80	28
Oil consumption, EJ	42	15	5
Oil imports, Mb/d	12	3.4	1.7
Electricity generation, TWh	4200	2500	700
Electricity share from coal	50%	80%	70%
Fossil C emitted in CO_2, MtC	1700	1400	300

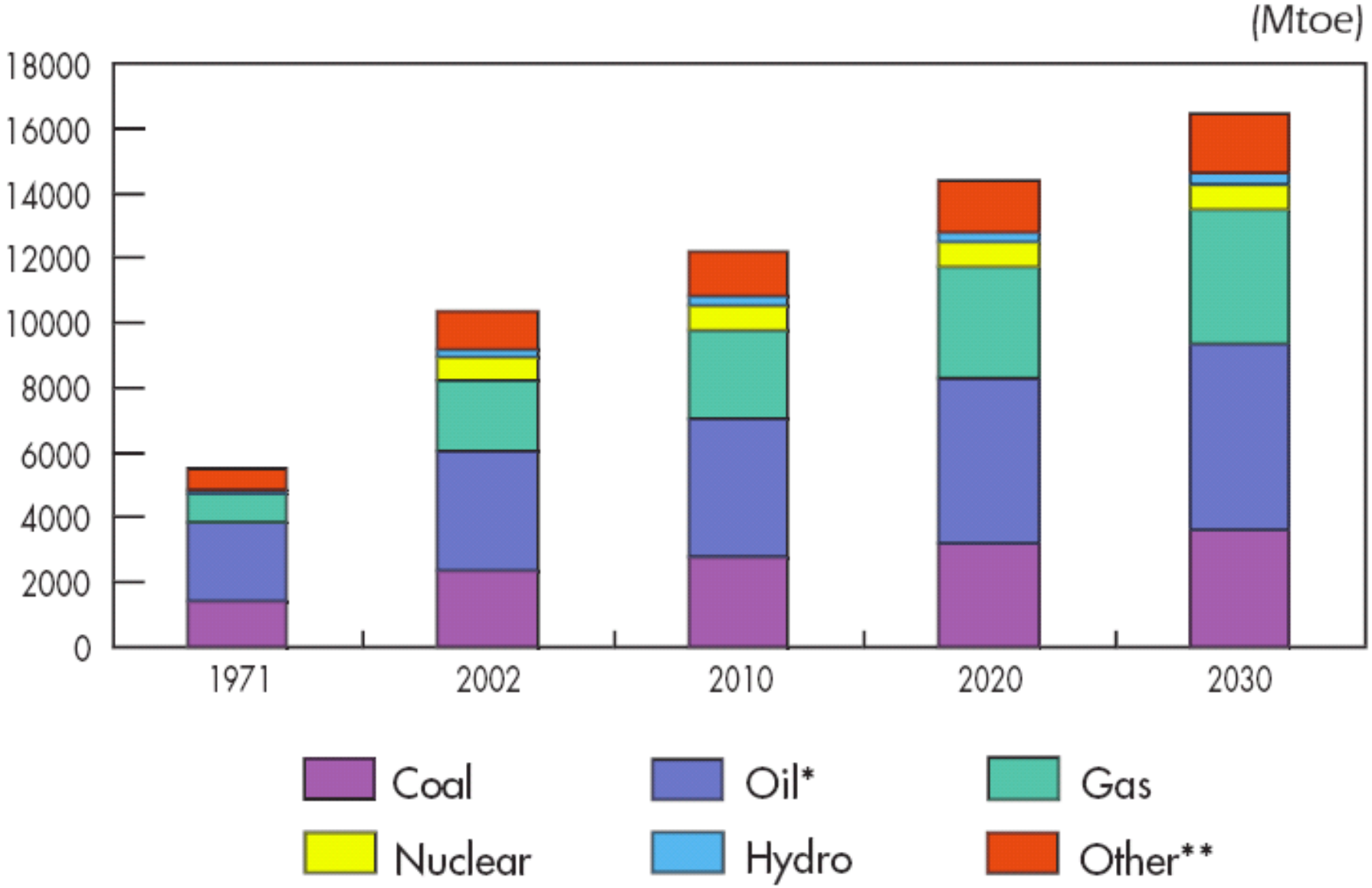
ppp = at purchasing-power parity, EJ = exajoules, TWh = terawatt-hours, MtC = megatons of carbon in CO_2. Total energy supply includes biomass fuels. Electricity generation is gross, not net.

Expected growth in US & Chinese demand in next 25 years is high

US Energy Information Administration “reference” forecast

	2005	2030
Primary energy, exajoules		
World	514	750
United States	106	150
China	80	140
Electricity, trillion kWh		
World	17.3	30
United States	4.0	6.0
China	2.4	4.8

Fossil fuels continue to play the dominant role



This is the "reference" (BAU) primary-energy projection of the International Energy Agency (IEA).

Coal-fired capacity forecasts to 2030

Actual and projected coal-fired capacity, GWe

	USA	*China*	*India*	*World*
2003	310	239	67	1120
2010	319	348	95	1300
2020	345	531	140	1600
2030	457	785	161	2000

Source: US EIA, International Energy Outlook 2006

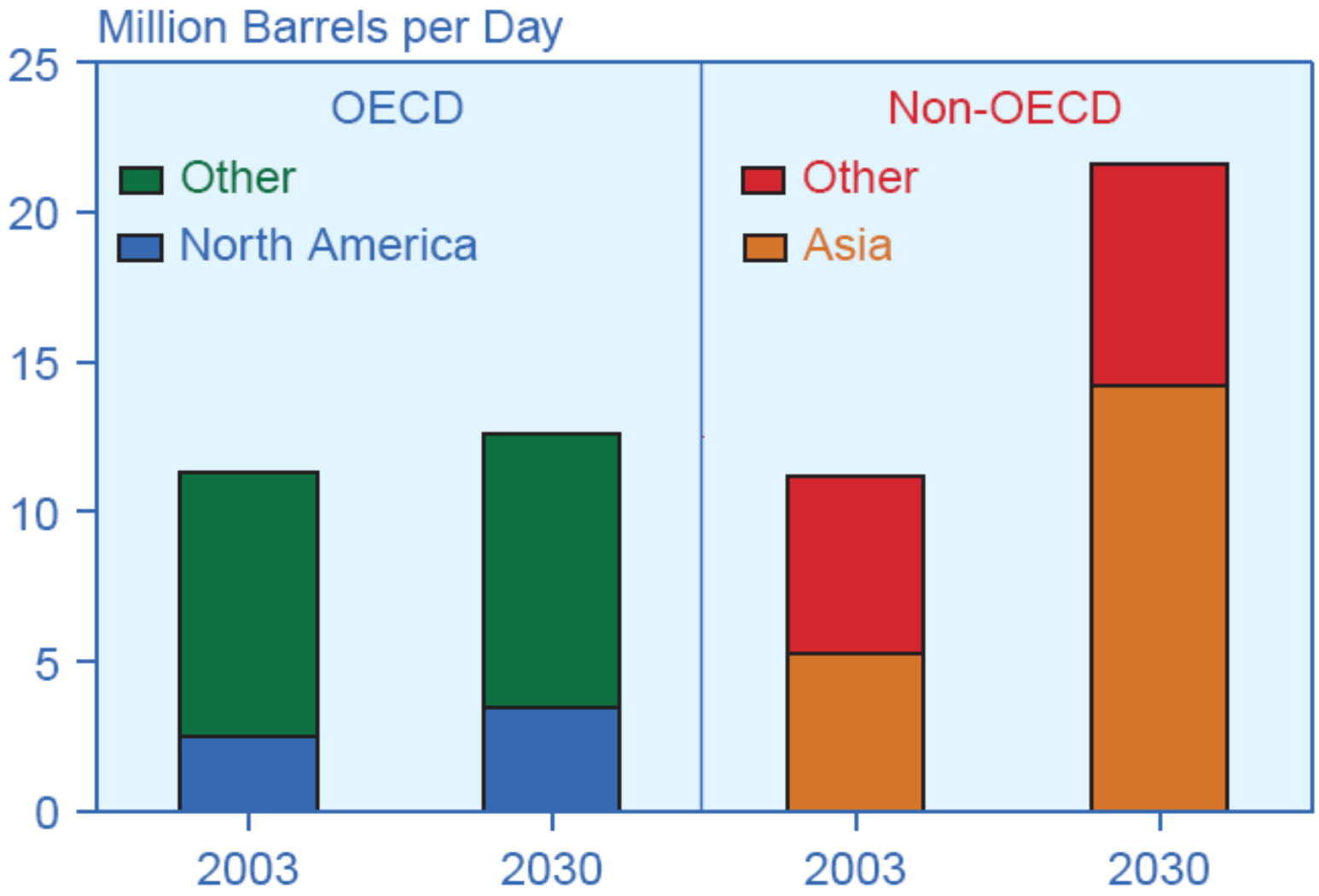
“Reference” growth through the 21st century leads to huge energy & electricity increases

- World use of primary energy reaches 2.5 times the 2000 level by 2050, 4 times by 2100.
- World electricity generation reaches 5 times the 2000 level by 2100.
- World CO_2 emissions reach 3 times the 2000 level by 2100.
- China passes USA in CO_2 emissions in 2007 or 2008 and becomes increasingly dominant thereafter.

The biggest dangers with this "business as usual" scenario are…

- Oil and natural gas supply: Economic damage from sudden price increases. International tensions and conflict over access and terms.
- Air pollution: Health damage from SOx, NOx, and soot. Acid rain from SOx and NOx.
- Global climate change: Increased floods, droughts, heat waves, powerful typhoons & hurricanes, sea-level rise, damage to agriculture & fisheries (and more) from climate disruption by CO_2, other greenhouse gases, soot.

Imports of Persian Gulf oil by region, 2003 & 2030



Source: EIA International Energy Outlook 2006

Developing Asia's dependence on the Persian Gulf is already bigger than North America's and is expected to grow much faster.

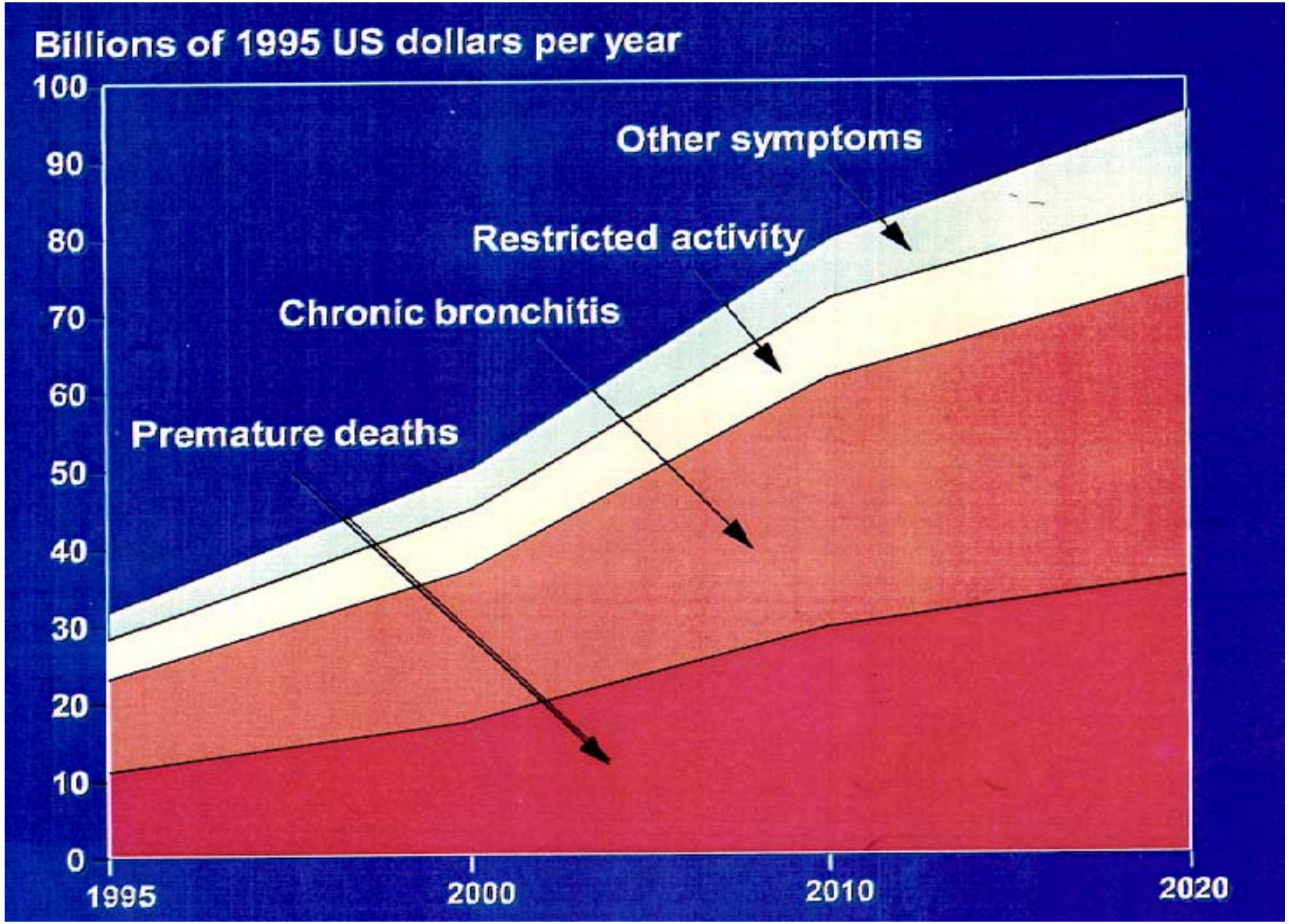
二氧化硫和氮氧化物产生量预测
Forecasts of S02 and NO2 Emissions

	情景 Scenario	2000	2010	2020
二氧化硫（万吨） SO_2 (10,000 tons)	A 情景 Scenario A	2719	4072	5738
	B 情景 Scenario B	2719	3900	4947
	C 情景 Scenario C	2719	3443	4056
氮氧化物（万吨） NO_X (10,000 tons)	A 情景 Scenario A	1988	3417	4982
	B 情景 Scenario B	1988	3273	4295
	C 情景 Scenario C	1988	2889	3521

Under the preferred (green) scenario, Chinese NOx emissions still increase 75% by 2020, SOx emissions by 50%.

Liu Shijin, The State Council, 2004

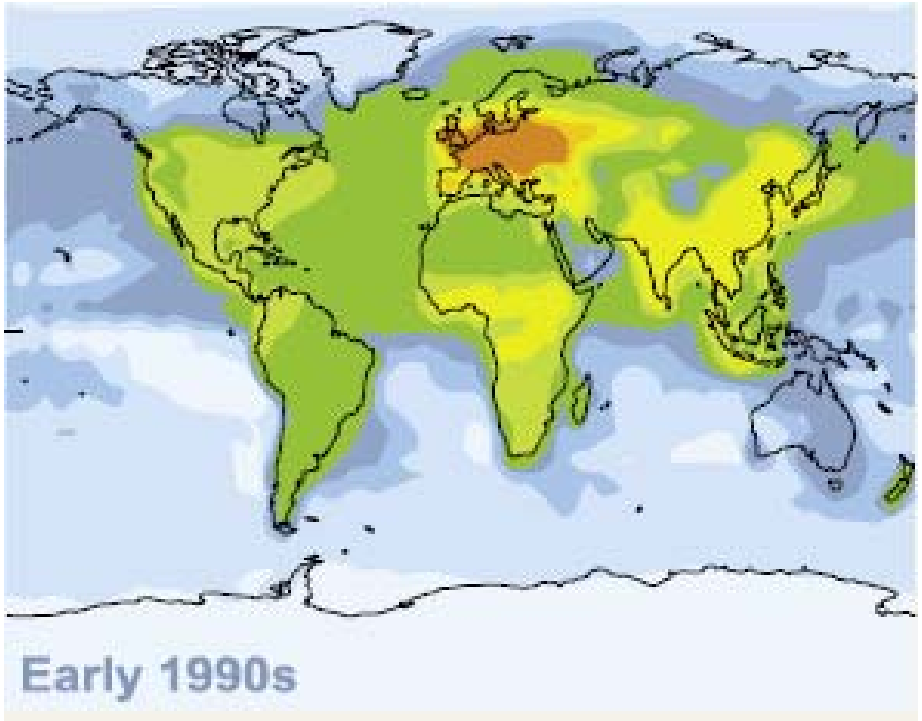
Health Costs from Particulate Pollution in China

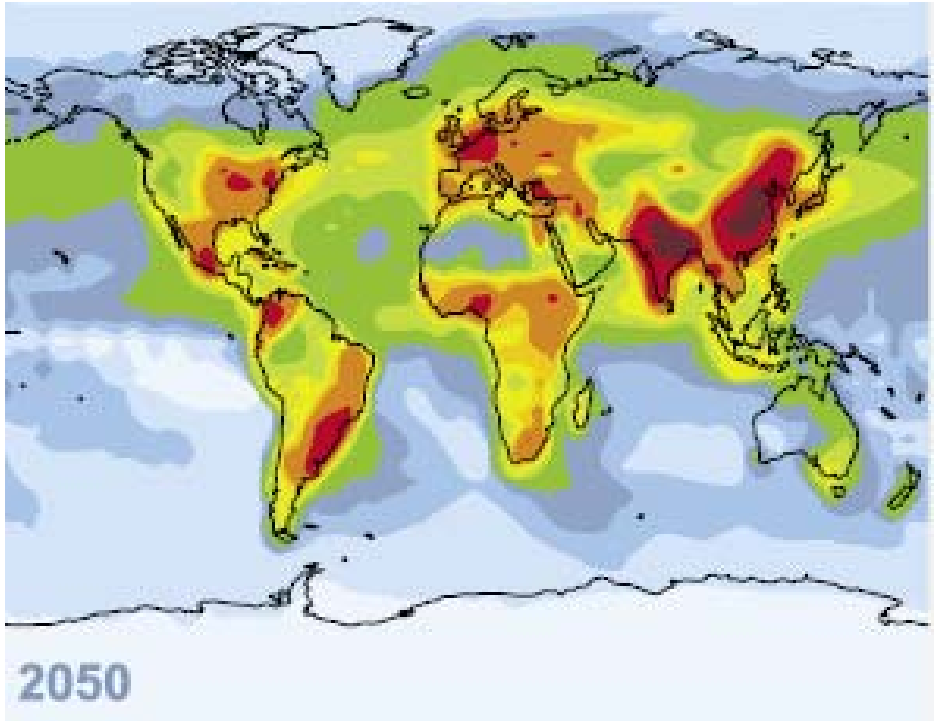


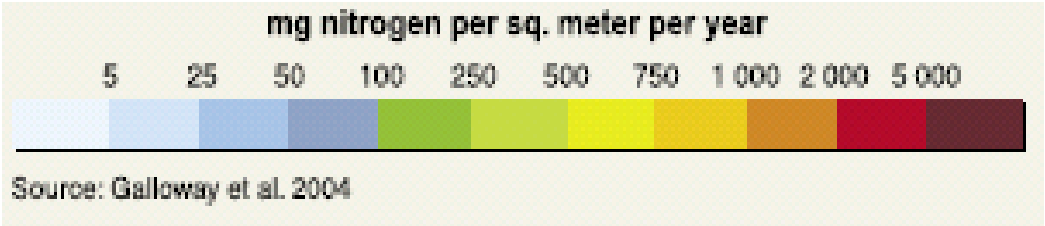
Source: Clear Water, Blue Skies; *China's Environment in the New Century*, World Bank, 1997.

Acid precipitation under BAU growth

Wet and dry reactive nitrogen deposition from the atmosphere, early 1990s and projected for 2050

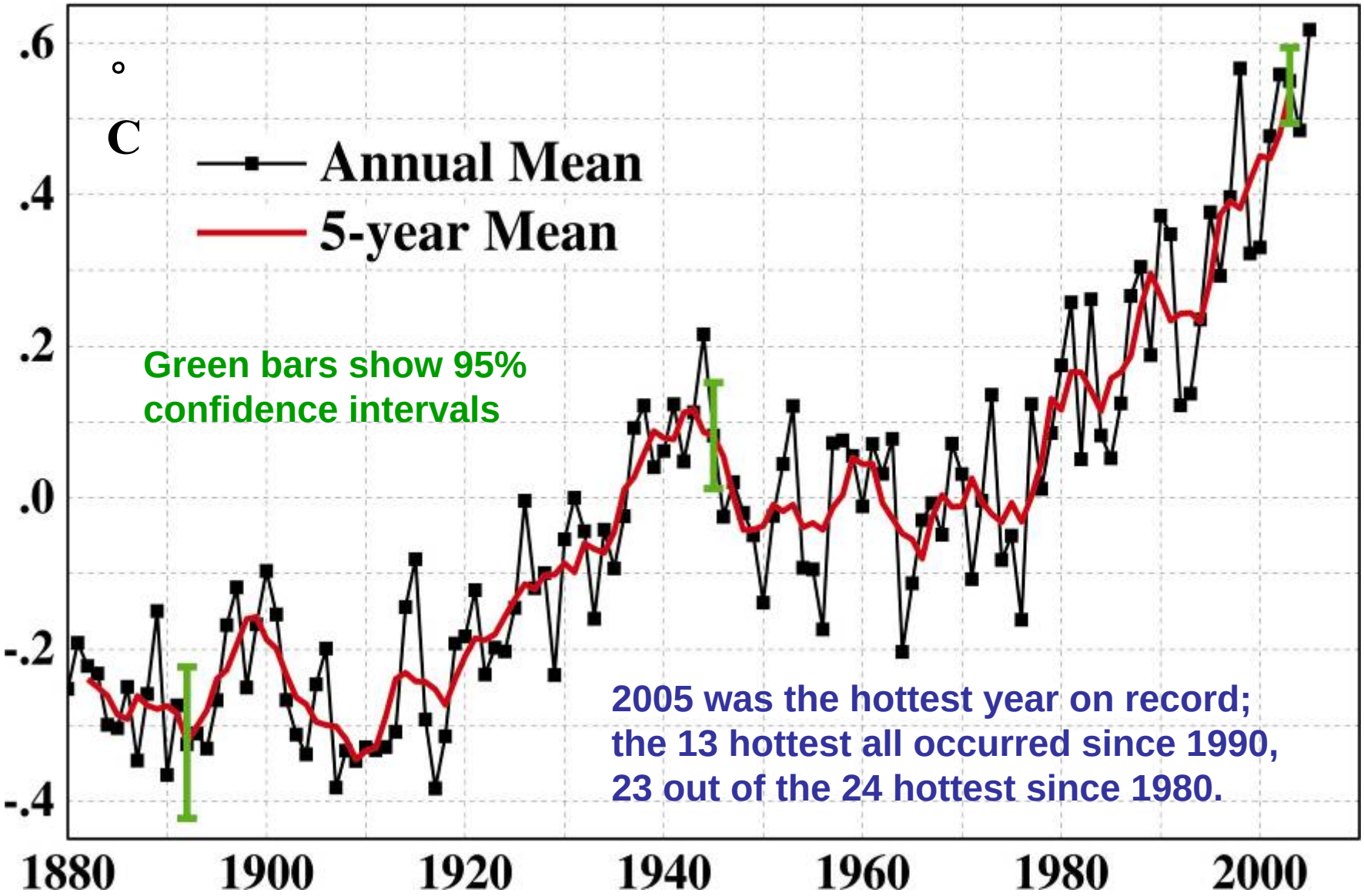






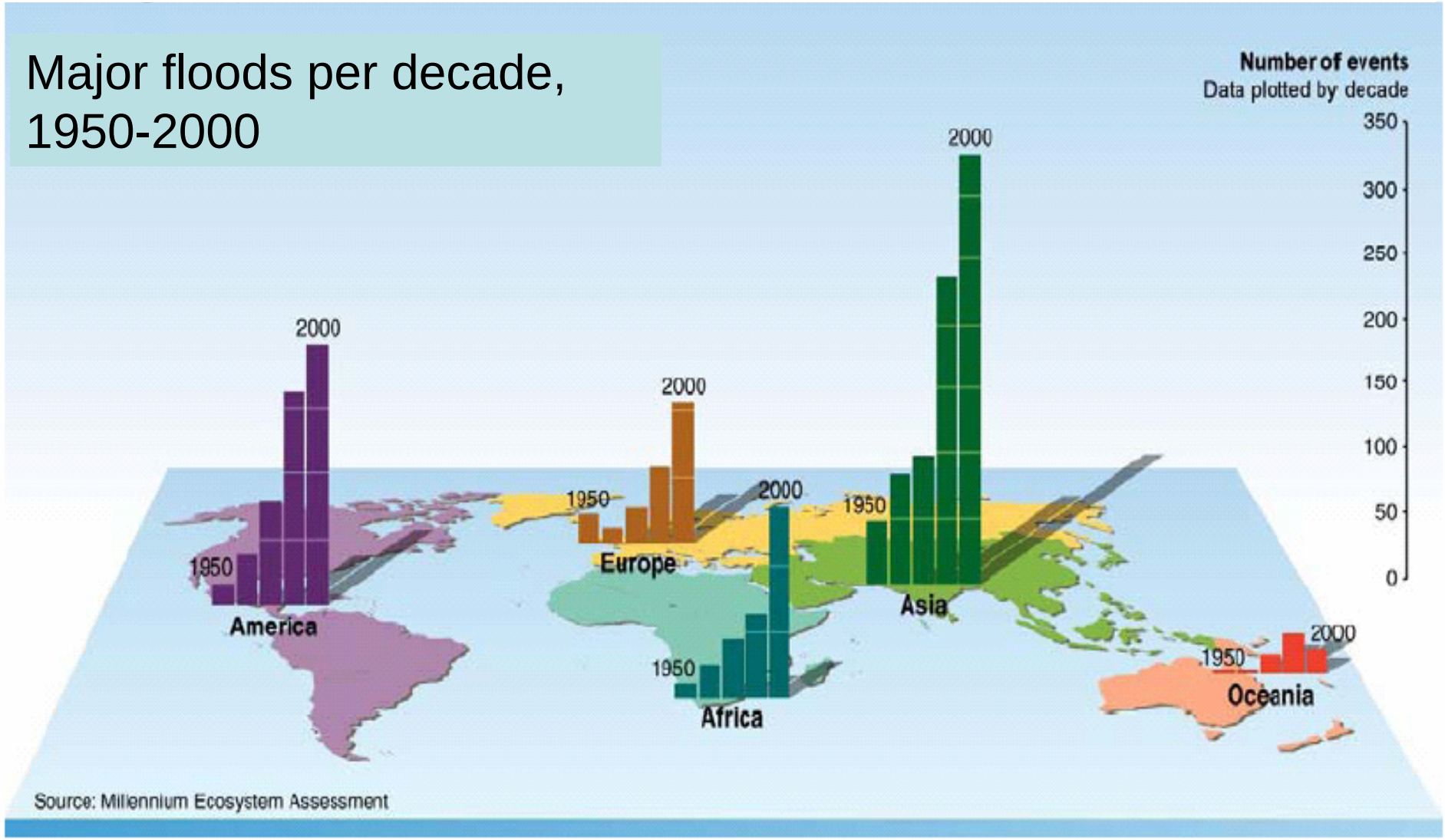
Global climate change is the most difficult of the three big problems

The Earth is getting warmer.



J. Hansen et al., *PNAS 103*: 14288-293 (26 Sept 2006)

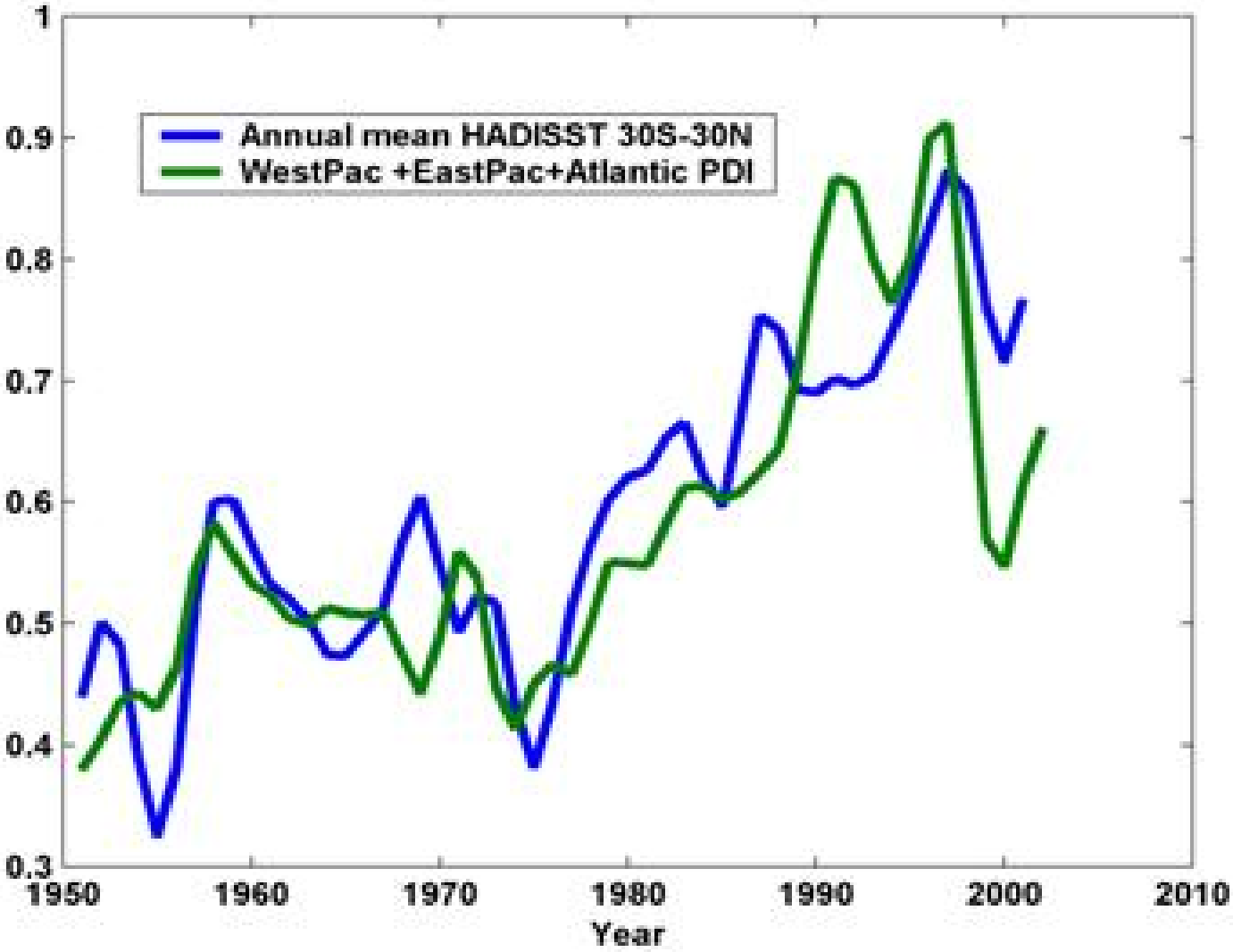
Harm from climate change is already occurring



There's a consistent 50-year upward trend in every region except Oceania, where the 1990s were a bit below the 1980s.

Harm is already occurring (continued)

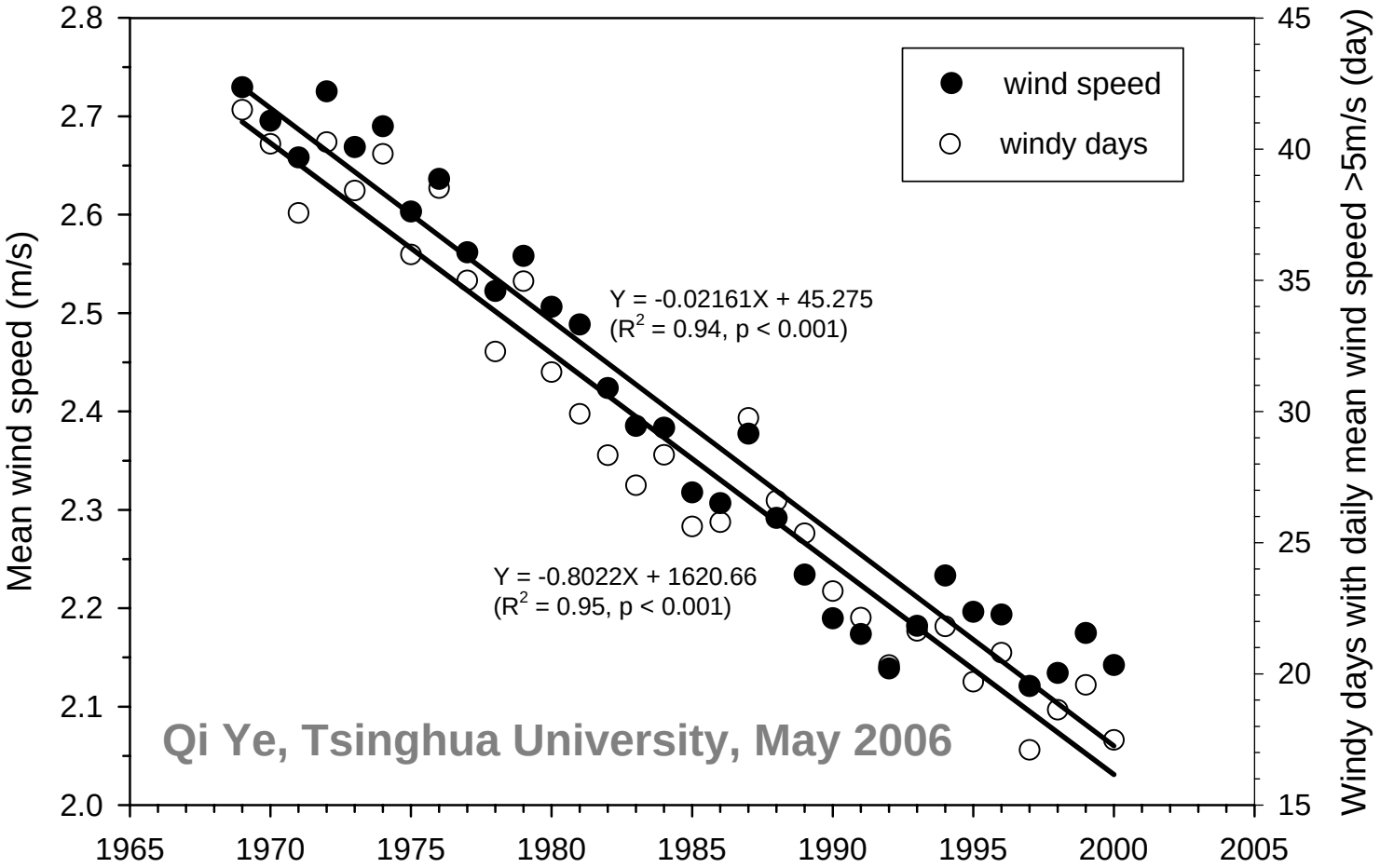
Total power released by tropical cyclones (green) has increased along with sea surface temperatures (blue).



Kerry Emanuel, MIT, 2006

Harm is already occurring (continued)

The East Asia monsoon has been weakening



The change is as predicted by Chinese climate modelers. It has produced increased flooding in the South of China and increased drought in the North.

Glaciers feeding China's rivers are shrinking

Qinghai - Xizhan (Tibet) plateau

the roof-of-the-world, 2.5 million km^2

important role in climate of China

hot-spot of climate change

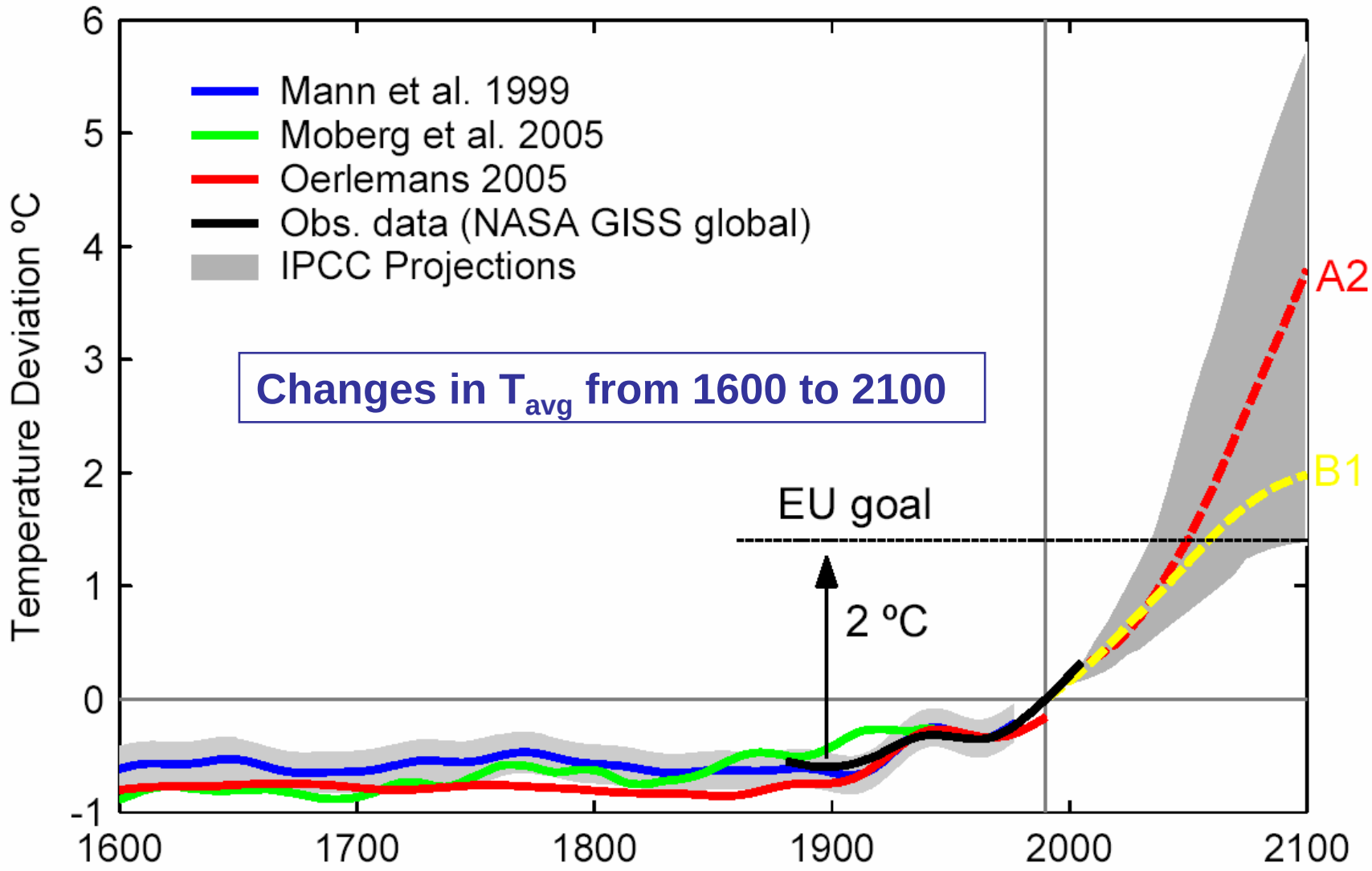
temperature rise by ~0.9°C since 1980s

Increase in thawing of permafrost

Decrease in glacier area by 7% per year

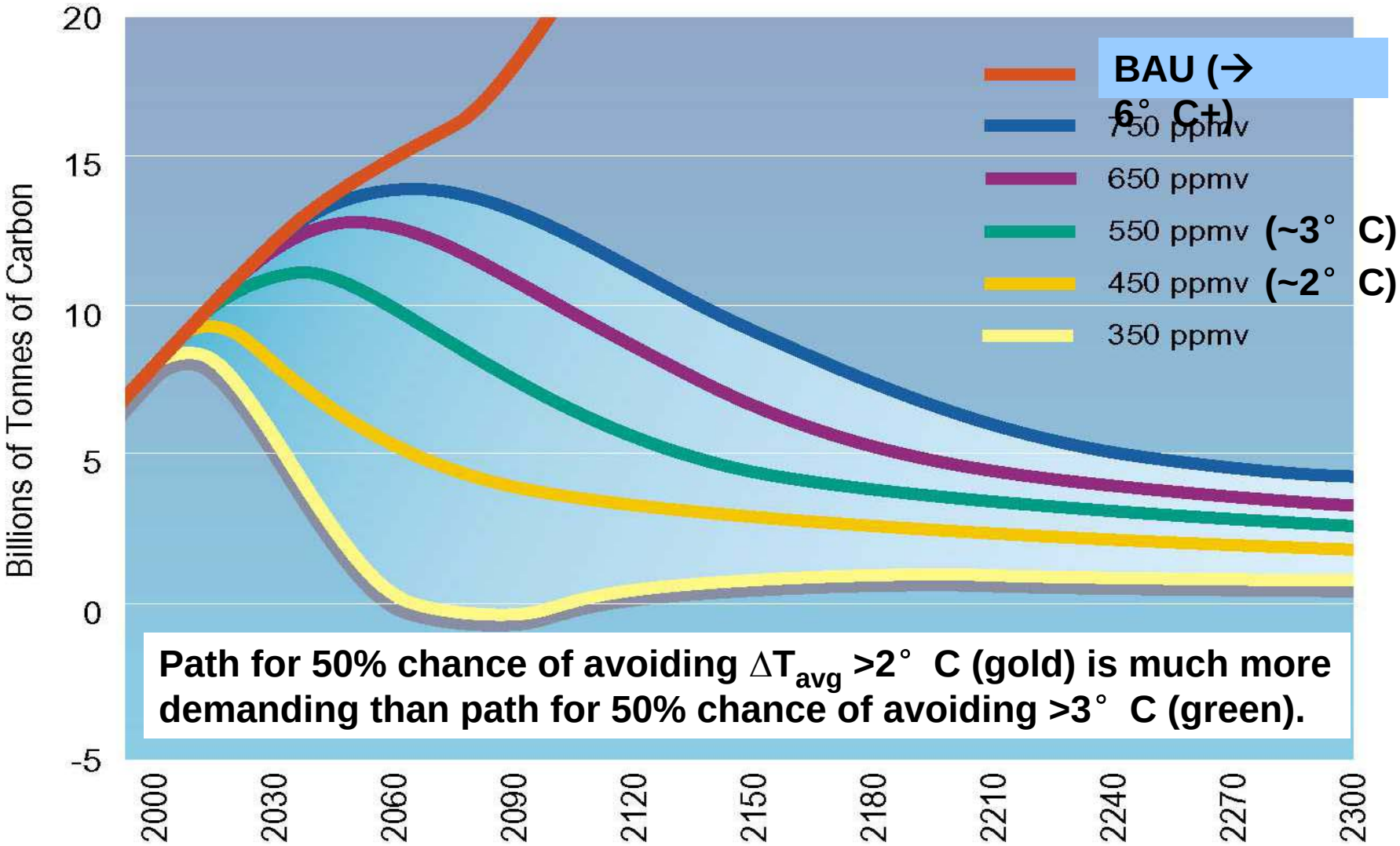
Xiangming Xiao, U of New Hampshire, May 2005

Far bigger change occurs in the BAU future

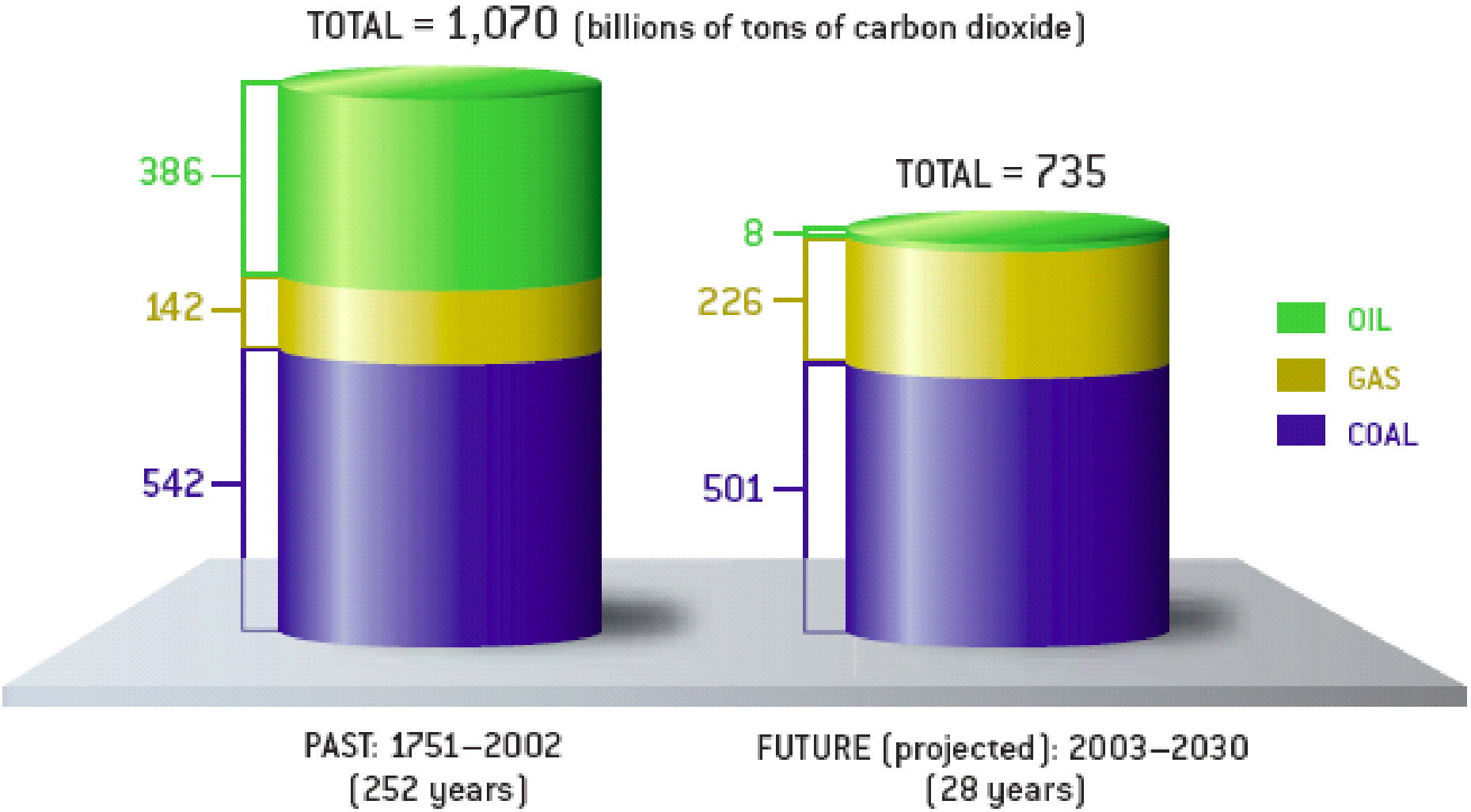


Last time T was 2ºC above 1900 level was 130,000 years ago, and sea level was 4-6 m higher. Last time it was 3ºC above 1900 level was ~25 million years ago, and sea level was 20-30 m higher.

CO_2 emissions paths: BAU versus stabilizing CO_2 concentration to limit ΔT_{avg}



What if we don't implement CCS? CO_2 emissions from power plants to be built in the next 25 years



LIFETIME FOSSIL-FUEL EMISSIONS from power plants projected to be built during the next quarter of a century will be comparable to all the emissions during the past 250 years. The left column

Courtesy David Hawkins, Rob Socolow, & Scientific American

Some key references

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UN Scientific Expert Group on Climate Change & Sustainable Development, *Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable*, United Nations Foundation, February 2007 http://www.unfoundation.org/SEG/

National Commission on Energy Policy, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges,* December 2004; and *Energy Policy Recommendations for the President* and the 110th Congress, April 2007 http://www.energycommission.org

Intergovernmental Panel on Climate Change, Climate Change 2007: Climate Change Impacts, Adaptation, and Vulnerability, Summary for Policy Makers. April 2007. http://www.ipcc.ch/

Intergovernmental Panel on Climate Change, *Climate Change 2007: Mitigation. Summary for Policy Makers.* May 2007. http://www.ipcc.ch/

Thank you!