Science and Technology for Sustainable Well-Being

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Presidential Lecture at the Annual Meeting of the American Association for the Advancement of Science
San Francisco, 15 February 2007

It is clear that the future course of history will be determined by the rates at which people breed and die, by the rapidity with which nonrenewable resources are consumed, by the extent and speed with which agricultural production can be improved, by the rate at which the under-developed areas can industrialize, by the rapidity with which we are able to develop new resources, as well as by the extent to which we succeed in avoiding future wars. All of these factors are interlocked.

Harrison Brown (1917-1986),
The Challenge of Man's Future, 1954

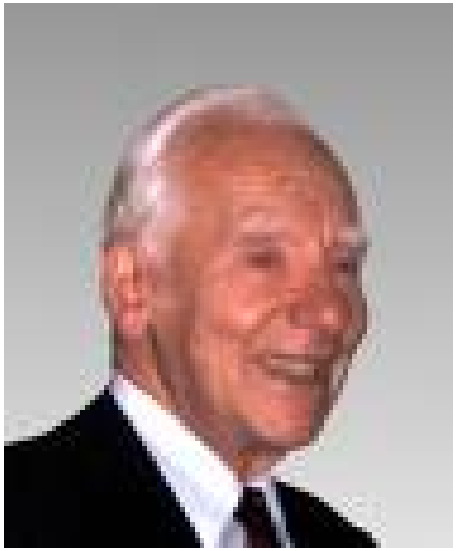
My pre-occupation with the great problems at the intersection of science and technology with the human condition – and with the interconnectedness of these problems with each other – began when I read *The Challenge of Man's Future* in high school. I later worked with Harrison Brown at Caltech.

I had the great good fortune to work with several other giants in the study and practice of science-society interactions who have now passed on.

Harvey Brooks

Gilbert White

Roger Revelle



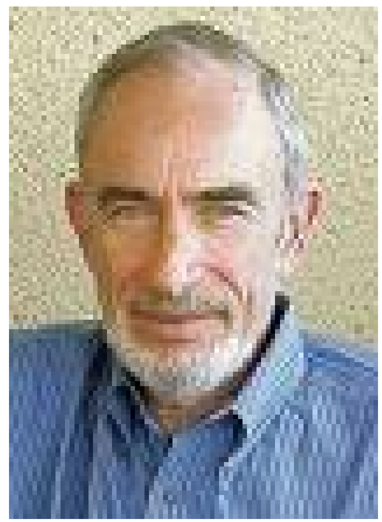
Joseph Rotblat

Jerry Wiesner

Dick Garwin

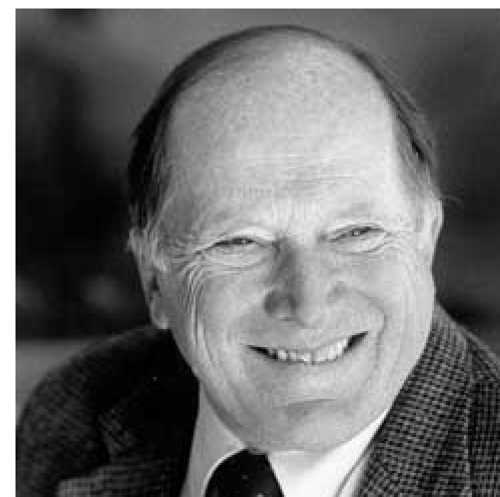
The next generation of giants in interdisciplinary "public interest science" is still with us. I learned much from those pictured here.

Lew Branscomb



Paul Ehrlich

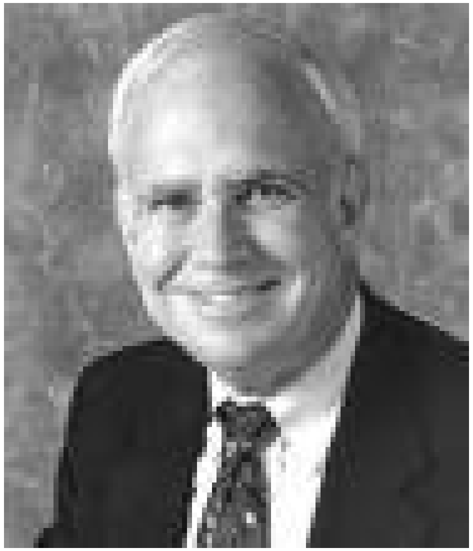
Murray Gell-Mann



George Woodwell

A number of my predecessors in the presidency of the AAAS have likewise focused their efforts particularly on the intersection of science and technology with the problems of sustainable well-being that I will be discussing tonight.

Gil Omenn



Peter Raven

Shirley Ann Jackson

Jane Lubchenco

The AAAS is itself not about science in isolation, but about science <u>in</u> society.

AAAS

ADVANCING SCIENCE, SERVING SOCIETY

About AAAS

Q: What is the AAAS mission?

A: AAAS seeks to "advance science and innovation throughout the world for the benefit of all people." To fulfill this mission, the AAAS Board has set the following broad goals:

- Foster communication among scientists, engineers and the public;
- Enhance international cooperation in science and its applications;
- Promote the responsible conduct and use of science and technology;
- Foster education in science and technology for everyone;
- Enhance the science and technology workforce and infrastructure;
- Increase public understanding and appreciation of science and technology; and
- Strengthen support for the science and technology enterprise.

Foundations of human well-being

Human well-being rests on a foundation of three pillars, the preservation & enhancement of all 3 of which constitute the core responsibilities of society:

- <u>economic conditions and processes</u>

  such as employment, income, wealth, markets, trade, productive technologies…

- <u>sociopolitical conditions and processes</u>

  such as law & order, national & homeland security, governance, justice, education, health care, science, culture & the arts, liberty, privacy…

- <u>environmental conditions and processes</u>

  such as air, water, soils, mineral resources, the biota, nutrient cycles, climatic processes…

Foundations (continued)

- Arguments about which one of the three pillars is "most important" are pointless.
  - Each of the three is <u>indispensable</u>.

    Failure in any one of them means collapse of the human enterprise (the metaphor of the three-legged stool).
  - The three <u>interact</u>.

    The economic system cannot function without inputs from the environmental system, nor can it function without elements of societal stability provided by the sociopolitical system.

    And societal stability itself cannot be maintained in the face of environmental disaster, as Katrina and New Orleans demonstrated is true even in the most economically prosperous country in the world.

My definitions

- Development means improving the human condition in all its aspects, not only economic but also sociopolitical and environmental.

- Sustainable development means doing so by means and to end points that are consistent with maintaining the improved conditions indefinitely.

- Sustainable well-being implies pursuing sustainable development to achieve well-being where it is absent and putting the maintenance & expansion of well-being onto a sustainable basis where it is being provided unsustainably today.

Impediments to sustainable well-being

- persistence of poverty & preventable disease
- impoverishment of the environment
- pervasiveness of armed conflict
- oppression of human rights
- wastage of human potential

Factors driving or aggravating the impediments

- Non-use, ineffective use, and misuse of science and technology
- Maldistribution of consumption and investment
- Incompetence, mismanagement, and corruption
- Continuing population growth
- Ignorance, apathy, and denial

Contributors to global mortality in 2000

Millions of Years of Life Lost (WHO, World Health Report 2002)

• childhood & maternal malnutrition	200
• high blood pressure, cholesterol, over-weight, low physical activity	150
• unsafe sex	80
• tobacco	50
• unsafe water	50
• war & revolution, 20th century avg	40
• indoor smoke from solid fuels	35
• alcohol	30
• urban air pollution	6
• climate change	5

Contributors to global mortality in 2000

Millions of Years of Life Lost (WHO, World Health Report 2002)

- childhood & maternal malnutrition **(POVERTY)** 200
- high blood pressure, cholesterol, overweight, low physical activity **(CONSUMPTION)** 150
- unsafe sex **(IGNORANCE, DENIAL)** 80
- tobacco **(IGNORANCE, DENIAL)** 50
- unsafe water **(POVERTY)** 50
- war & revolution, 20^{th} century avg **(CONFLICT)** 40
- indoor smoke from solid fuels **(TECHNOLOGY)** 35
- alcohol **(IGNORANCE, DENIAL)** 30
- urban air pollution **(CONSUMPTION, TECHNOLOGY)** 6
- climate change **(CONSUMPTION, TECHNOLOGY, DENIAL)**

S&T for sustainable well-being: What can they contribute?

- Science:
  - improving understanding of threats & possibilities
  - enabling advances in technology
- Technology:
  - driving economic growth via new products & services, reduced costs, increased productivity
  - reducing resource use & environmental impacts
- S&T:
  - integrated assessment of options
  - advice to decision-makers & the public about costs, benefits, dangers, uncertainties
  - S&T education toward a more S&T-literate society

S&T for sustainable well-being: Four key challenges

- Meeting the basic needs of the poor
- Managing the competition for land, soil, water, and the net primary productivity of the planet
- Mastering the energy-economy-environment dilemma
- Moving toward a nuclear-weapon-free world

Meeting the basic needs of the poor:

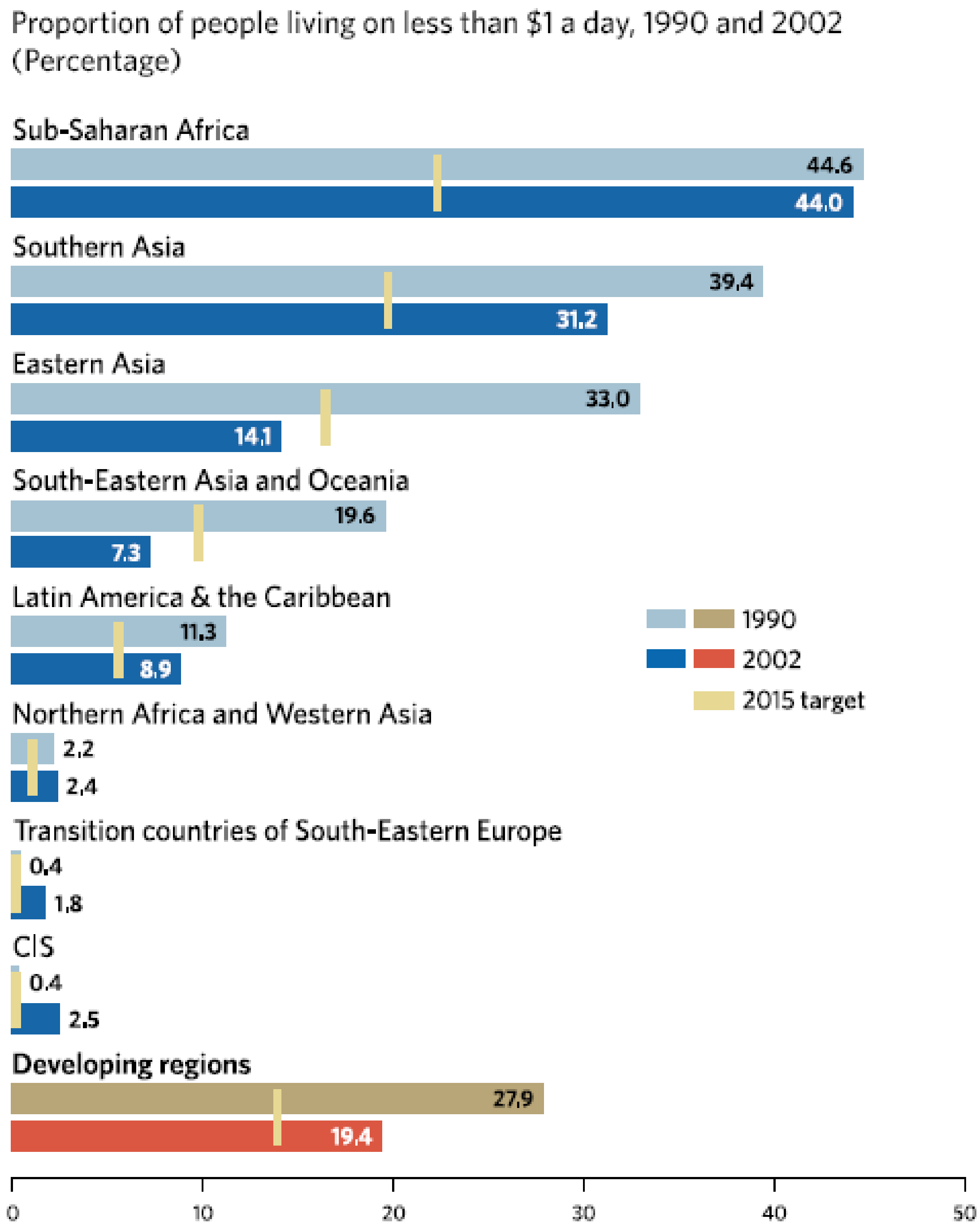
The UN Millennium Development Goals

The test of our progress is not whether we add more to the abundance of those who have much; it is whether we provide enough for those who have too little.

Franklin D. Roosevelt
Second Inaugural Address, 1937

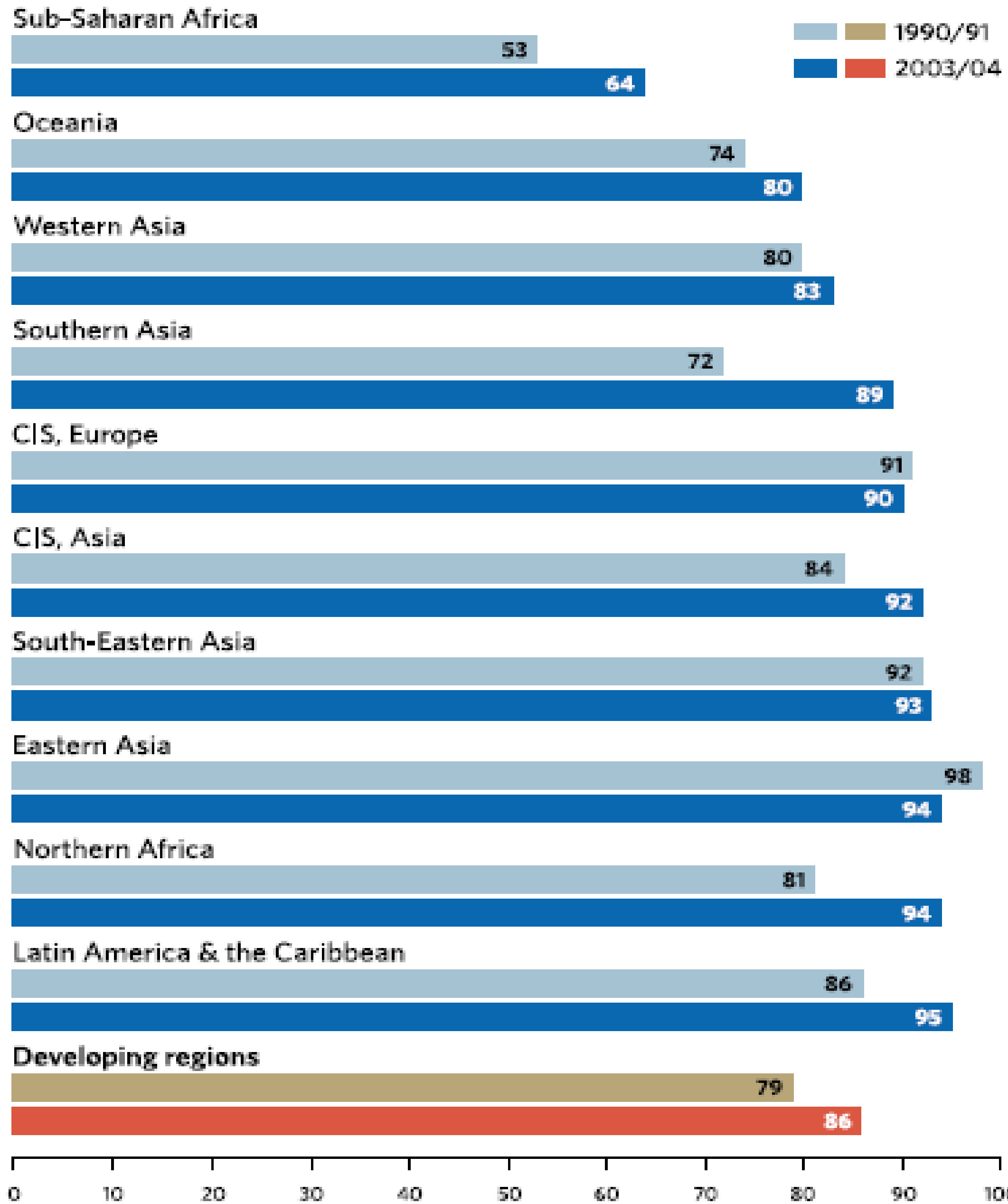
Goal 1
Eradicate extreme poverty & hunger

TARGET: Halve, between 1990 and 2015, the proportion of people living on less than $1/day and the proportion of people suffering from hunger.



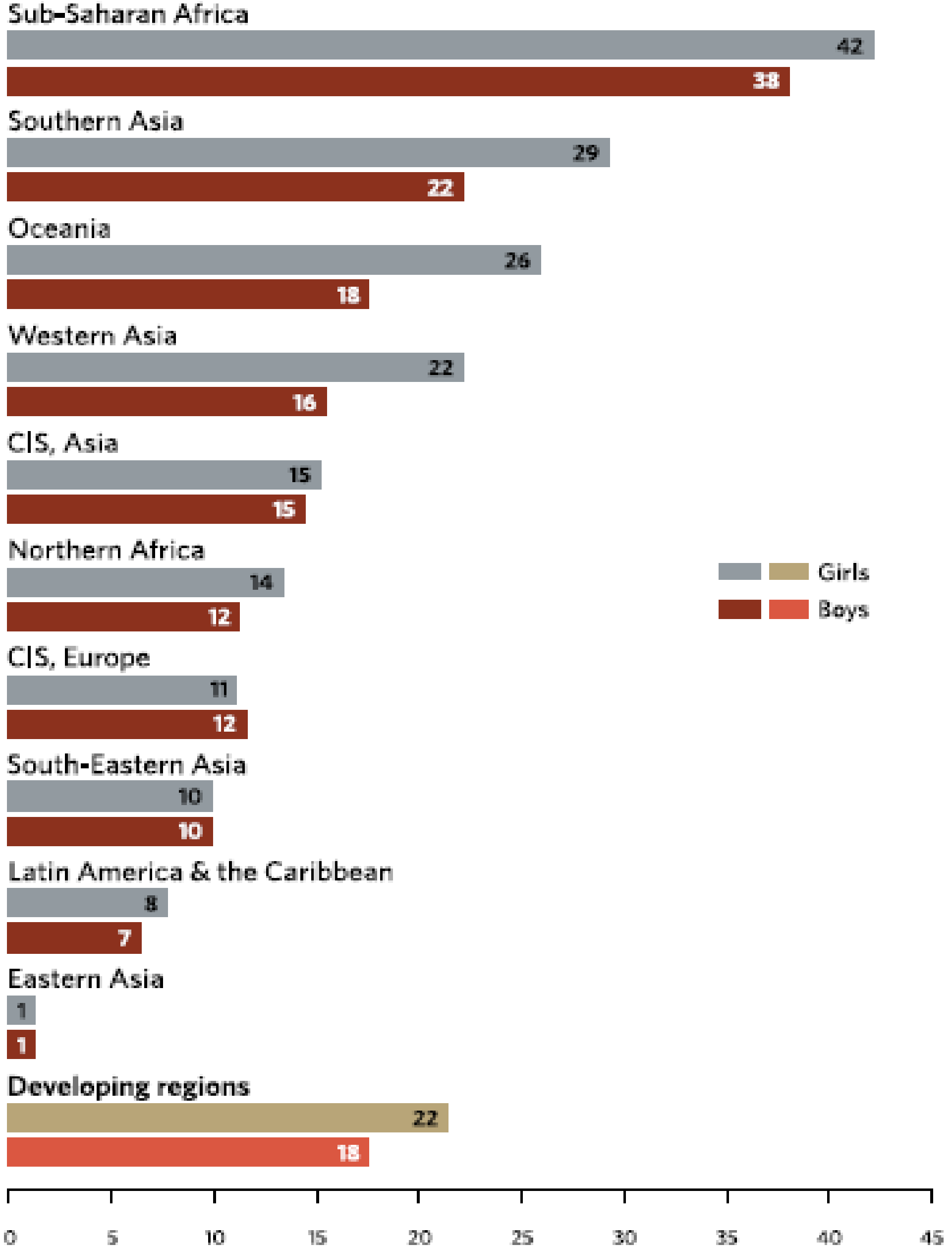
Goal 2
Achieve universal primary education

Net enrolment ratio in primary education, 1990 / 91 and 2003 / 04
(Percentage)



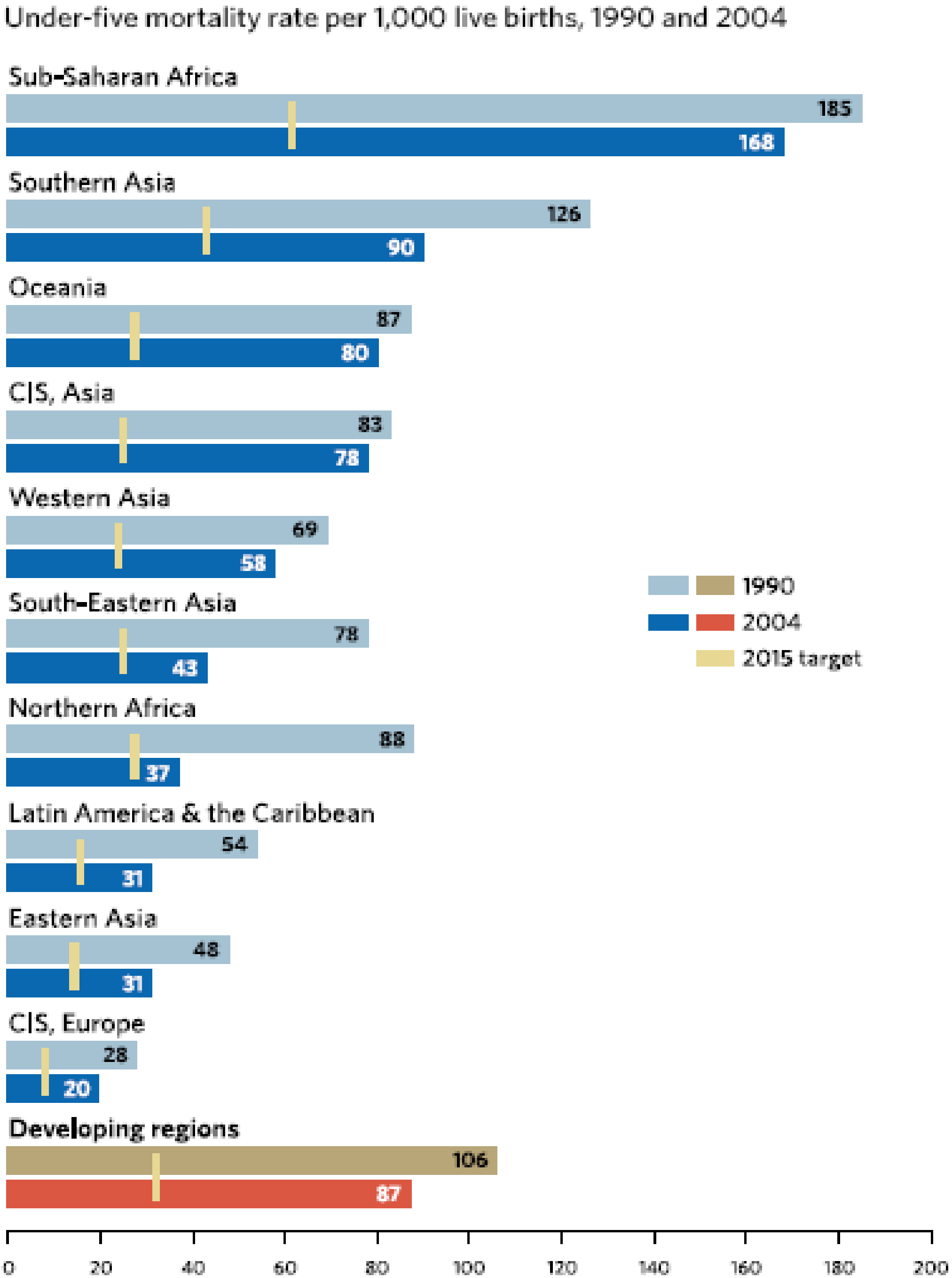
Goal 3
Promote gender equality and empower women

Proportion of children of primary school age out of school by sex, 1996/2004 (Percentage)

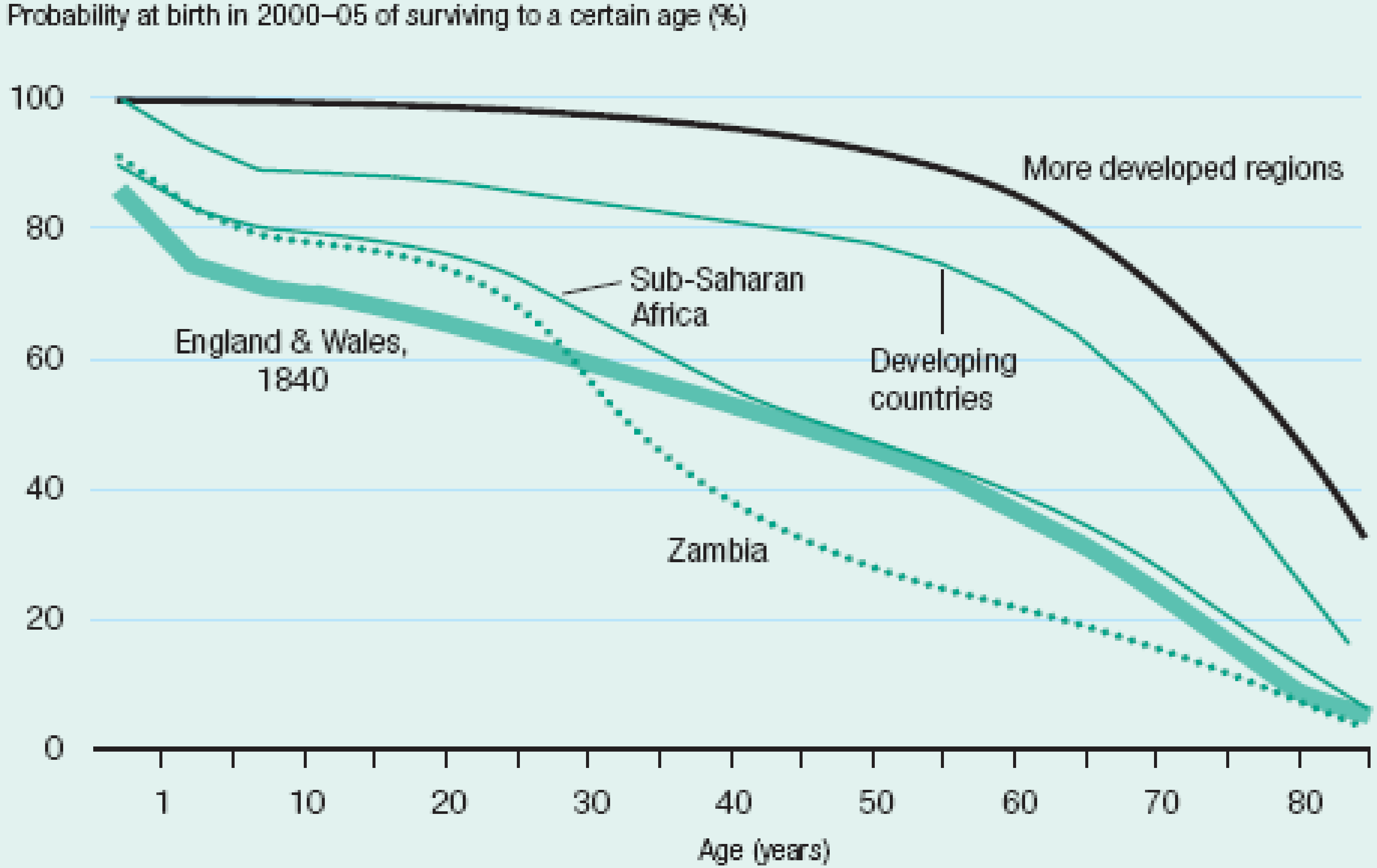


Goal 4
Reduce child mortality

TARGET: Reduce by 2/3, between 1990 and 2015, the under-5 mortality rate.



Survival curve in sub-Saharan Africa resembles that of 1840s England

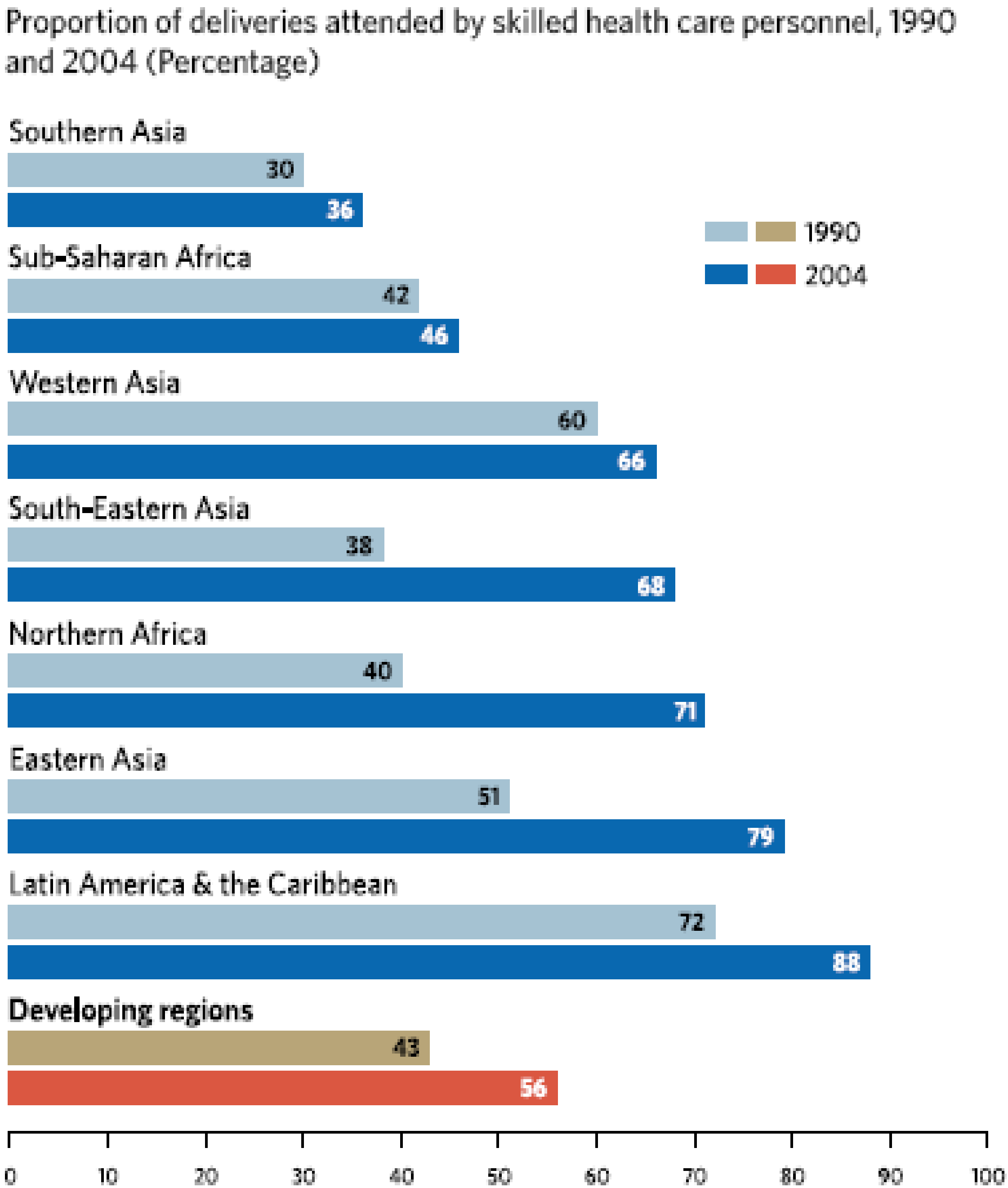


Source: UN 2005d and University of California, Berkeley and Max Planck Institute for Demographic Research 2005.

UNDP Human Development Report 2005

Goal 5
Improve maternal health

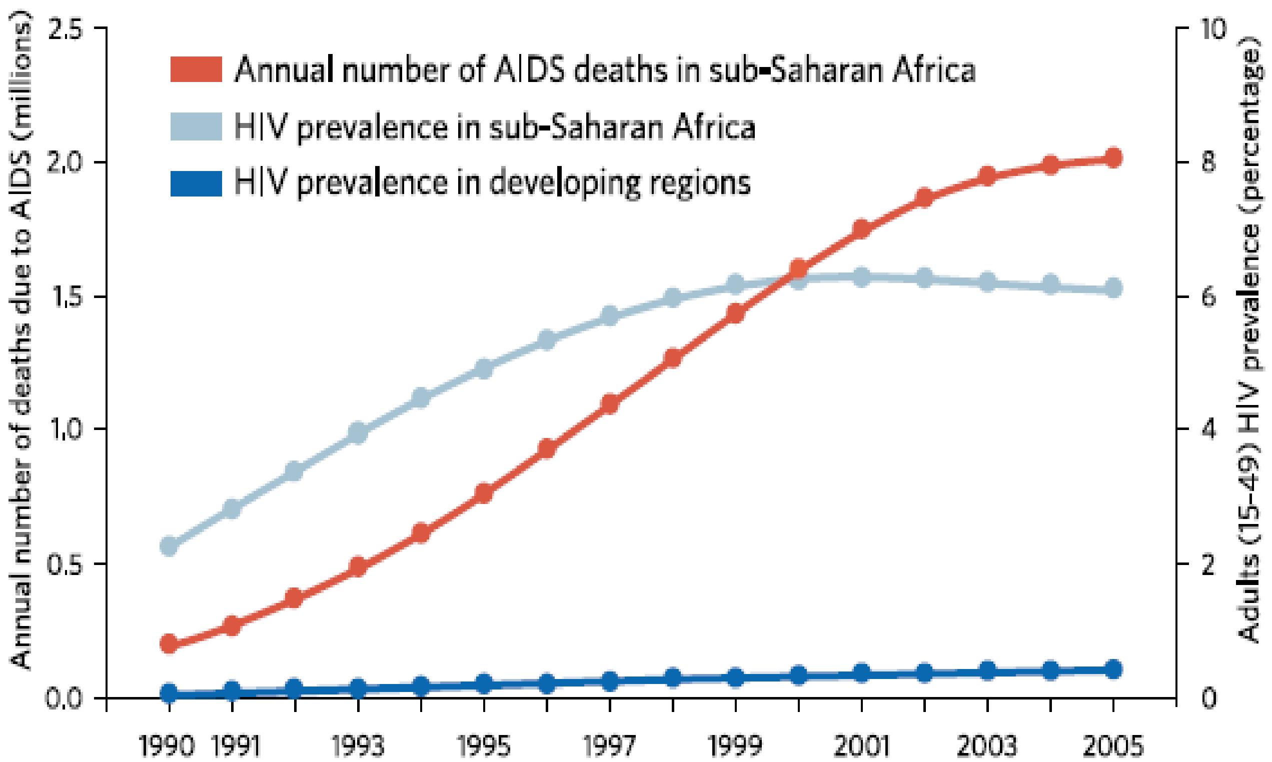
TARGET: Reduce by 3/4, between 1990 and 2015, the maternal mortality rate



Goal 6
Combat HIV/AIDS, malaria & other diseases

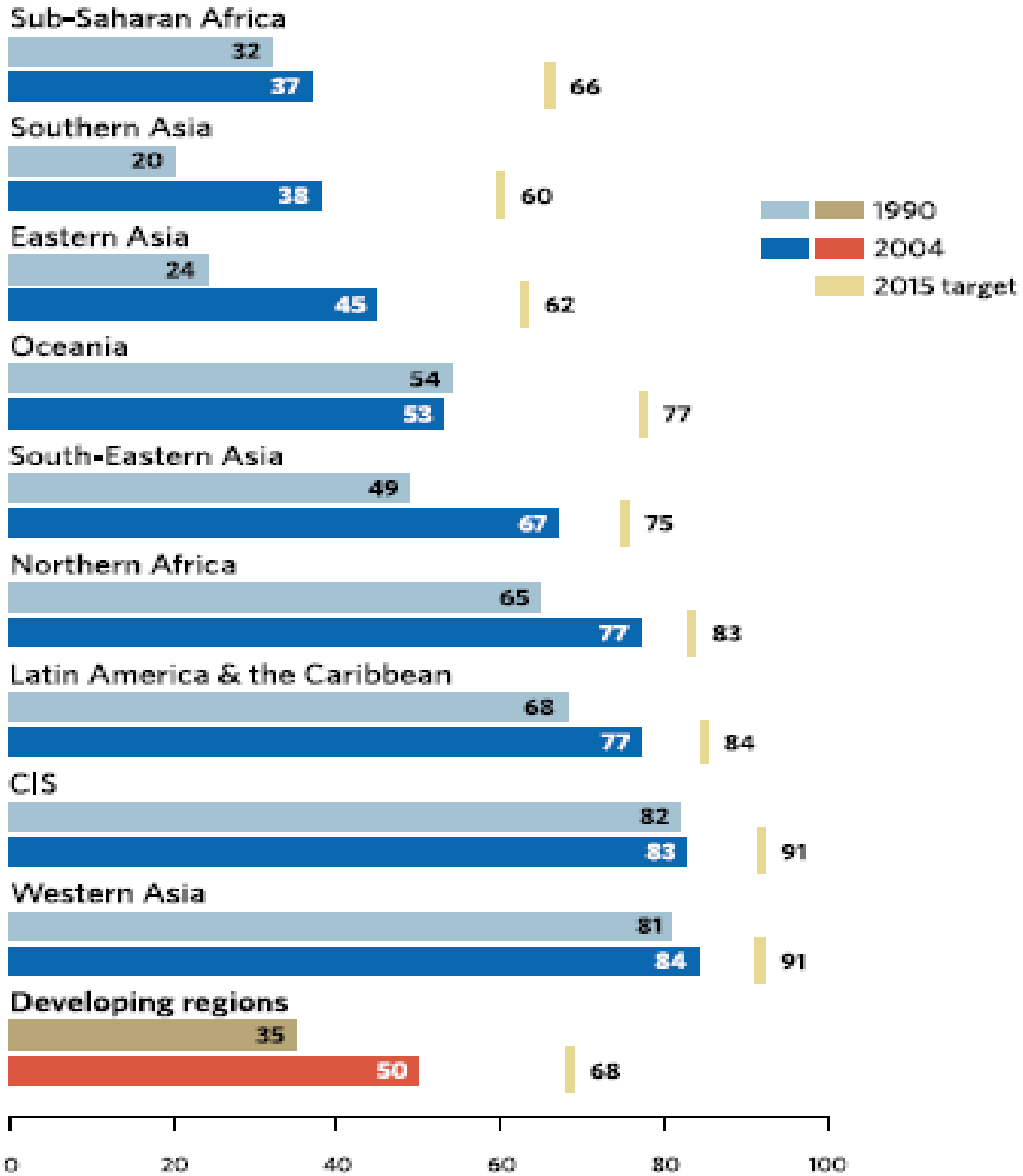
TARGET: By 2015 have halted and begun to reverse the spread of HIV aids and the incidence of malaria and other major diseases.

HIV prevalence in adults aged 15-49 in sub-Saharan Africa and all developing regions (Percentage) and number of AIDS deaths in sub-Saharan Africa (Millions), 1990-2005

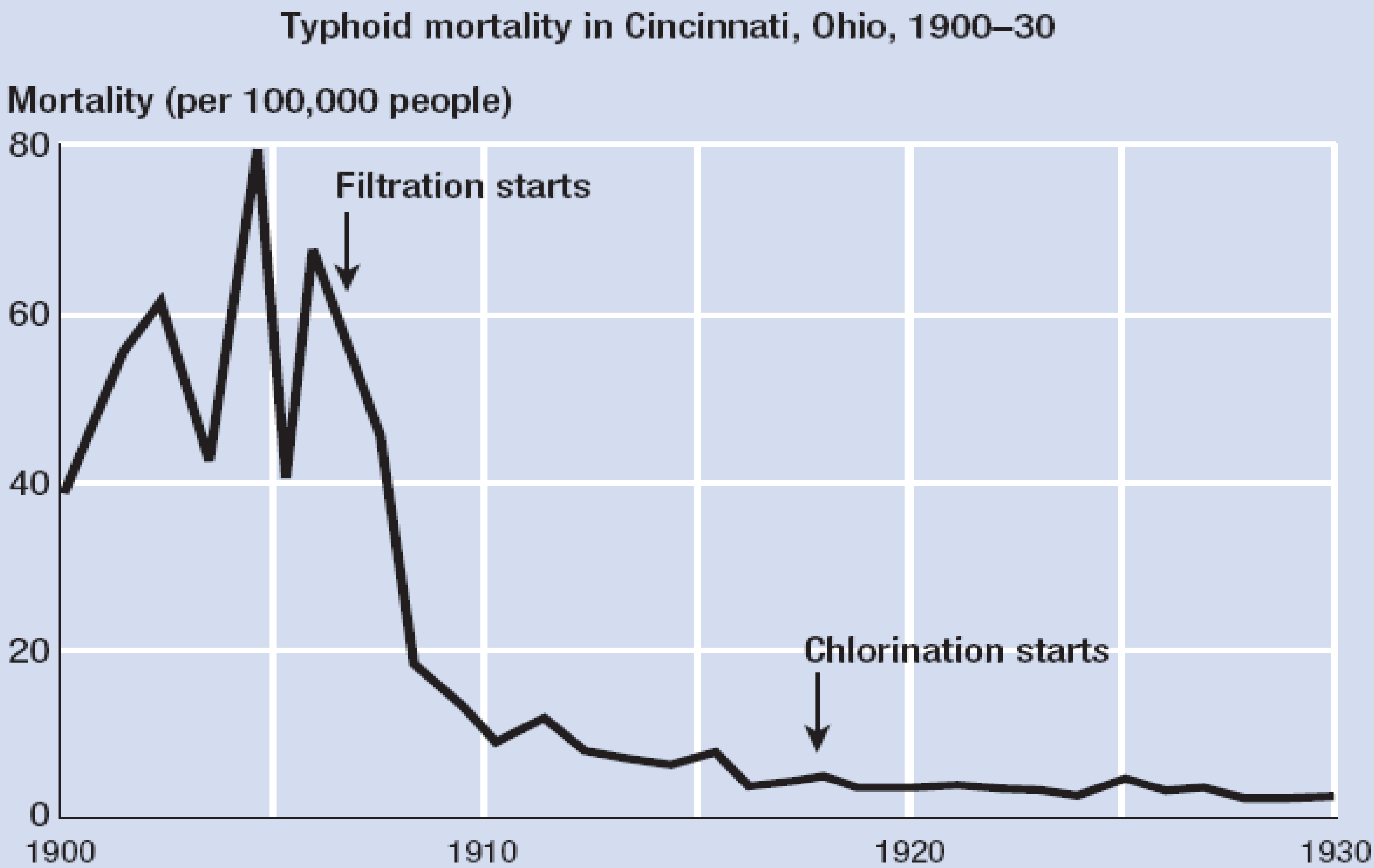


Goal 7
Ensure environmental sustainability

Proportion of population using improved sanitation, 1990 and 2004
(Percentage)



Effective technologies need not be complicated

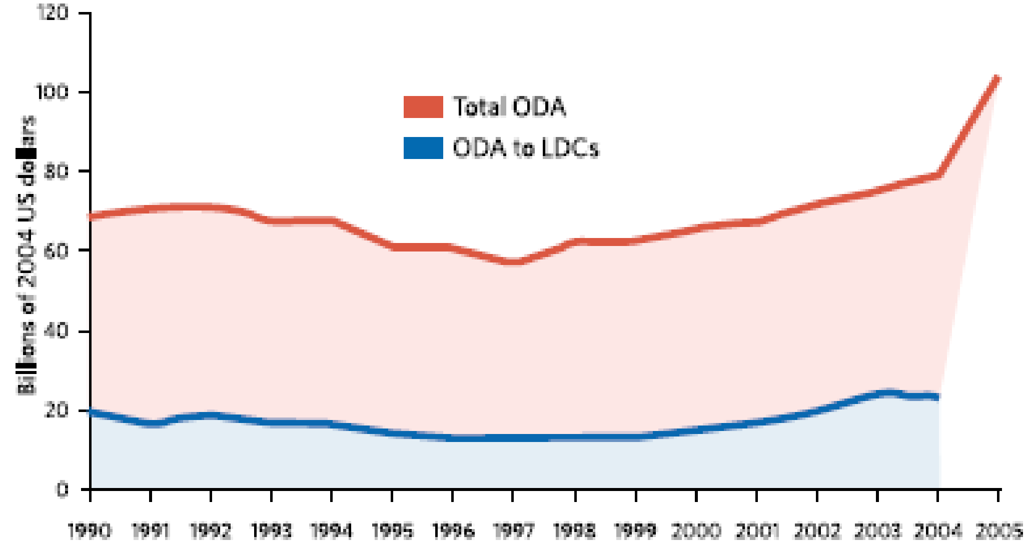


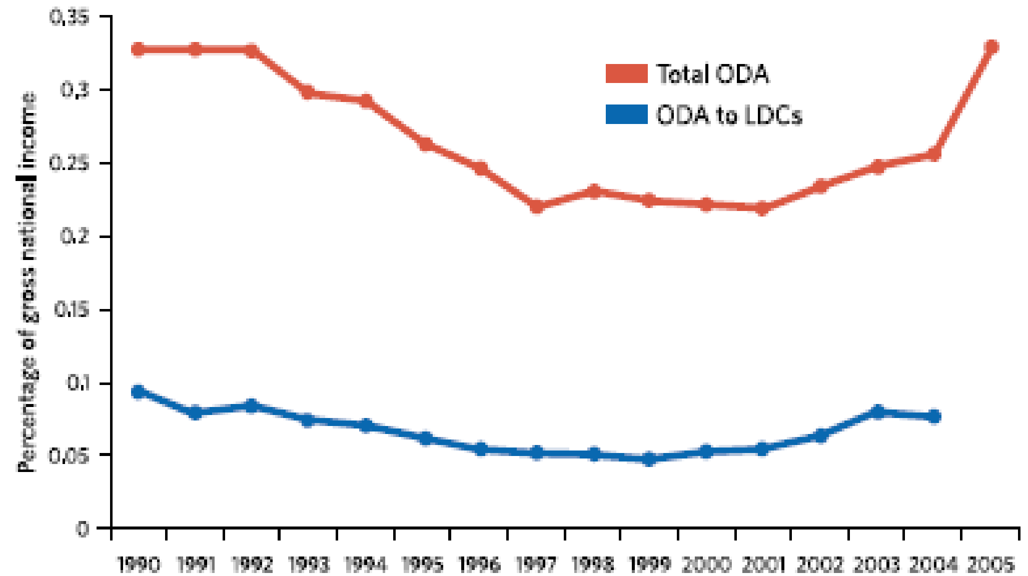
Source: University of California, Berkeley, and MPIDR 2006; CDC 2006; Cutler and Miller 2005.

UNDP Human Development Report 2006

Goal 8
Develop a global partnership for development

Official development assistance from developed countries, 1990-2005
(Constant 2004 United States dollars and as a proportion of donor country gross national income)

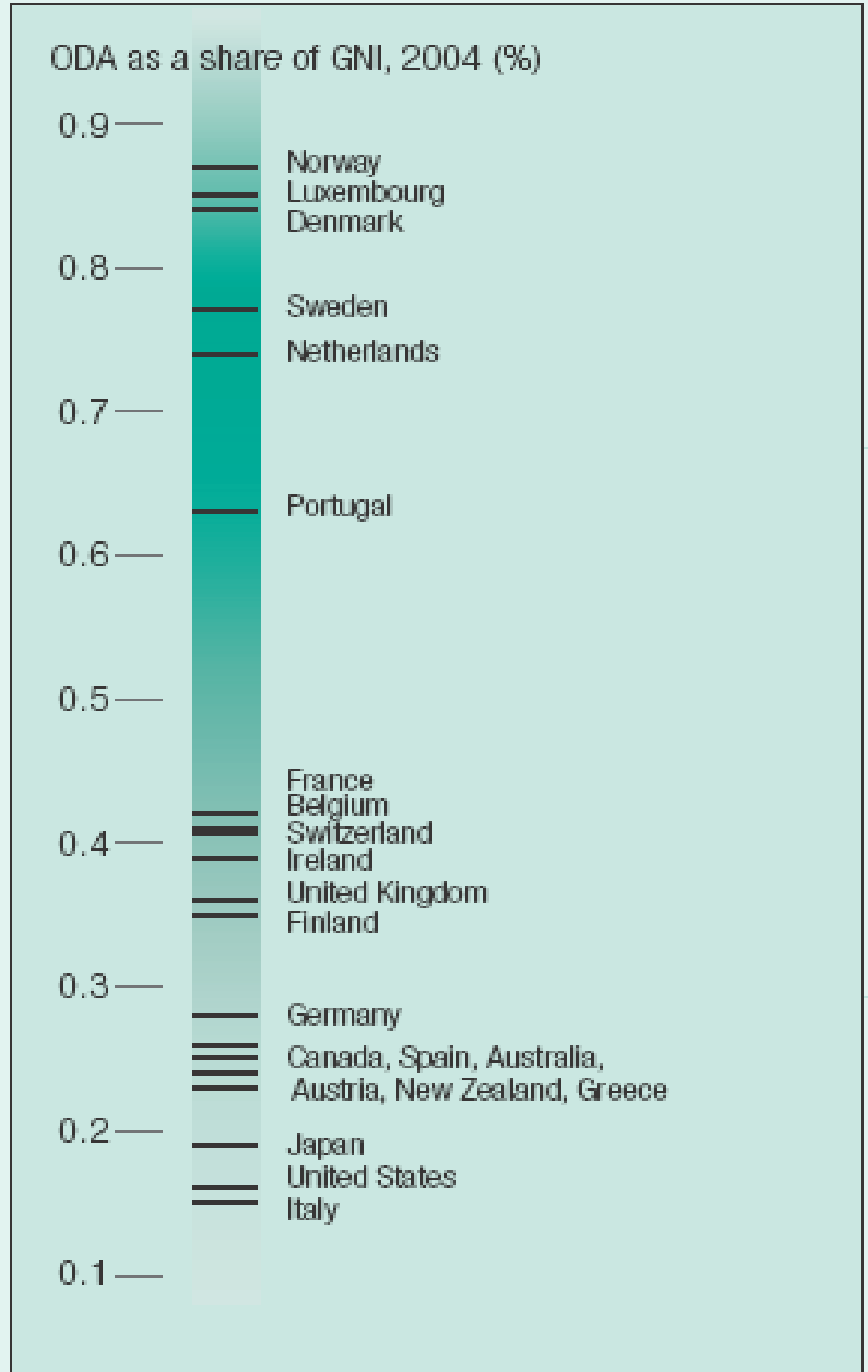




Total Official Development Assistance is to all developing countries.

LDCs = Least Developed Countries

The United States is the second stingiest of OECD nations in Official Development Assistance as a percentage of our GDP.



Managing the competition for land, soil, water, and the net primary productivity of the planet

Competing human uses for the land, soil, water, and NPP of the Earth

- land for housing, commerce, industry, and transport infrastructure
- land, soil, water, and net primary productivity for production of food, forage, fiber, biofuels, chemical feedstocks
- land, water, & biota for recreation, beauty, solace of unspoiled nature, and ecosystem functions

Key ecosystem functions

- regulation of water flows
- purification/detoxification of soil, water, air
- nutrient cycling
- soil formation
- controls on pests & pathogens
- pollination of flowers & crops
- biodiversity maintenance
- climate regulation (evapotranspiration, reflectivity)
- carbon sequestration

Challenges to managing the competition among these uses

- pressure of rising population & affluence
- rising tide of toxic spillovers from agriculture, industry, energy supply
- disruption of global & regional climate by greenhouse gases from fossil-fuel combustion
- haphazard, unintegrated, and short-range planning
- frequent failure to charge a price for destroying environmental resources and services

The competition for fresh water: Where's the water and where is it going?

	cubic kilometers
Water in the oceans	1,400,000,000
Water locked up in ice	30,000,000
Ground water	10,000,000
Water in lakes & rivers	100,000

	cubic kilometers per year
Precipitation on land	120,000
Evaporation from land	70,000
River runoff & groundwater recharge	50,000
Available river flow & recharge*	12,000
Withdrawals for human use	5,000
World desalting capacity	13

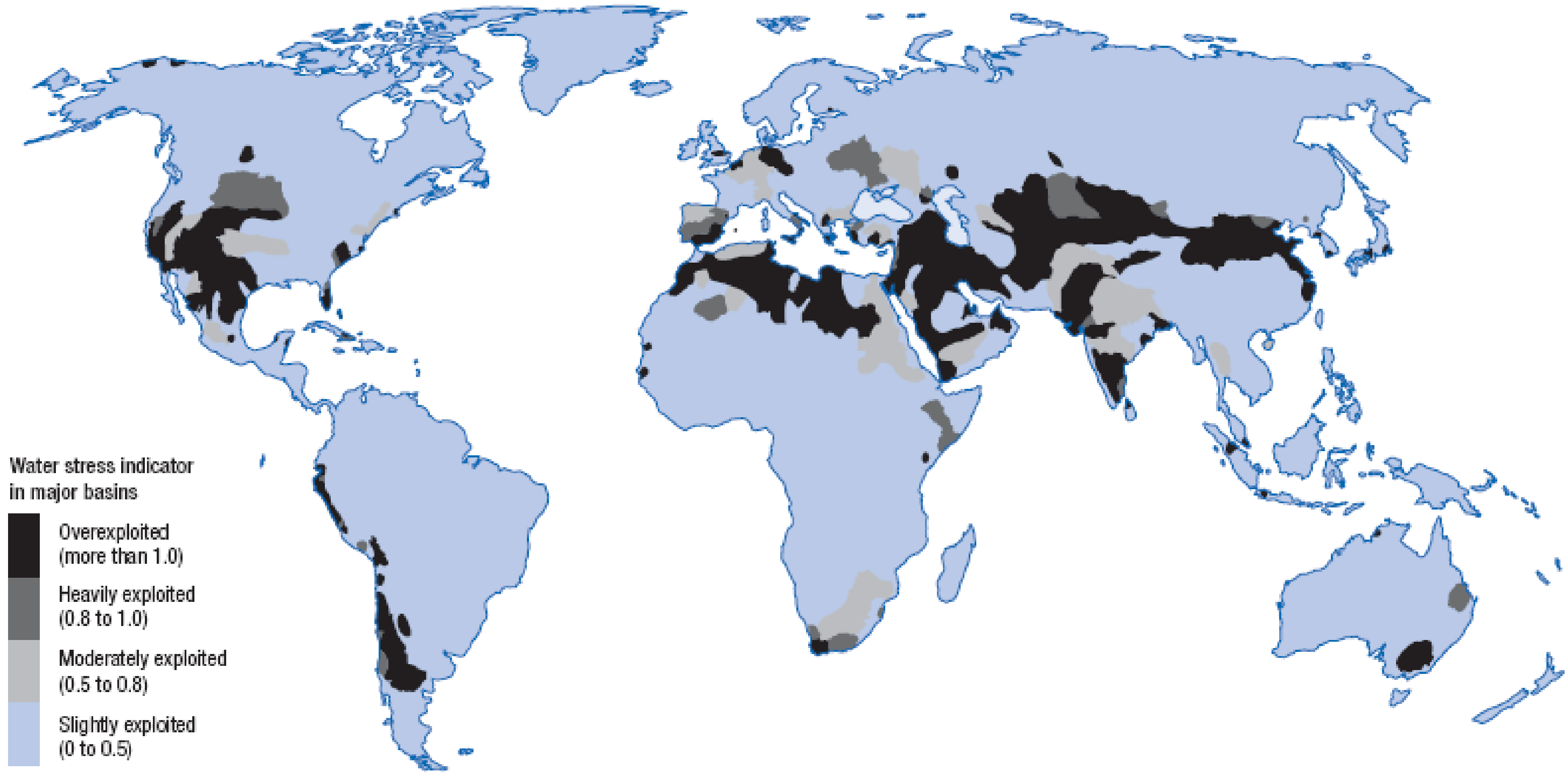
* = runoff + recharge – uncaptured storm runoff – remote areas

Key numbers for water demand

	cubic kilometers per year
Global withdrawals for human use	5,000
of which agriculture	*3,500*
…industry	*1,000*
…domestic	*500*
of which drinking water	*5*
…bottled water	*0.17*

	cubic meters per person per year
Global average withdrawals per person	800
Nigeria…	50
Israel…	300
China…	500
Mexico…	800
Italy…	1,000
United States…	2,000

The geography of water stress

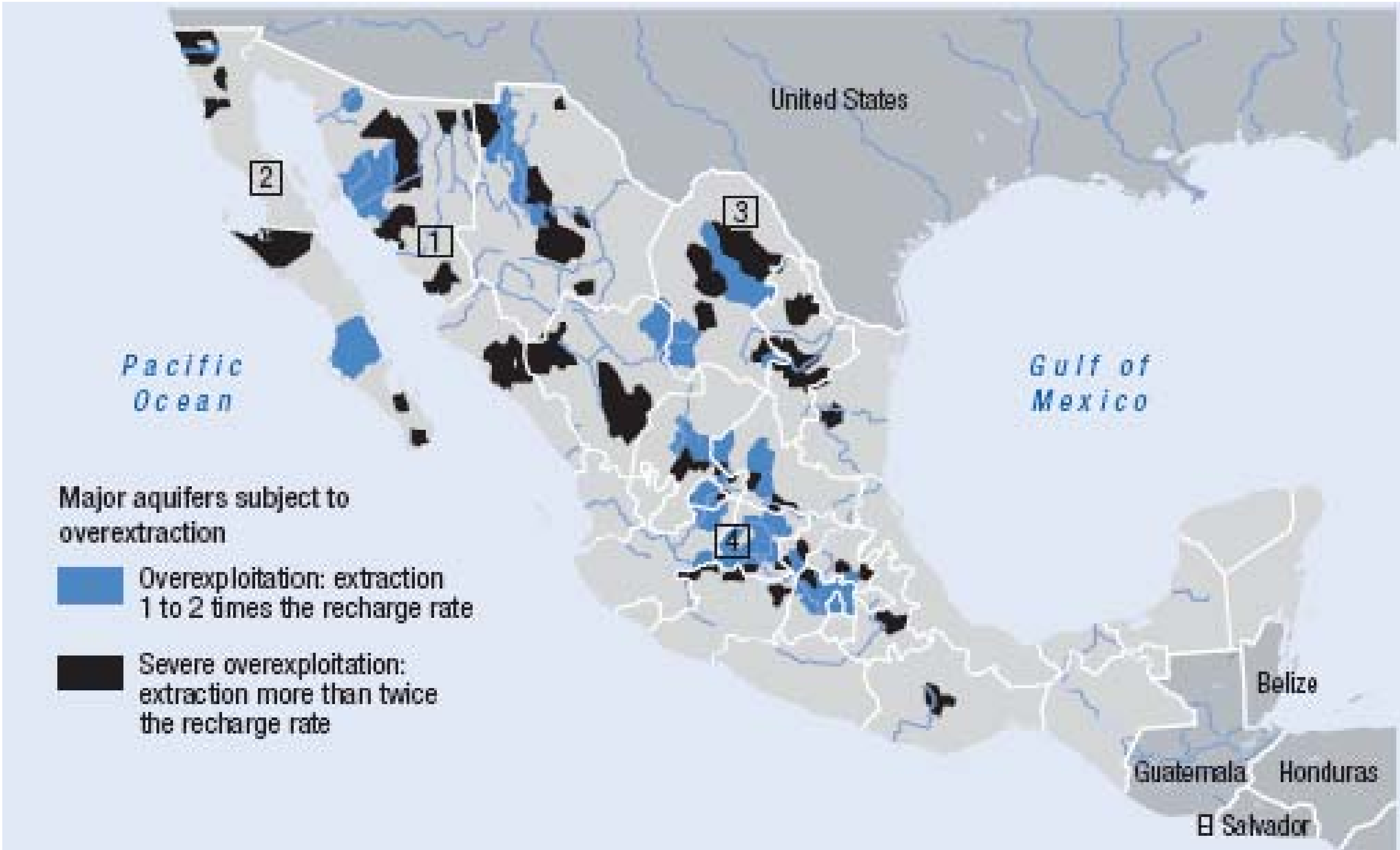


Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Source: Smakhtin, Revenga and Döll 2004.

UNDP Human Development Report 2006

Sinking aquifers: the case of Mexico



1. Hermosillo Coast. Intensive production of agricultural exports and wheat for domestic market.
2. Baja California. Large-scale commercial production of fruit and vegetables by companies linked to US market.
3. Coahuila. One of Mexico's fastest sinking aquifers and major site for production of alfafa to supply feed to livestock sector.
4. El Bajio. Source of 90% of Mexico's frozen fruit and vegetable export. Production dominated by large-scale commercial farms and agro-industrial processing plants supplying US market.

UNDP Human Development Report 2006

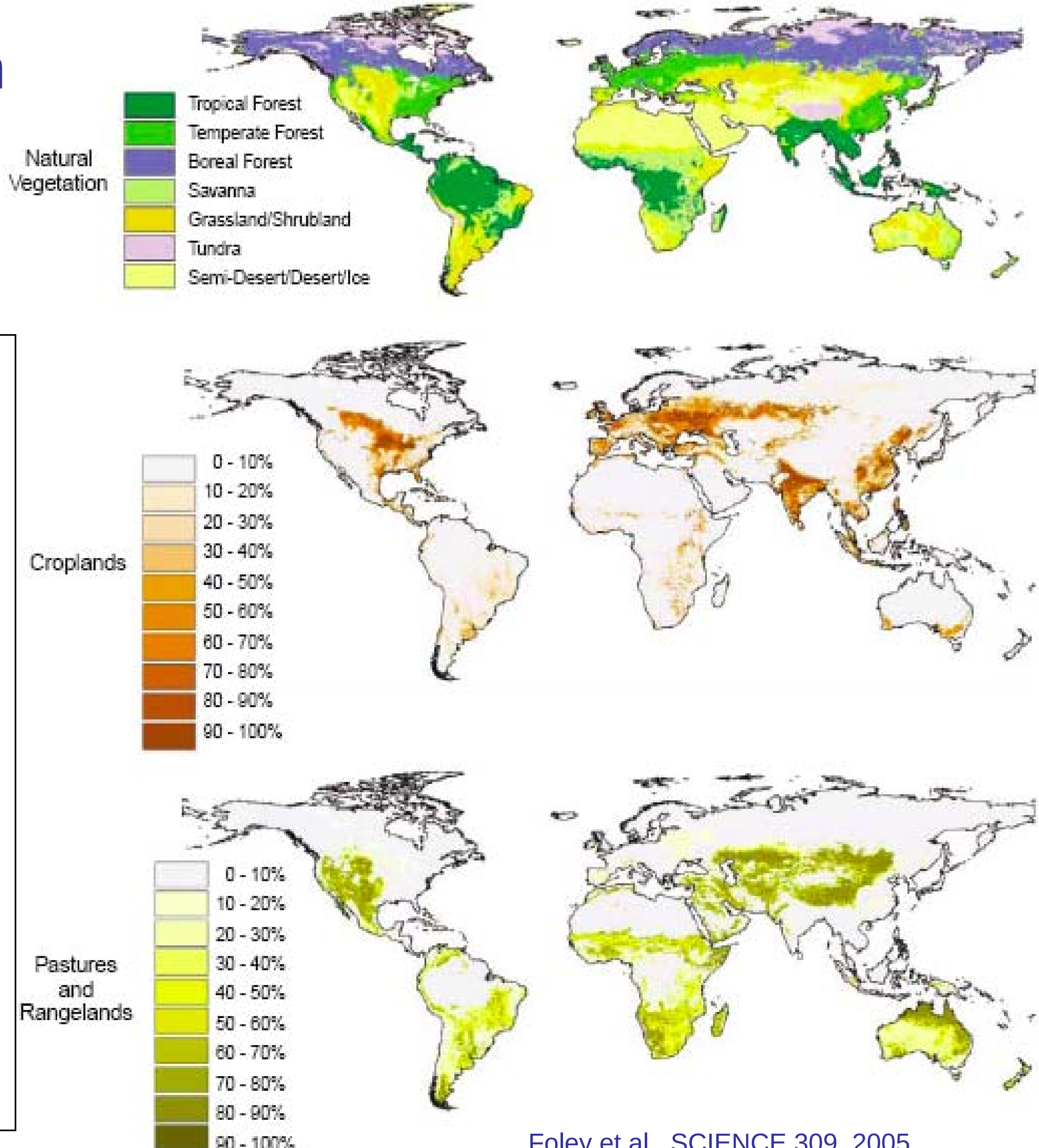
The competition for land

Croplands & pasture-lands now cover ~40% of world land area.

Forest area has declined by ~10 million km2 (about 20%) in the last 300 years, with most of the loss in the last 50.

Desert & near-desert land has <u>increased</u> by nearly as much.

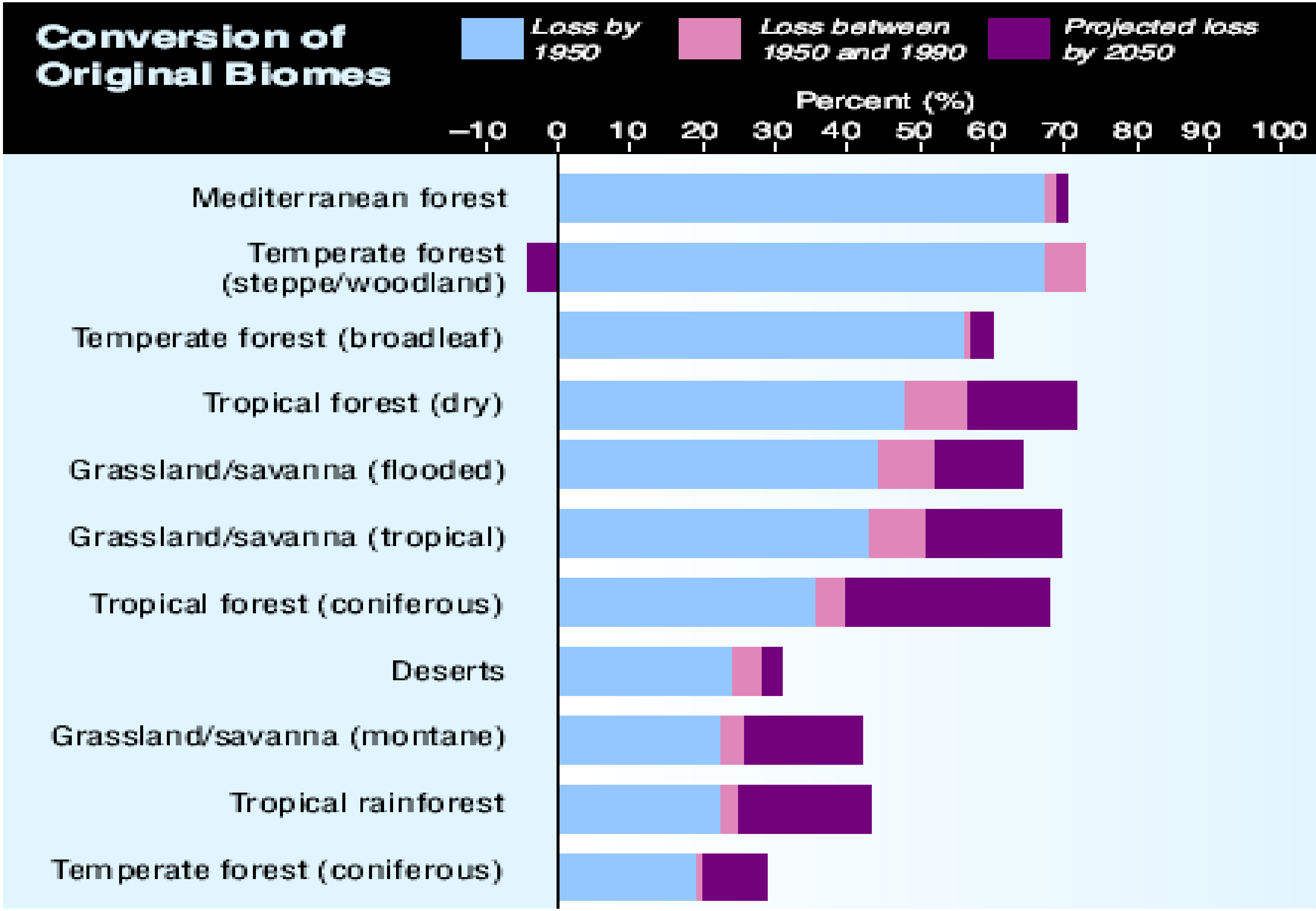
Cities, roads, & airports now cover 2% of world land.



Foley et al., SCIENCE 309, 2005

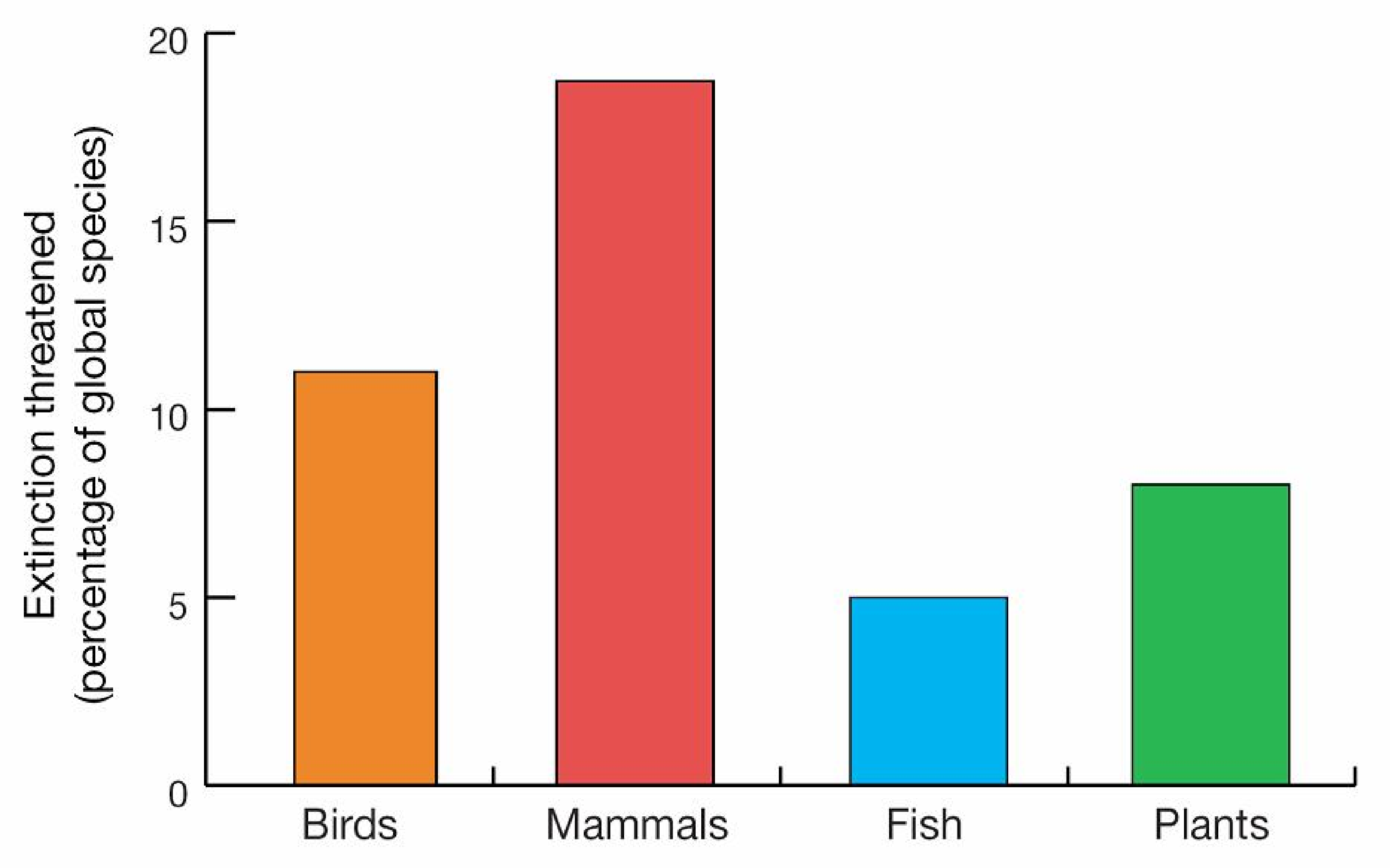
Deforestation for soy growing in the state of Mato Grosso, Brazil

Moutinho and Schwartzman, 2005



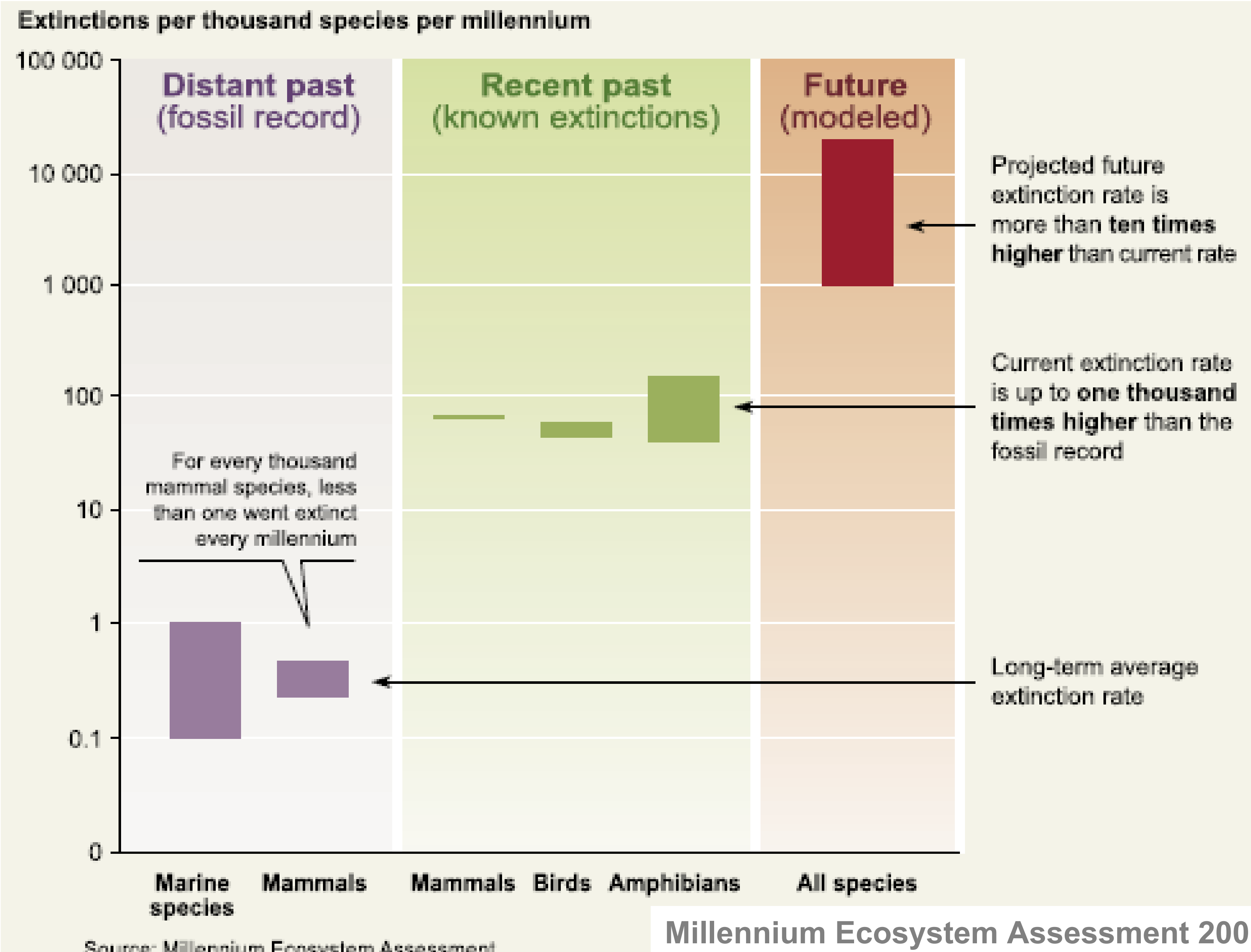
Millennium Ecosystem Assessment 2005

Percentage of species threatened with extinction



Chapin et al., 2000

Comparing past, present, and future extinction rates



Millennium Ecosystem Assessment 2005

Mastering the energy-economy-environment dilemma

The essence of the dilemma

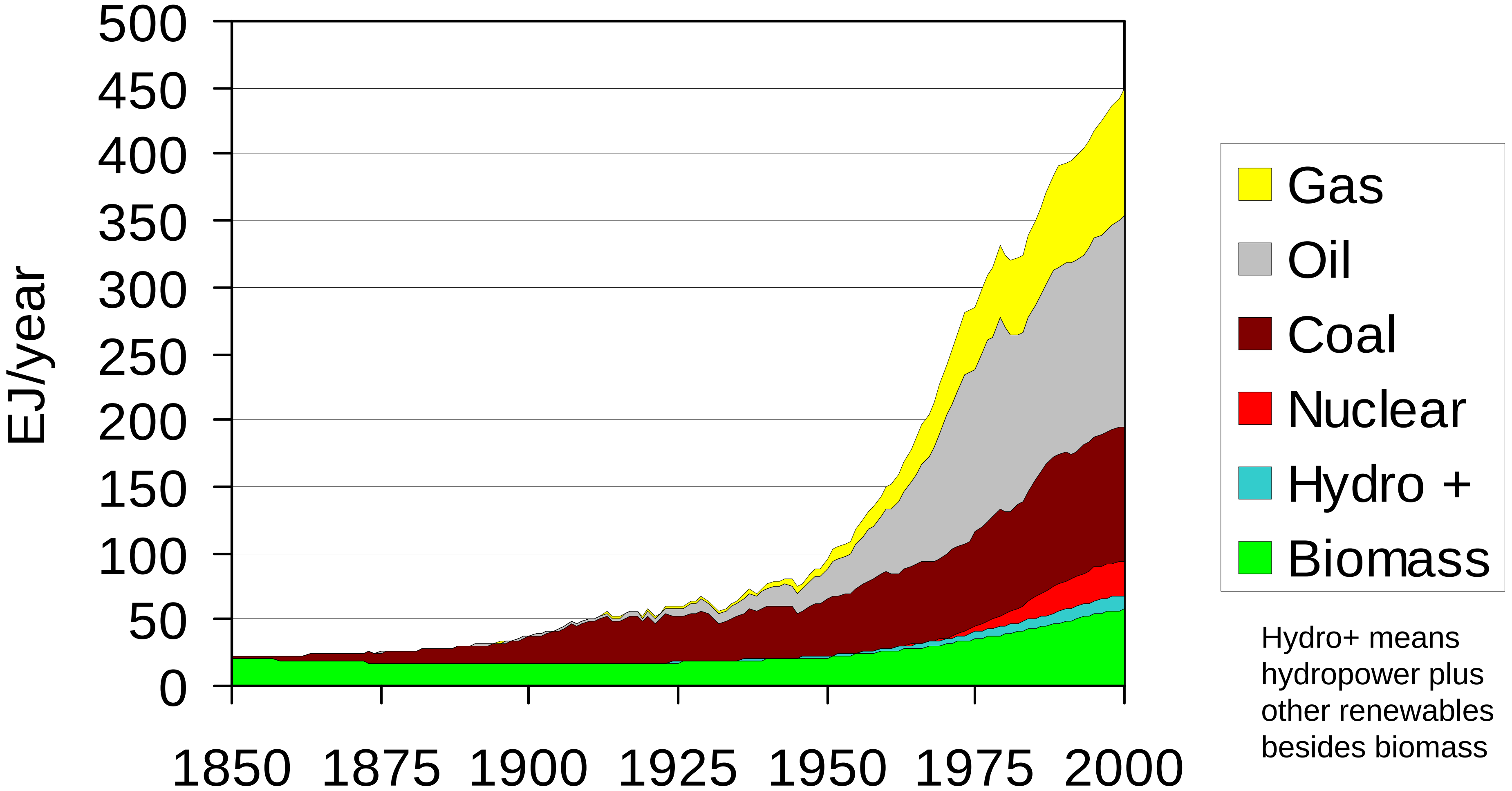
- Reliable and affordable energy is essential for meeting basic human needs and fueling economic growth.
- But many of the most difficult and dangerous environmental problems at every level of economic development arise from the harvesting, transport, processing, & conversion of energy.

Energy supply is the source of…

- most indoor and outdoor air pollution
- most radioactive waste
- much of the hydrocarbon and trace-metal pollution of soil and ground water
- essentially all of the oil added by humans to the seas
- most of the human-caused emissions of greenhouse gases that are altering the global climate.

After four decades of studying these issues, I've concluded that energy is the core of the environment problem, environment is the core of the energy problem, and resolving the energy-economy-environment dilemma is the core of the problem of sustainable well-being for industrial & developing countries alike.

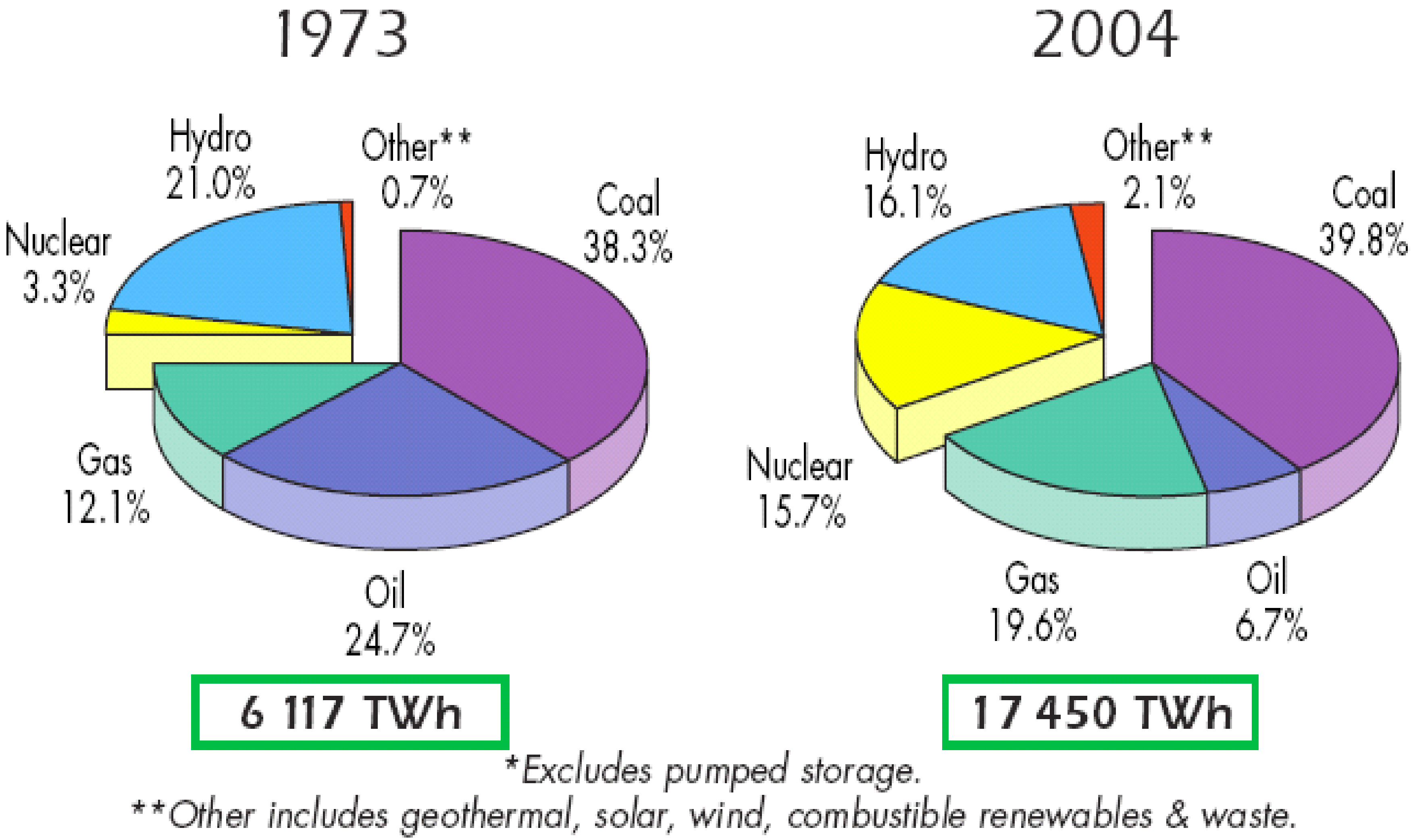
History of world supply of primary energy



Hydro+ means hydropower plus other renewables besides biomass

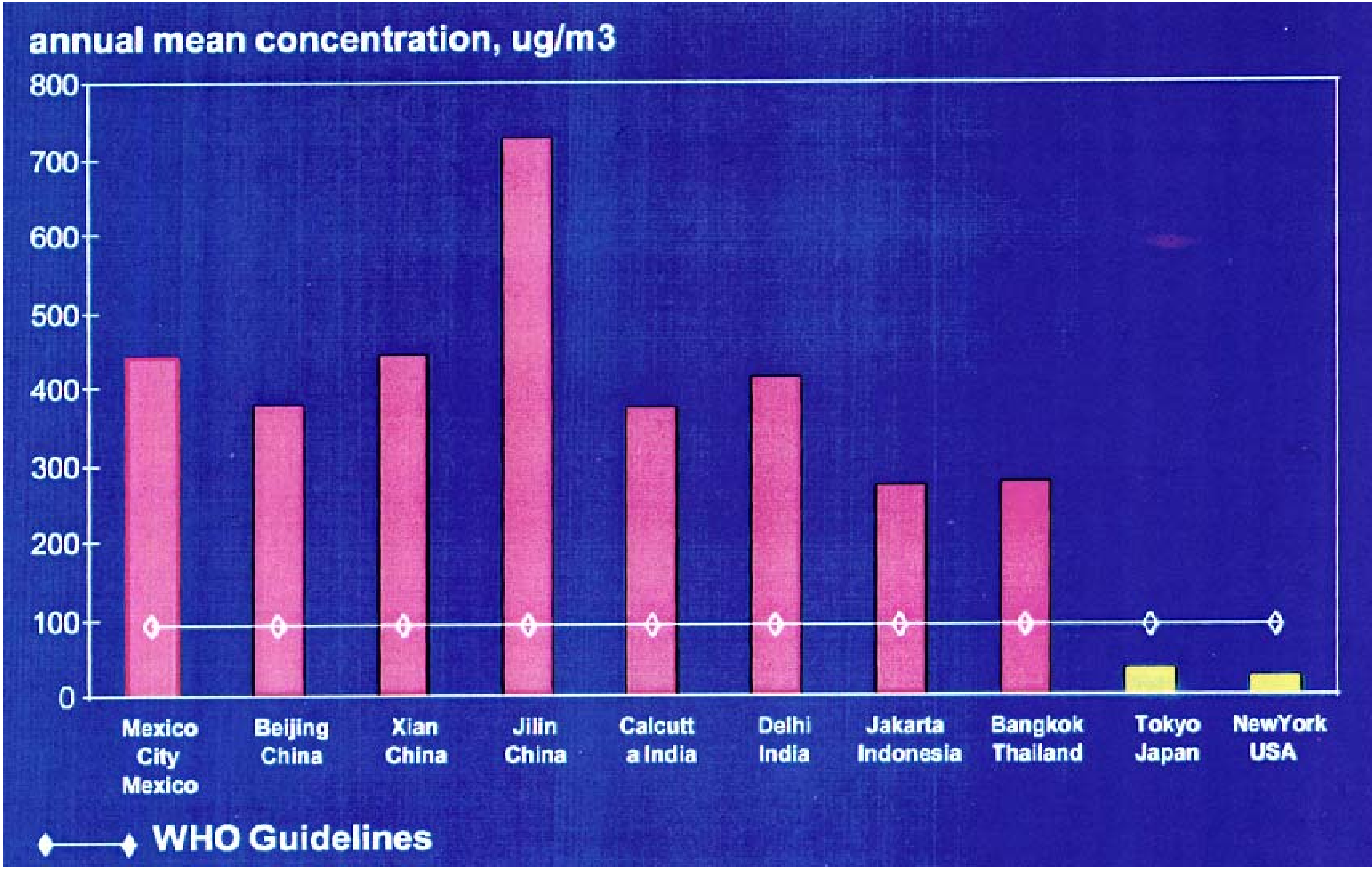
Energy supply grew 20-fold between 1850 and 2000. Fossil fuels supplied 80% of the world's energy in 2000.

About 1/3 of primary energy supply is used to generate electricity



Shares of nuclear, natural gas, & coal growing, those of oil & hydro shrinking. USA gets 50% of its electricity from coal, China gets 80% from coal.

Particulate pollution in selected cities



OECD Environmental data 1995; WRI China tables 1995; Central Pollution Control Board, Delhi. “Ambient Air Quality Status and Statistics, 1993 and 1994”; Urban Air Pollution in Megacities of the World, WHO/UNEP, 1992; EPA, AIRS database.

But indoor particulate pollution is much worse

Indoor & outdoor exposure to total suspended particulate matter (TSP) worldwide, 1996

	Average TSP Concentration (ug/m3)		Percent of world population exposure (% of person-hr-ug/m3)	
	indoor	outdoor	indoor	outdoor
Industrialized				
urban	100	70	7	1
rural	80	40	2	0
Developing				
urban	250	280	25	9
rural	400	70	52	5

85% of global particulate exposure is from indoor air!

Kirk R. Smith, pers. comm., 1999

Business-as-usual (BAU) forecasts to 2030

	2004	2030
Primary energy, exajoules		
World	500	750
United States	107	150
China	73	140
Electricity, trillion kWh		
World	16.5	30
United States	4.0	6.0
China	1.9	4.8

Under continuation of BAU

- World use of primary energy reaches 2.5 times the 2000 level by 2050 and 4 times the 2000 level by 2100.

- World electricity generation reaches 3 times the 2000 level by 2050 and 5 times the 2000 level by 2100.

- The sustainability problem with the business-as-usual energy path is <u>not</u> that we’re running out of energy.

- It’s that we’re running out of cheap and easy liquid fuels and running out of environment.

The two hardest pieces of the problem are…

- Reducing the dangers of urban air pollution and overdependence on oil in the face of ongoing & projected growth in the number of cars in the world

- Providing the affordable energy needed to create & sustain prosperity without wrecking the global climate with carbon dioxide emitted by fossil-fuel burning

…and the second is the bigger challenge of the two.

What climate is & what climate-change means

Climate is the <u>pattern</u> of weather, meaning averages, extremes, timing, spatial distribution of…

- hot & cold
- cloudy & clear
- humid & dry
- drizzles & downpours
- snowfall, snowpack, & snowmelt
- zephyrs, blizzards, tornadoes, & typhoons

When climate changes, the <u>patterns</u> change.

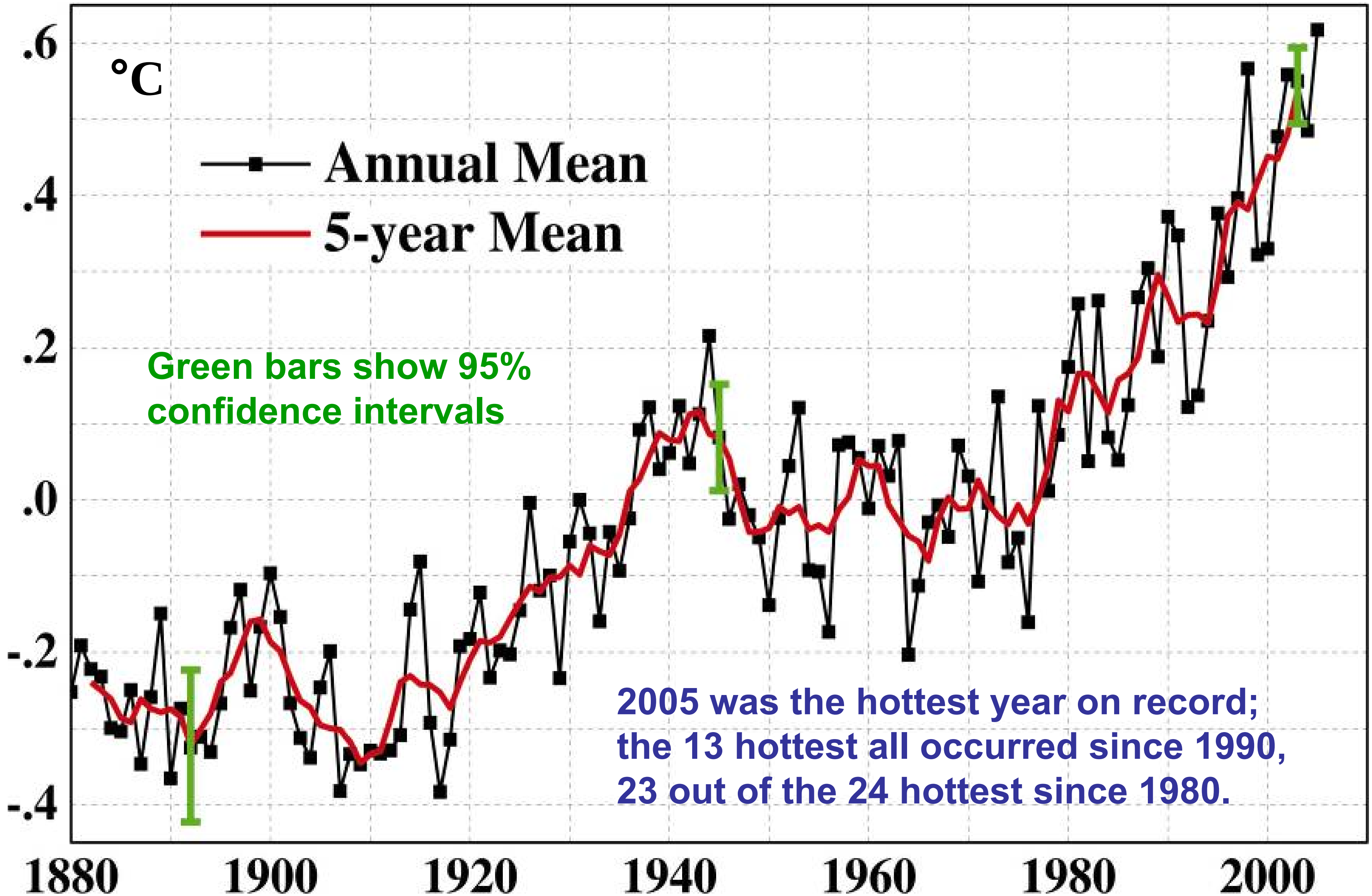
Global average temperature is just an <u>index</u> of the state of the global climate as expressed in these patterns. Small changes in the index → big changes in the patterns.

What climate change puts at risk

Climate governs (so climate change affects)

- availability of water
- productivity of farms, forests, & fisheries
- prevalence of oppressive heat & humidity
- geography of disease
- damages from storms, floods, droughts, wildfires
- property losses from sea-level rise
- expenditures on engineered environments
- distribution & abundance of species

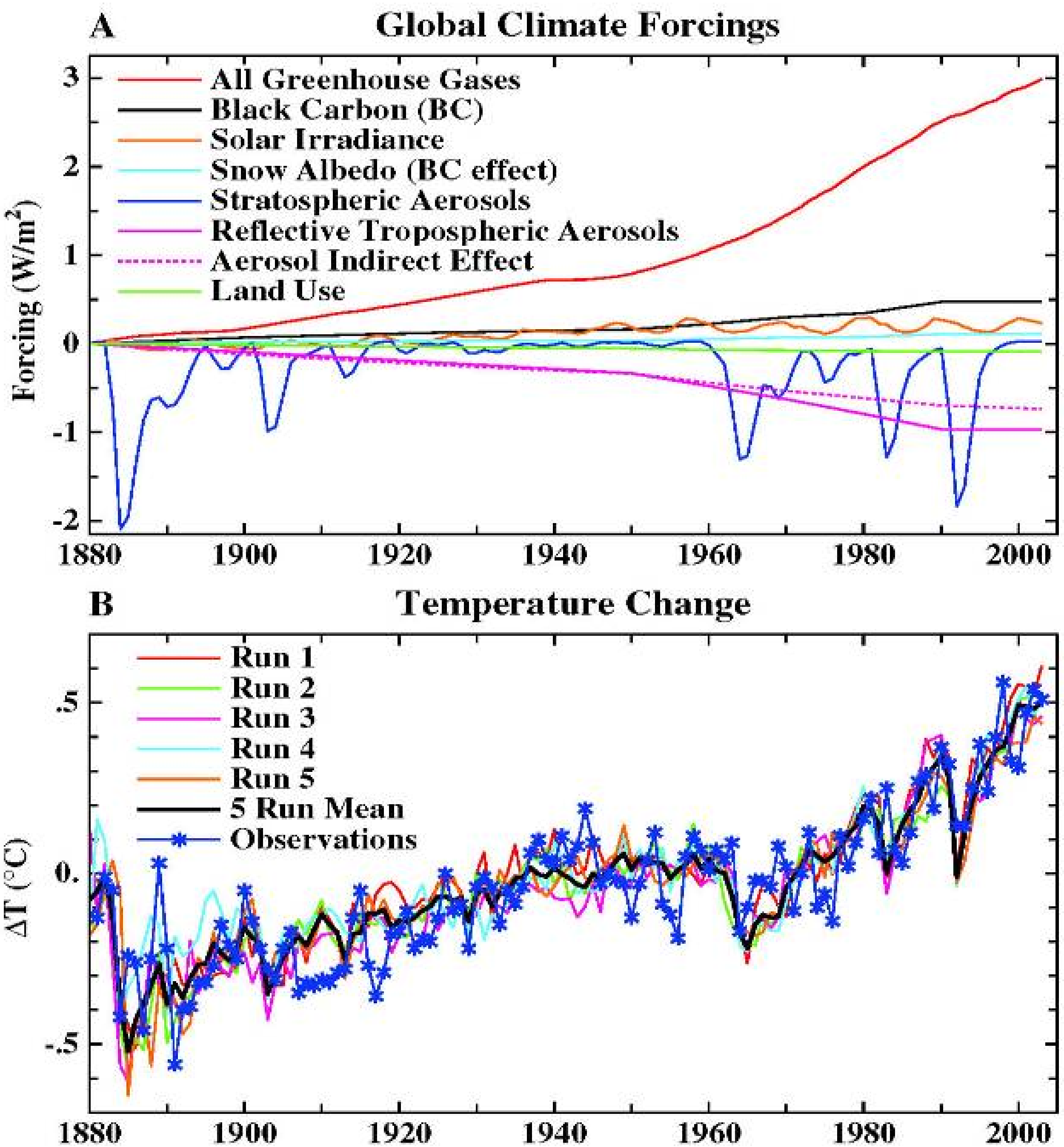
The Earth is getting warmer.



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

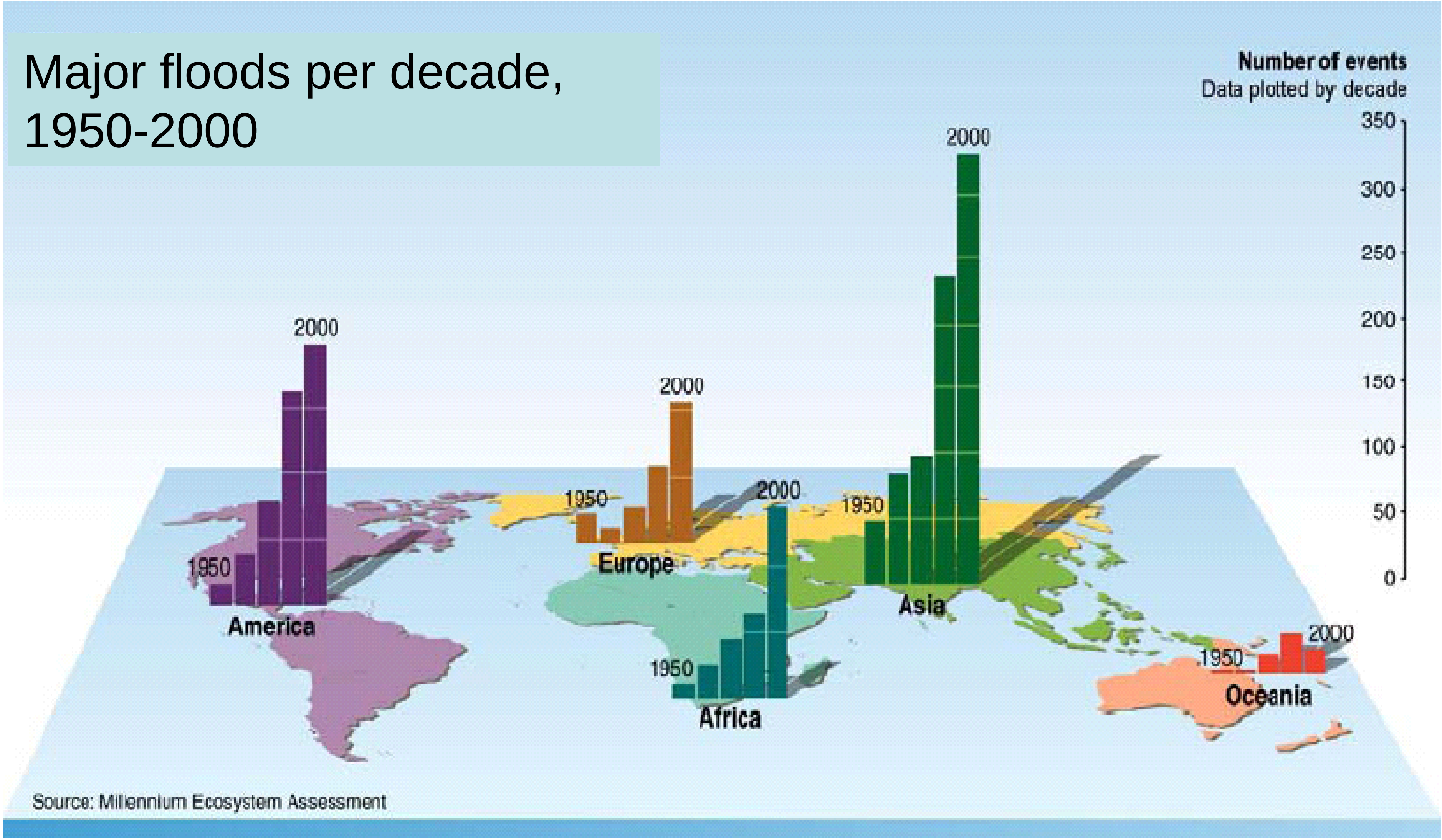
We know why. Current computer model with sensitivity ~0.75ºC per W/m^2, using best estimates of natural & human influences (A) as input, reproduces almost perfectly the last 125 years of observed temperatures (B).

Other “fingerprints” of GHG influence on climate also match observations.



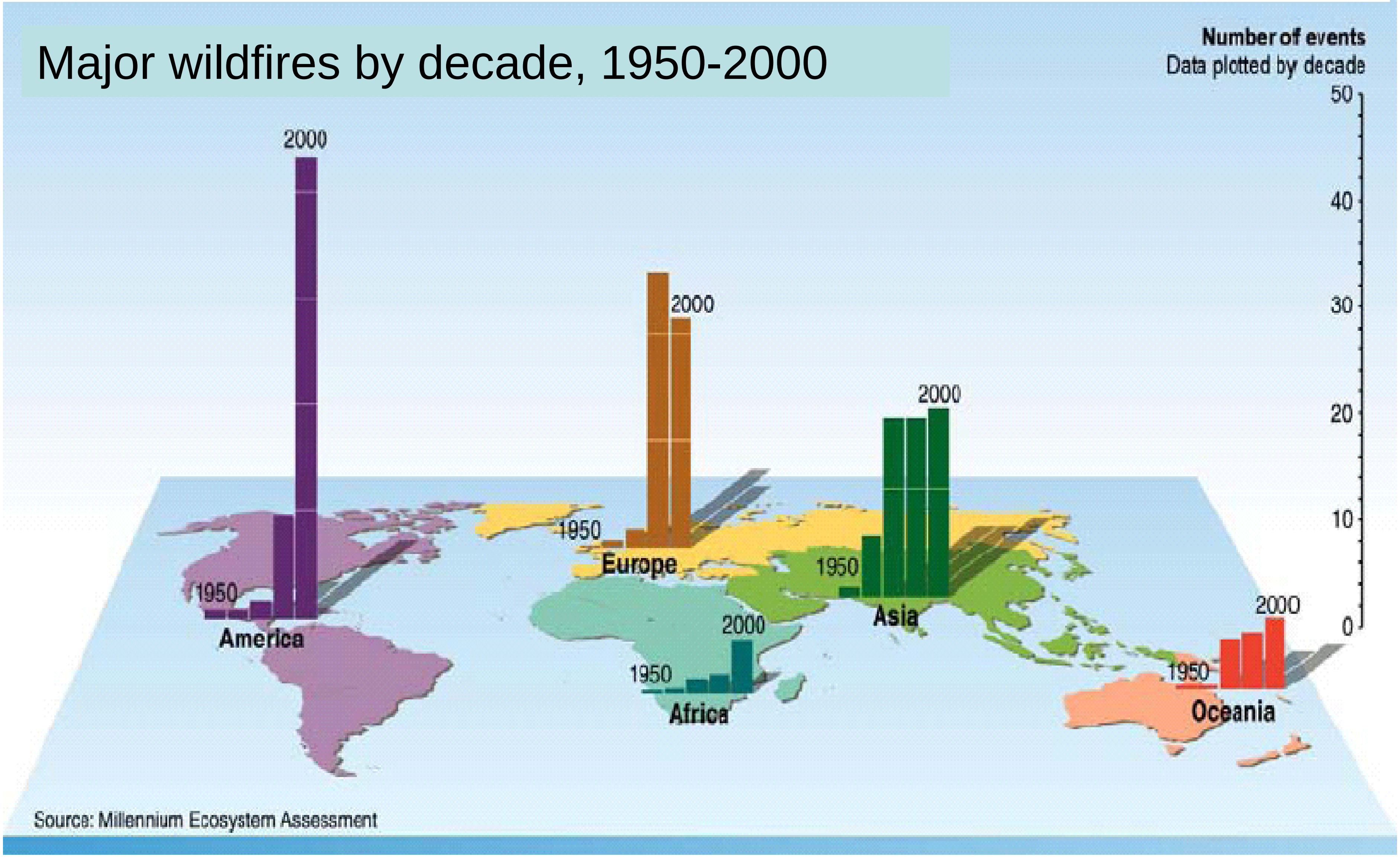
Source: Hansen et al., *Science 308*, 1431, 2005.

Changes in climate are already causing harm



There's a consistent 50-year upward trend in every region except Oceania.

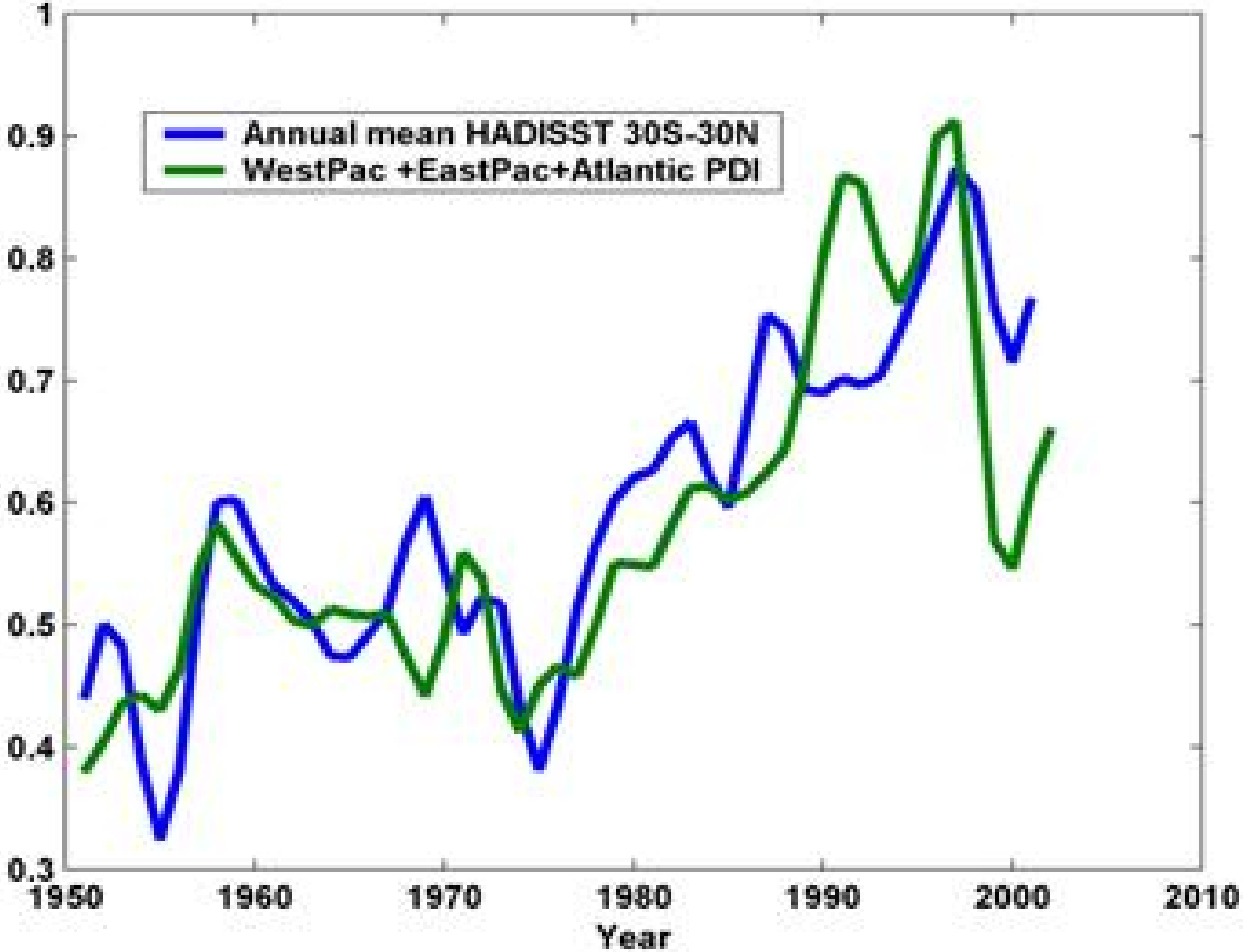
Harm is already occurring (continued)



The trend has been sharply upward everywhere.

Harm is already occurring (continued)

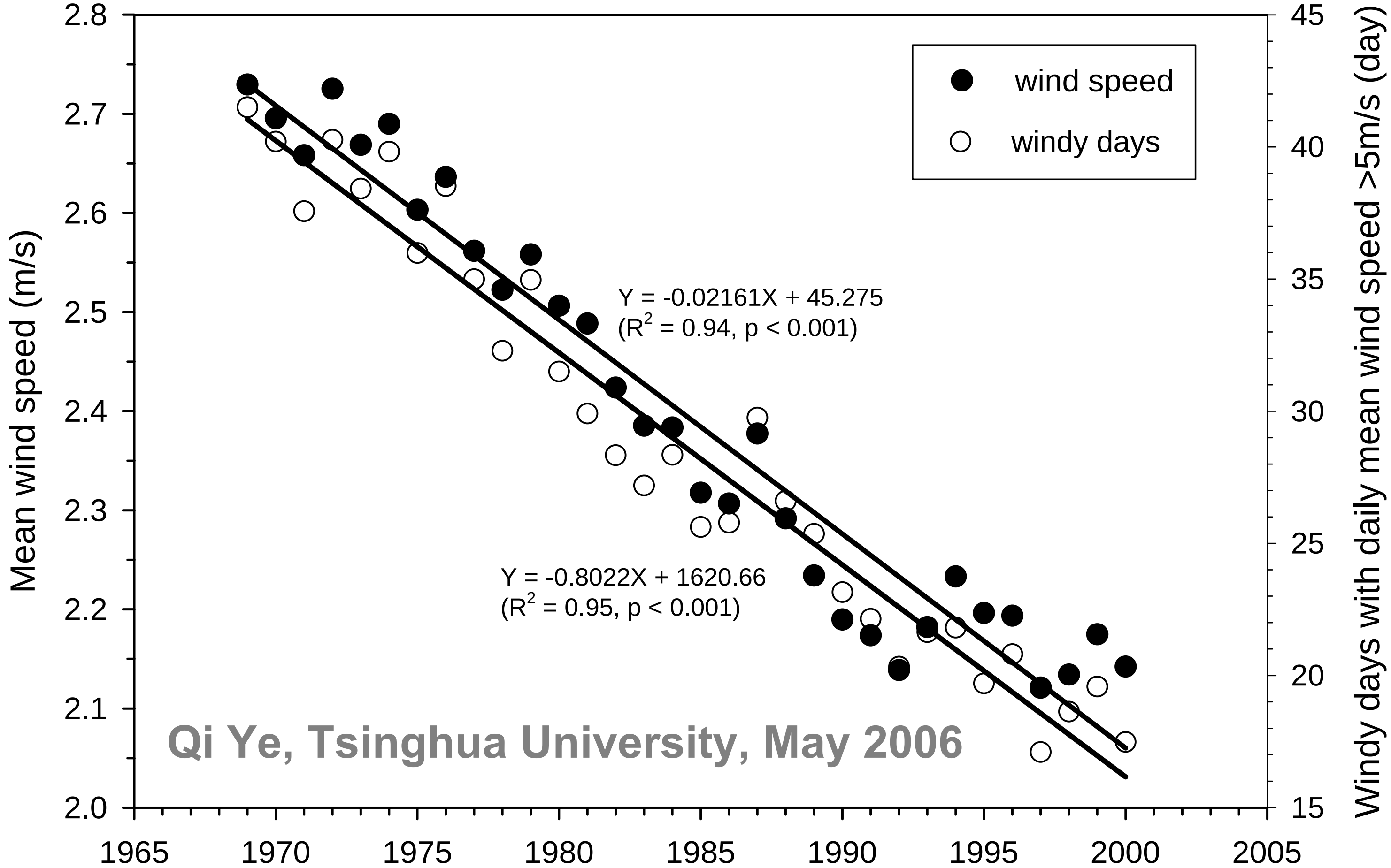
Total power released by tropical cyclones (green) has increased along with sea surface temperatures (blue).



Kerry Emanuel, MIT, 2006

Harm is already occurring (continued):

The East Asia monsoon is 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.

Harm is already occurring (concluded)

WHO estimates climate change already causing ≥150,000 premature deaths/yr in 2000

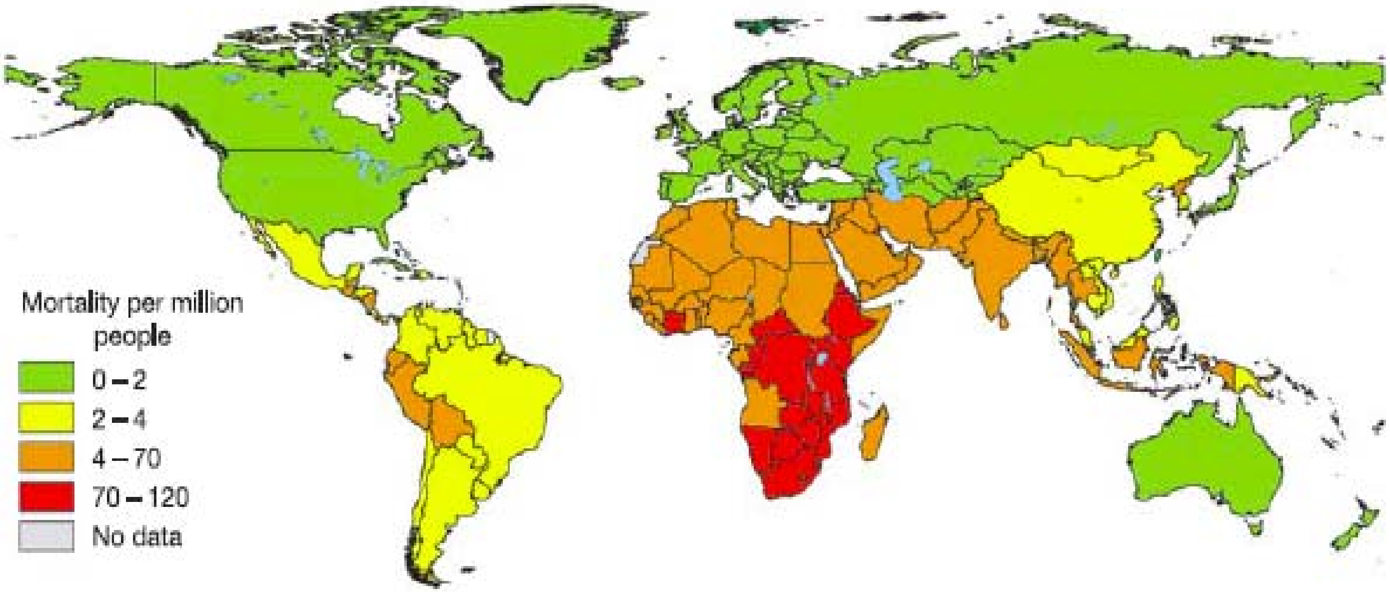
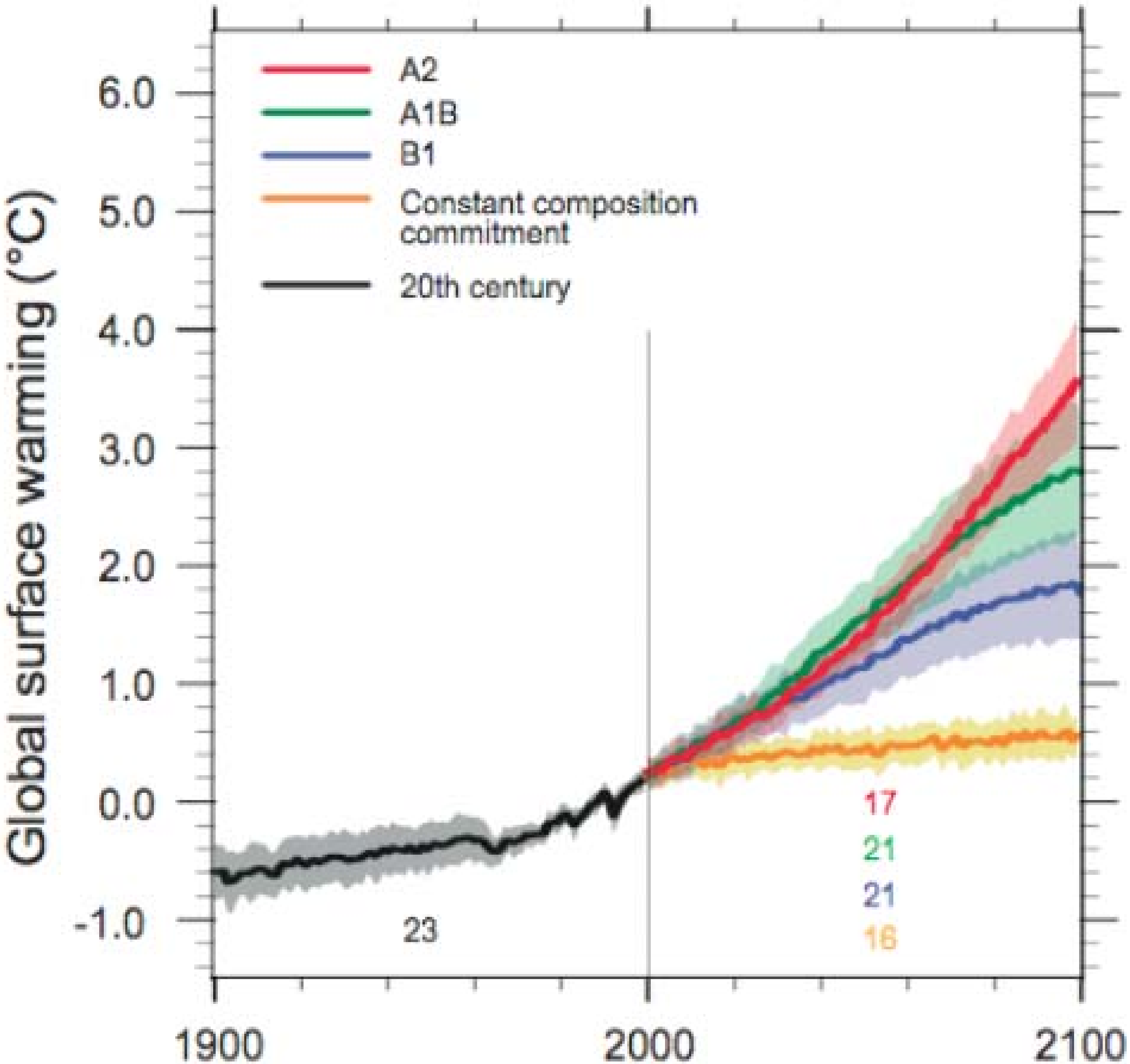


Figure 2 | WHO estimated mortality (per million people) attributable to climate change by the year 2000. The IPCC 'business as usual' greenhouse gas emissions scenario, 'IS92a' and the HadCM2 GCM of the UK Hadley Centre were used to estimate climate changes relative to 'baseline' 1961–1990 levels of greenhouse gases and associated climate conditions. Existing quantitative studies of climate–health relationships were used to estimate relative changes in a range of climate-sensitive health outcomes including: cardiovascular diseases, diarrhoea, malaria, inland and coastal flooding, and malnutrition, for the years 2000 to 2030. This is only a partial list of potential health outcomes, and there are significant uncertainties in all of the underlying models. These estimates should therefore be considered as a conservative, approximate, estimate of the health burden of climate change. Even so, the total mortality due to anthropogenic climate change by 2000 is estimated to be at least 150,000 people per year. Details on the methodology are contained in ref. 57.

Where we're headed: IPCC 2007 scenarios



Colored numbers below curves are nos. of climate models used for each scenario. Bands denote 1 standard deviation from the mean in these ensembles.

T reached in 2100 on middle trajectory was last seen on Earth in the Eocene (25-35 million years ago) when sea level was 20-30 m higher.

IPCC 2007

Where we're headed: Agriculture in the tropics

Crop yields in tropics start dropping at ∆T ≥ 1-1.5°C

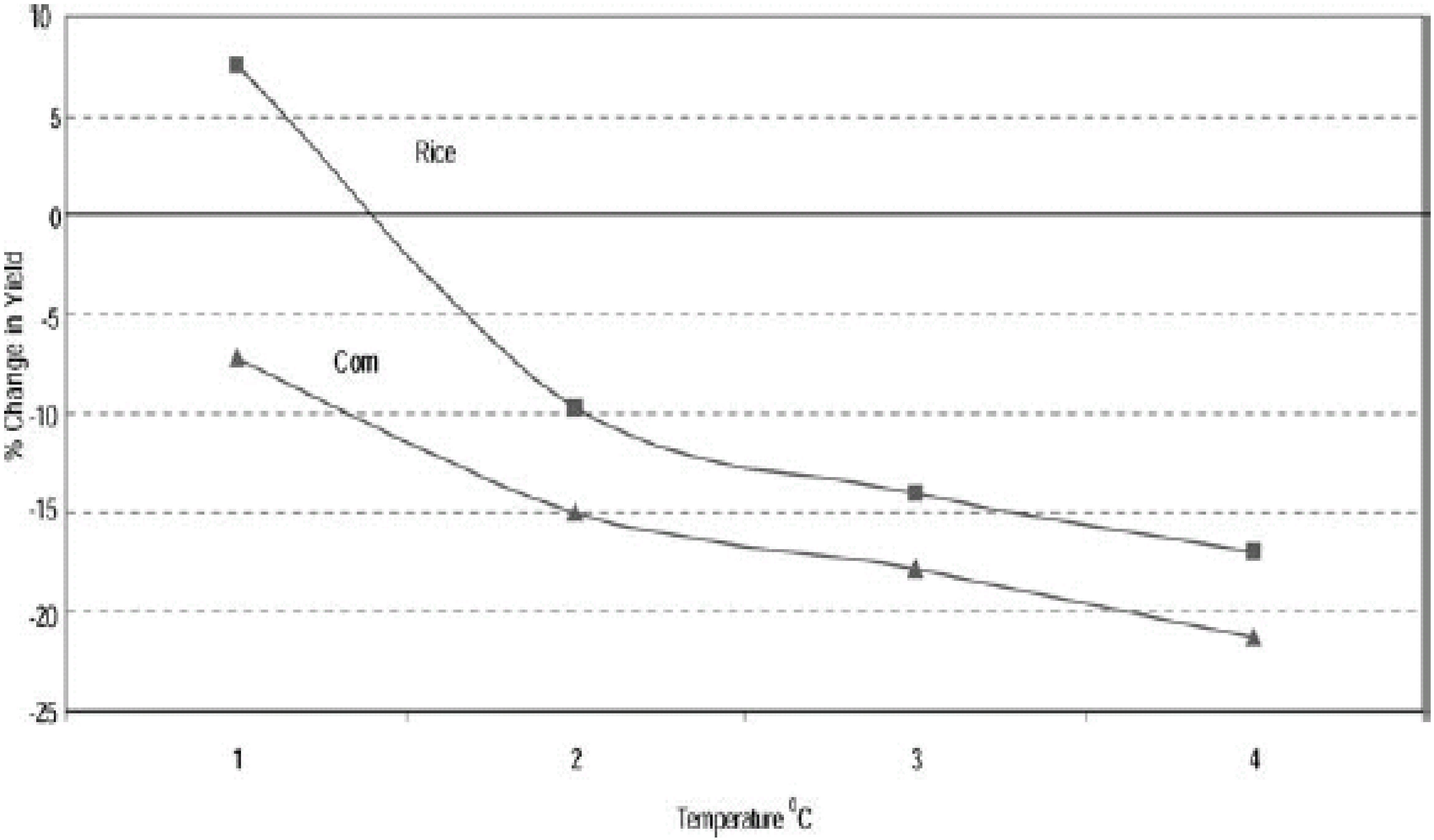
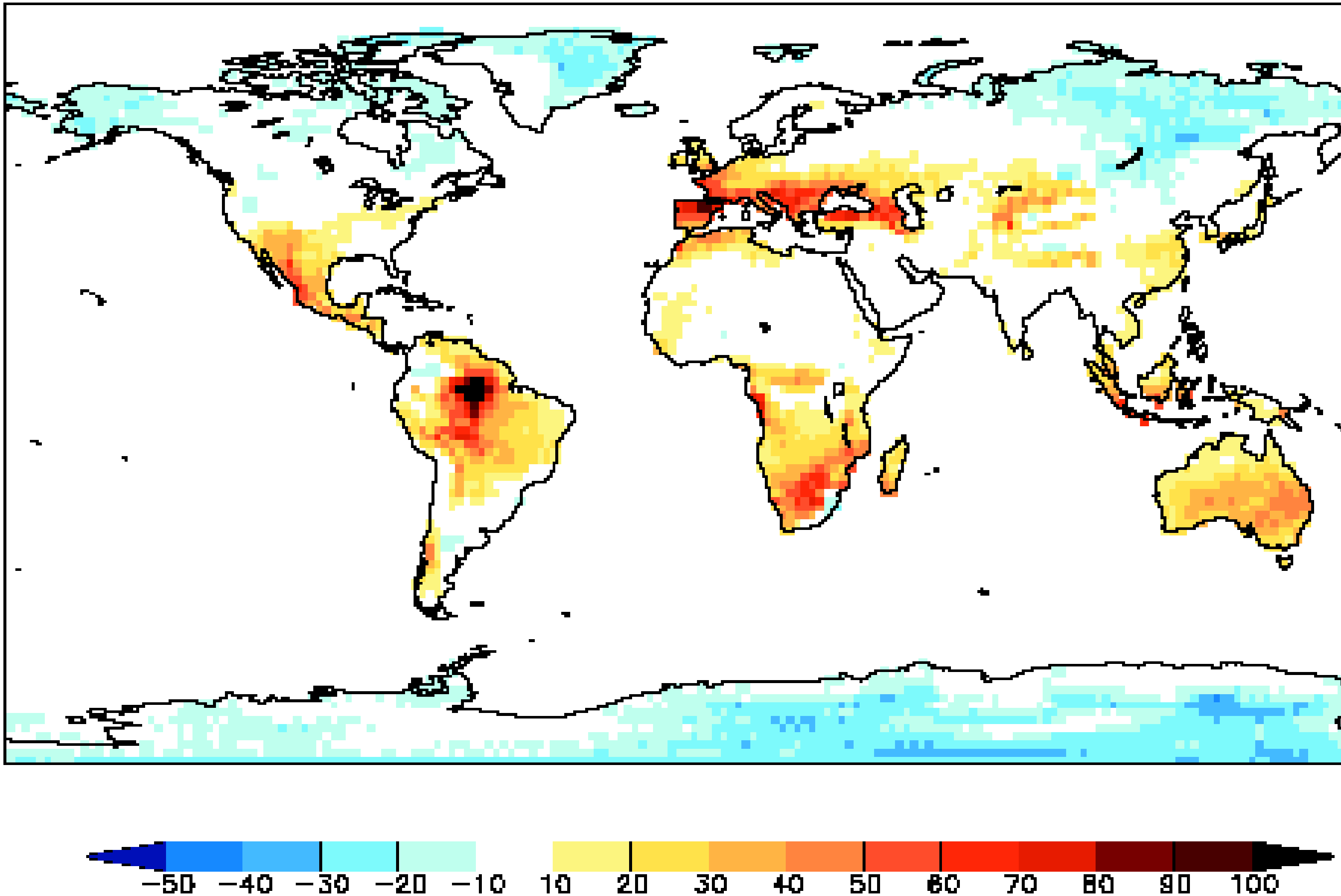


Figure 1. Corn and Rice yields versus temperature increase in the tropics averaged across 13 crop modeling studies. All studies assumed a positive change in precipitation. CO_2 direct effects were included in all studies.

Easterling and Apps, 2005

Where we're headed: droughts

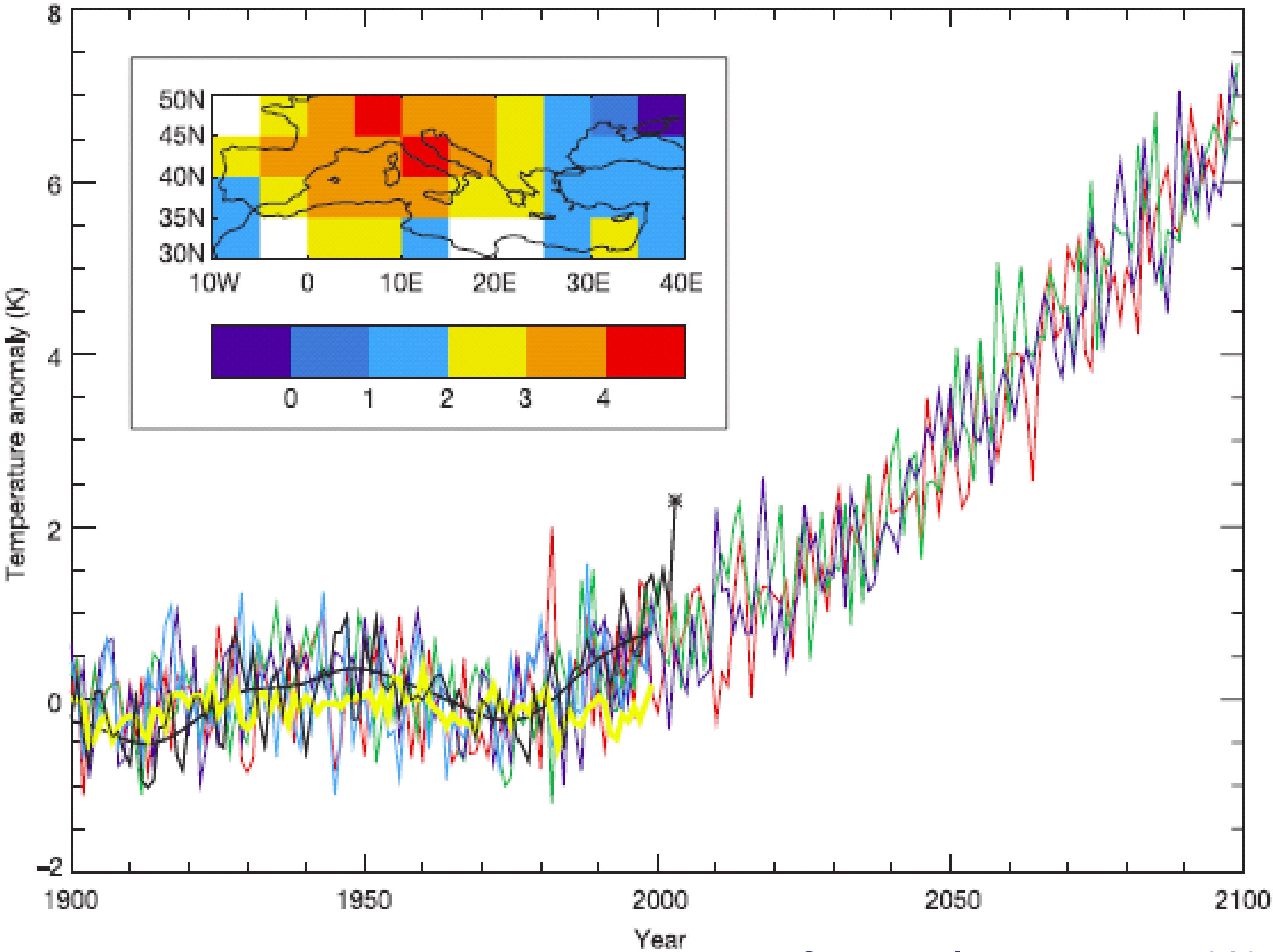
Drought projections for IPCC's A1B scenario



Percentage change in average duration of longest dry period, 30-year average for 2071-2100 compared to that for 1961-1990.

Where we're headed: Heat waves

Extreme heat waves in Europe, already 2X more frequent because of global warming, will be "normal" in mid-range scenario by 2050



Black lines are observed temps, smoothed & unsmoothed; red, blue, & green lines are Hadley Centre simulations w natural & anthropogenic forcing; yellow is natural only.

Asterisk and inset show 2003 heat wave that killed 35,000.

Stott et al., *Nature 432*: 610-613 (2004)

Where we're headed

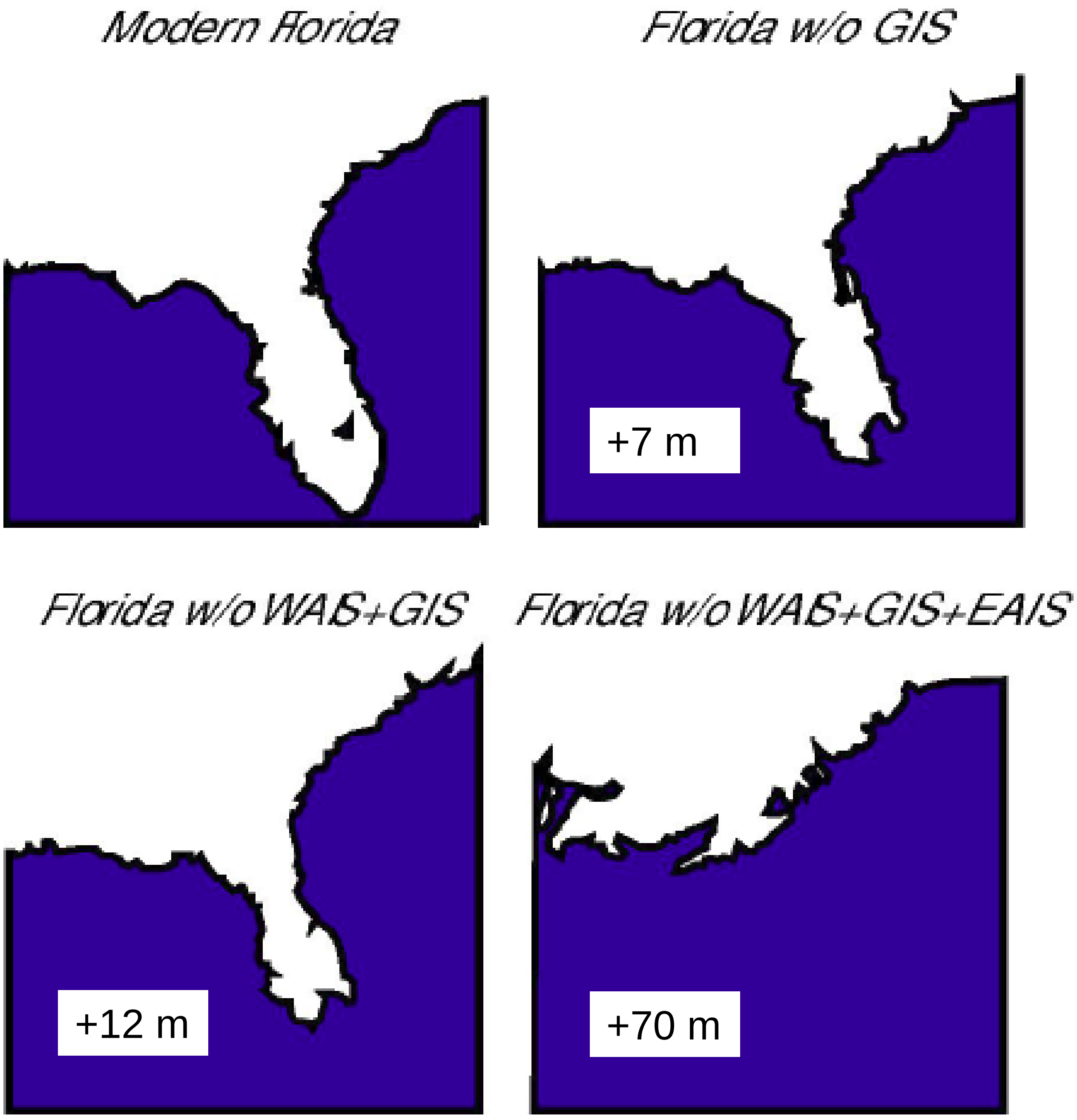
Melting the Greenland and Antarctic Ice Sheets would raise sea level up to 70 meters.

This would probably take 1000s of years, but rates of 2-5 m per century are possible.

GIS = Greenland Ice Sheet

WAIS = West Antarctic Ice Sheet

EAIS = East Antarctic Ice Sheet



Dr. Richard Alley, 2005

Faced with this challenge…

Society has three options:

- Mitigation, which means measures to reduce the pace & magnitude of the changes in global climate being caused by human activities.

    Examples of mitigation include reducing emissions of GHG, enhancing "sinks" for these gases, and "geoengineering" to counteract the warming effects of GHG.

- Adaptation, which means measures to reduce the adverse impacts on human well-being resulting from the changes in climate that do occur.

    Examples of adaptation include changing agricultural practices, strengthening defenses against climate-related disease, and building more dams and dikes.

- Suffering the adverse impacts that are not avoided by either mitigation or adaptation.

Facing the challenge (continued)

Mitigation and adaptation are both essential.

- Human-caused climate change is already occurring.
- Adaptation efforts are already taking place and must be expanded.
- But adaptation becomes costlier and less effective as the magnitude of climate changes grows.
- The greater the amount of mitigation that can be achieved at affordable cost, the smaller the burdens placed on adaptation and the smaller the suffering.

Mitigation options

CERTAINLY

- Reduce emissions of greenhouse gases & soot from the energy sector
- Reduce deforestation; increase reforestation & afforestation
- Modify agricultural practices to reduce emissions of greenhouse gases & build up soil carbon

CONCEIVABLY

- “Geo-engineering” to create cooling effects offsetting greenhouse heating
- “Scrub” greenhouse gases from the atmosphere technologically

Emissions from energy are 65% of the problem, above all CO_2 from fossil-fuel combustion

The emissions arise from a 4-fold product…

$$C = P \times GDP / P \times E / GDP \times C / E$$

where C = carbon content of emitted CO_2 (kilograms), and the four contributing factors are

P = population, persons

GDP / P = economic activity per person, $/pers

E / GDP = energy intensity of economic activity, GJ/$

C / E = carbon intensity of energy supply, kg/GJ

For example, in the year 2000, the world figures were…

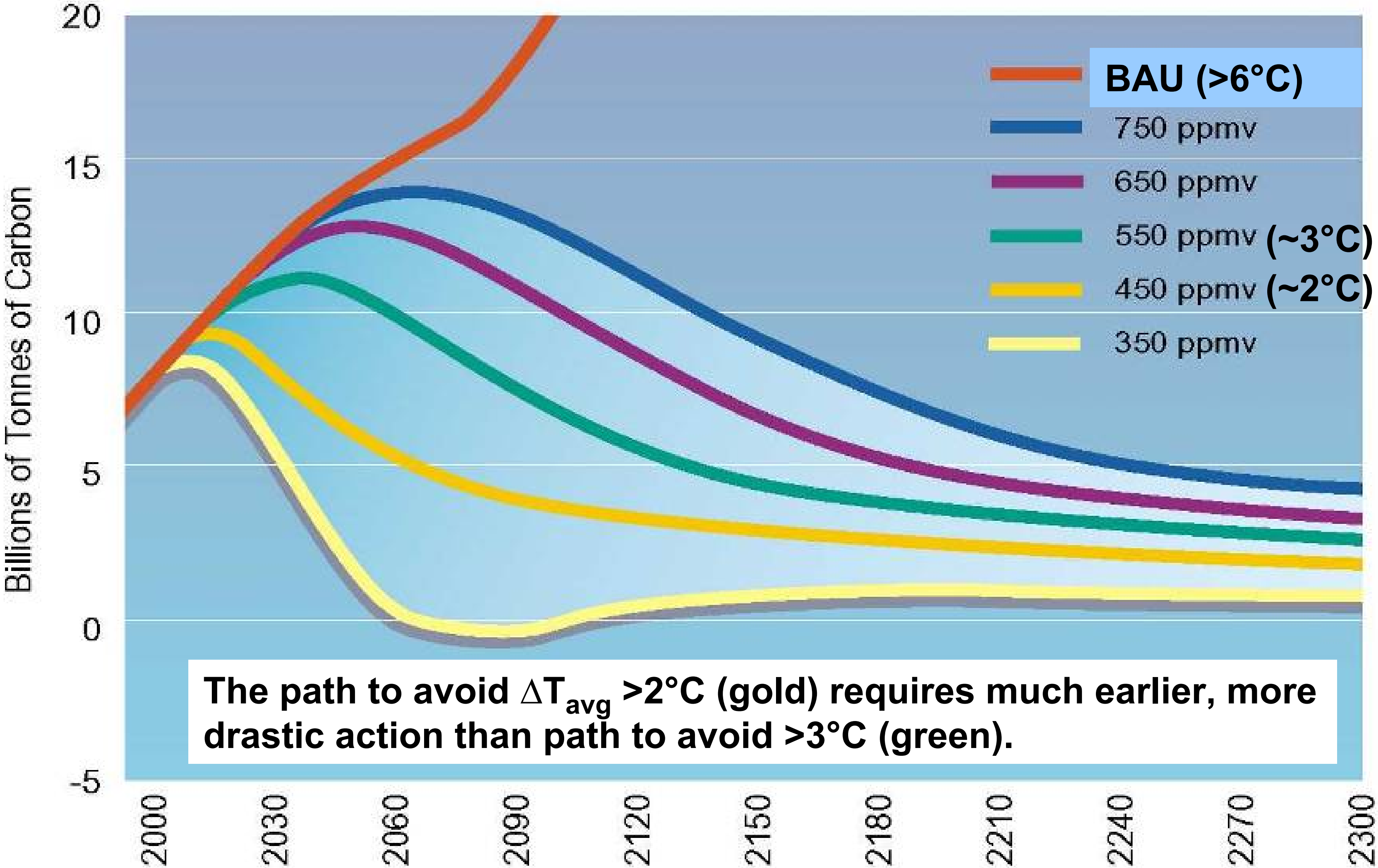
6.1×10^9 pers x $7400/pers x 0.01 GJ/$ x 14 kgC/GJ

= 6.4×10^{12} kgC = 6.4 billion tonnes C

Leverage on the four factors

- World population: lower is better for many reasons
- GDP/person: not a good lever, insofar as most people think higher is better
- Energy/GDP: can be lowered by increasing efficiency in power plants, vehicles, buildings, industry
- CO_2/energy: can be lowered mainly by…
  - substituting renewable (hydro, solar, wind, biomass, geothermal) and/or nuclear for fossil energy
  - deploying advanced fossil-fuel technology that can capture & store CO_2 rather than emitting it

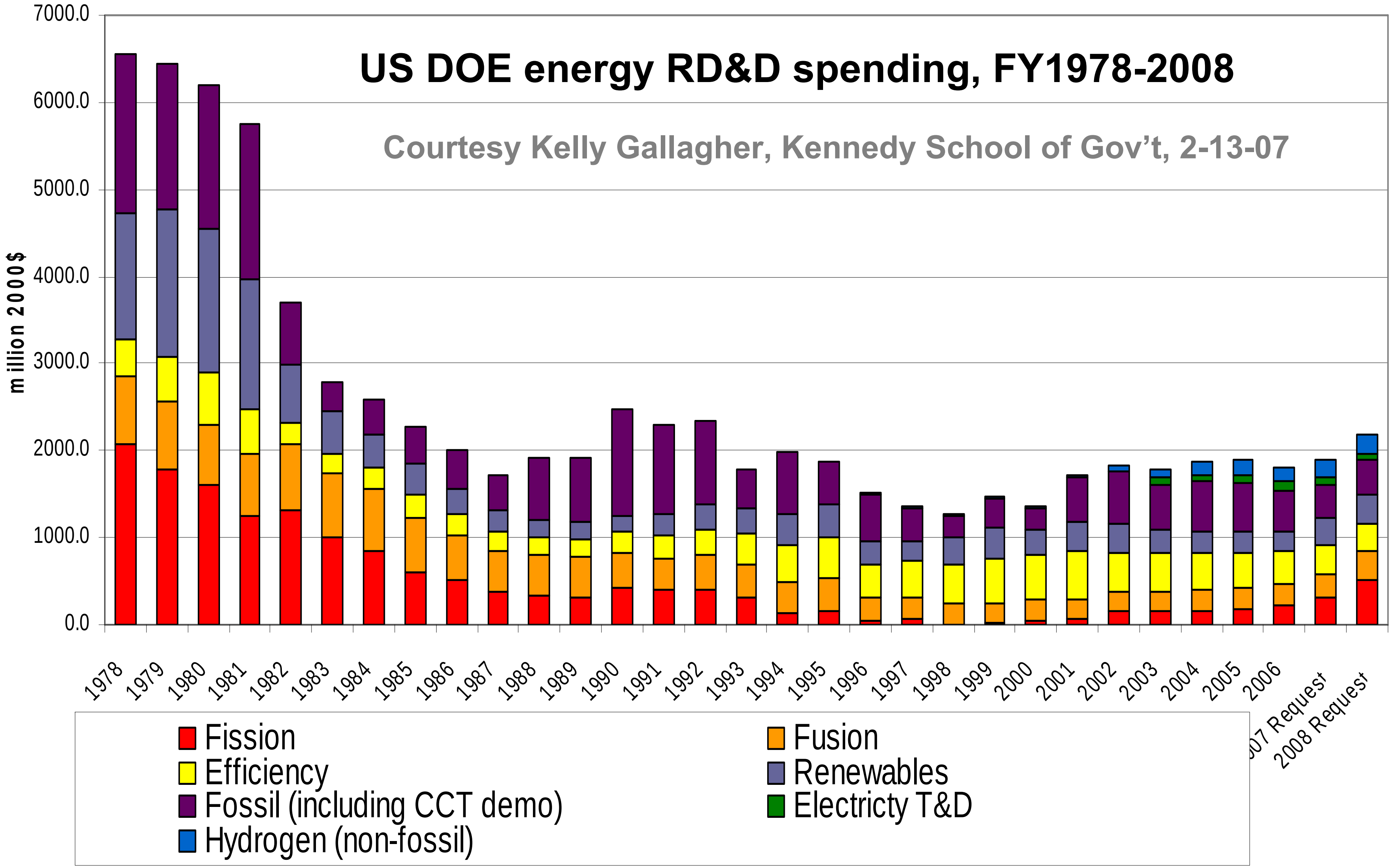
How hard must we pull the levers? Emission paths for stabilizing CO_2 concentrations to limit T increase



What needs to be done to get there?

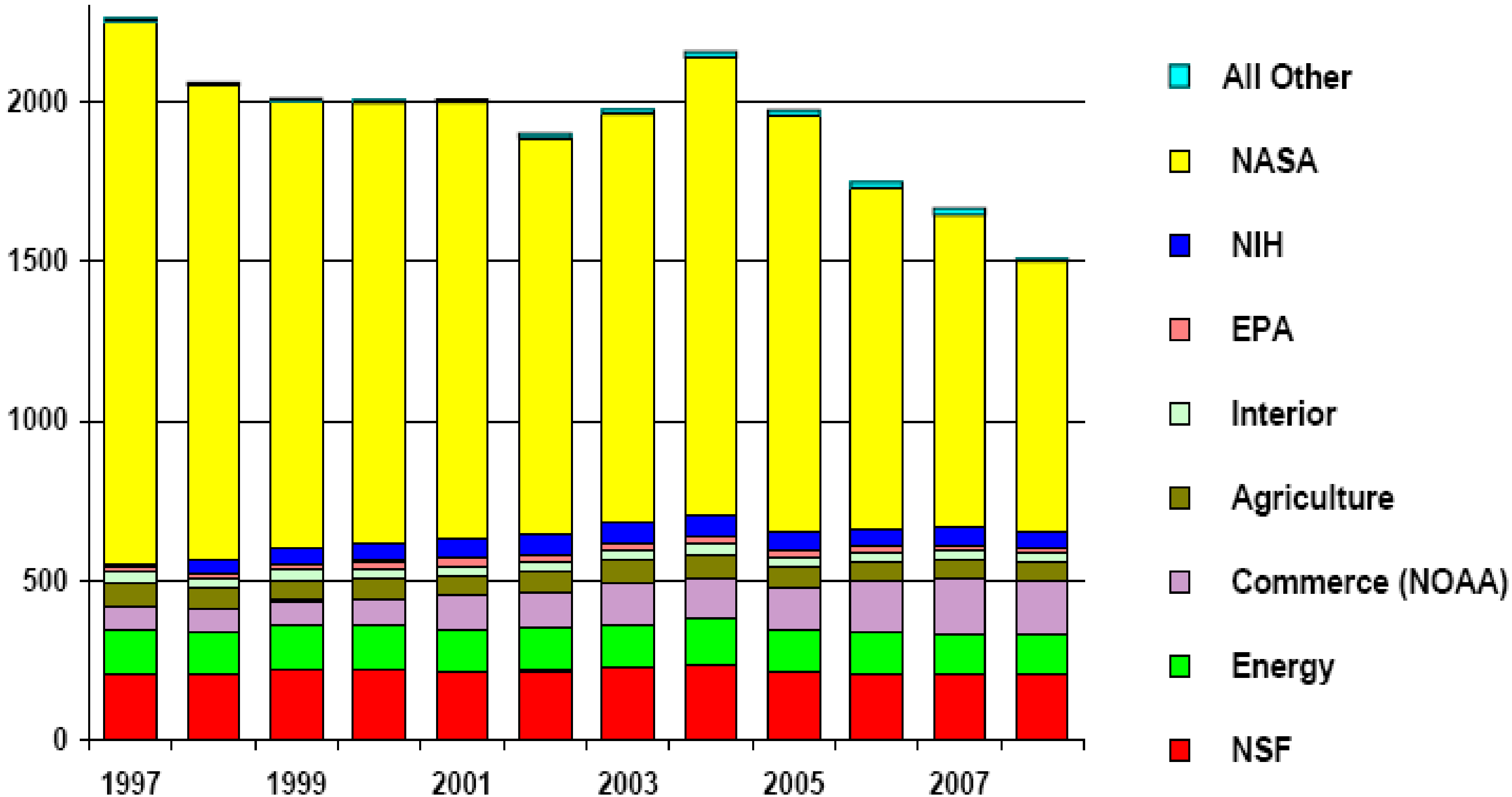
- Accelerate “win-win” technical and policy measures
- Put a price on carbon emissions so marketplace can work to find cheapest reductions
- Pursue a new global framework for mitigation and adaptation in the post-Kyoto period
- Increase investments in energy-technology research, development, demonstration
- Expand international cooperation on deploying advanced energy technologies

Increasing energy R&D should be the easiest part, but even that is not happening



Meanwhile, climate-change science is actually being cut!

Budget authority in constant FY2007$



Kei Kozumi, AAAS, 2-07

Moving toward a nuclear-weapon-free world

The legacy of Hiroshima

- August 6, 1945: city of Hiroshima the victim of the 1st nuclear weapon used in conflict; half the city vanishes; 140,000 killed.
- August 9, 1945: Nagasaki the victim of the 2nd; 75,000 killed.
- The two mushroom clouds punctuate the end of a world war unprecedented in scale, ferocity, destructiveness, but equally so in embrace of massive, systematic attacks on civilian populations as a legitimate, permissible means of waging war.
- The two nuclear bombings also provide underpinnings of post-war US security policy based on nuclear deterrence: nuclear weapons are usable tools of war; if pushed too far, USA might use them again.


Paul W. Tibbets
Col. USAF
Pilot: The Enola Gay

Nuclear-weapon-state postures, proliferation, and the prospects for nuclear terrorism prospects are intertwined

Maintaining the non-proliferation “bargain” requires that NWS take Article VI obligations seriously.

Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.

Non-Proliferation Treaty, Article VI, 1968

NWS postures, non-proliferation, & nuclear terrorism prospects are intertwined (continued)

- Evident intentions by NWS to
  - retain large arsenals indefinitely,
  - maintain high states of alert,
  - reserve “right” to use nuclear weapons first & against non-NWS
  - pursue development of new types of nuclear weapons for increased effectiveness or new purposes

  are all incompatible with the non-proliferation bargain and corrosive of the non-proliferation regime.

Nuclear weapons are held by a handful of states which insist that these weapons provide unique security benefits, and yet reserve uniquely to themselves the right to own them. This situation is highly discriminatory and thus unstable; it cannot be sustained. The possession of nuclear weapons by any state is a constant stimulus to other states to acquire them.

Canberra Commission on the Elimination of Nuclear Weapons, August 1995

NWS postures, non-proliferation, & nuclear terrorism prospects are intertwined (continued)

- Constraints on numbers & dispersion of nuclear weapons (strategic & nonstrategic) are essential
  - not just to reduce probability & consequences of accidental, erroneous, or unauthorized use
  - but also to reduce chances of weapons coming into hands of proliferant states and terrorists
- Proliferation itself expands opportunities (as well as incentives) for further proliferation and for terrorist acquisition of nuclear weapons
  - by putting nuclear weapons & nuclear-explosive materials into additional hands
  - and in contexts where there is little experience with protecting them.

Necessity of aiming for zero

- Ultimately, prohibition is the only alternative to proliferation
  - If possession does not tend toward zero, in the long run it will tend toward universality and the chances of use will tend toward unity.
- Prohibition is not only a practical but a legal and moral necessity.

There exists an obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament in all its aspects under strict and effective international control.

Unanimous Advisory Opinion of the International Court of Justice, July 1996

The committee has concluded that the potential benefits of a global prohibition of nuclear weapons are so attractive relative to the attendant risks that increased attention is now warranted to studying and fostering the conditions that would have to be met to make prohibition desirable and feasible.

Committee on International Security and Arms Control, US National Academy of Sciences, June 1997

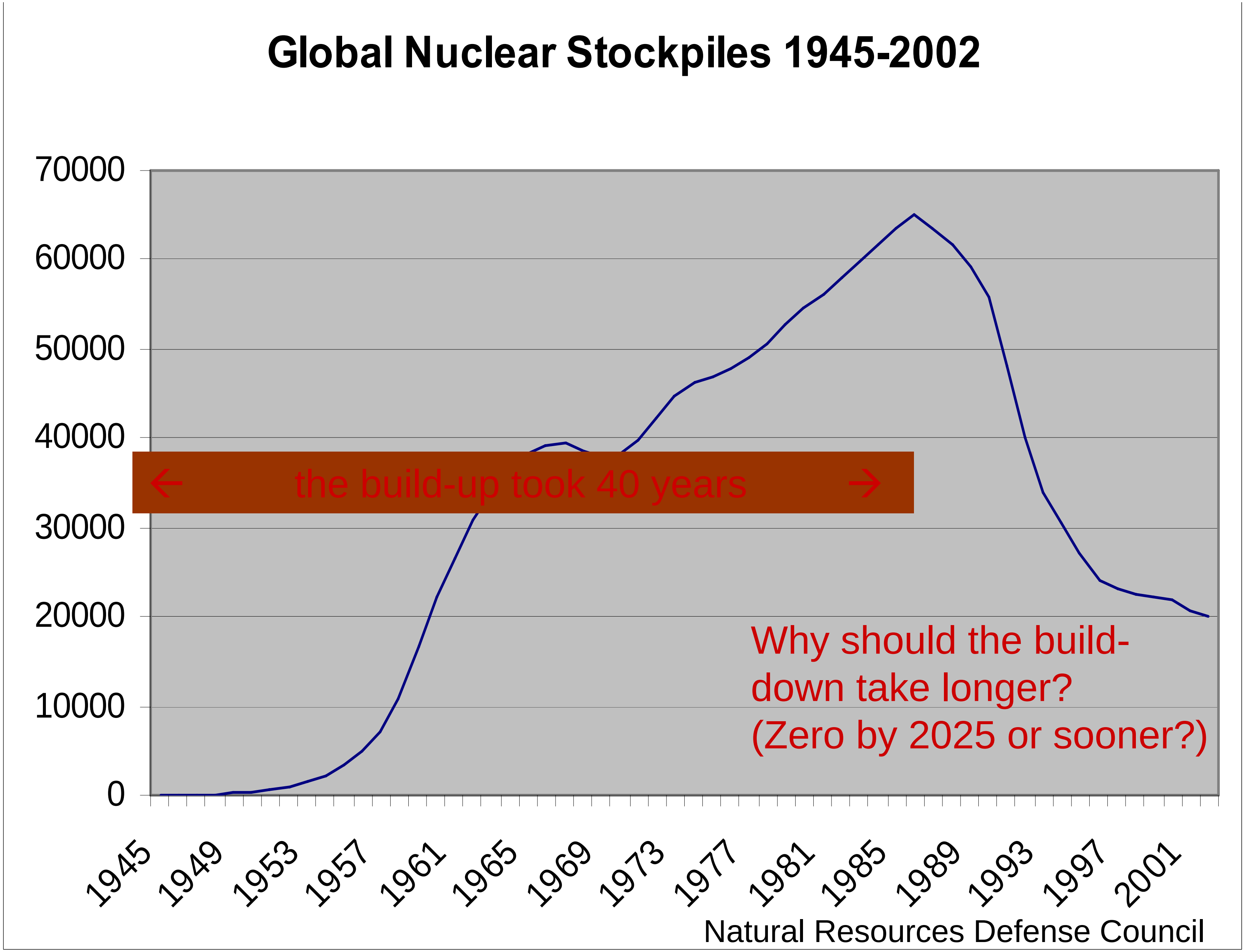
Feasibility of zero

- Prohibition does <u>not</u> require "un-inventing" nuclear weapons
  - We've productively prohibited murder, slavery, and chemical & biological weapons without imagining that these were being un-invented.
- Nor is verification an insurmountable obstacle
  - Verification (including "societal verification") can be better than most suppose.
  - Dangers from cheating are likely less than dangers to be expected if nuclear weapons are <u>not</u> prohibited.

The Feasibility of Zero (continued)

- There would be challenges & risks in a world of zero.
- But they would be far smaller than the dangers of a world in which nuclear weapons are permitted and thus, inevitably, widespread.

Aiming for zero: build-down following build-up



We endorse setting the goal of a world free of nuclear weapons and working energetically on the actions required to achieve that goal…

George Schultz, Henry Kissinger,
William Perry, and Sam Nunn,
Wall Street Journal, 1-06-07

What more is needed to address the challenges discussed here?

- A stronger focus by scientists and technologists on the largest threats to the human condition.
- Greater emphasis on analyses of threats and remedies by teams that are interdisciplinary, intersectoral, and international.
- Undergraduate education and graduate training better matched to these tasks.
- More attention to interactions among threats and to remedies that address multiple threats at once.
- Larger and more coordinated investments in advances in science and technology that meet key needs at lower cost with smaller adverse side effects.
- Clearer and more compelling arguments to policy-makers about the threats and the remedies.
- Increased public S&T literacy.

What is the AAAS doing?

AAAS Programs

Science & Policy

- Center for Science, Technology & Congress
- Center for Science, Technology & Security Policy
- Dialogue on Science, Ethics & Religion
- Fellowships for Scientists & Engineers
- R&D Budget Analysis
- Research Competitiveness
- Science & Human Rights
- Scientific Freedom, Responsibility & Law

Education

- Schools, Teachers, & Librarians
- Children, Families, & Communities
- Higher Education Research, Resources, & Policy
- Science for the Public
- Careers for All & Workforce Development

International Initiatives

- Sustainable Development
- International Cooperation
- Women's Collaboration
- Human Rights

Project 2061

- About Project 2061
- Learning Goals
- Curriculum Materials
- Research on Teaching & Learning
- Testing & Assessment
- Family & Community

AAAS Centers

- Center for Advancing Science and Engineering Capacity
- Center for Careers in Science and Technology
- Center for Curriculum Materials in Science
- Center for Public Engagement with Science and Technology
- Center for Science, Technology, and Congress
- Center for Science, Technology, and Security Policy
- Center for Science, Innovation, and Sustainability

The Association's journal, SCIENCE, is the place to go for cutting-edge insights about the science-society interface.

Science Magazine

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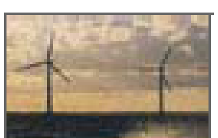
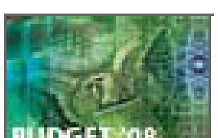


Special Issue: Sustainability and Energy ›
A collection of News and Perspective articles looks at the challenges of harnessing renewable energy and some of the people who are tacking these problems.



Science in the Budget ›
Pledging support to a few agencies that support physical sciences, but major cuts for the NIH, the proposed 2008 U.S. science budget is getting a decidedly mixed reception.

SCIENCE PODCAST

Our 02/09 show is all about sustainability and energy, with interviews on clean-energy science, R&D budgets, and policy.

Listen to the 02/09 show [MP3]

What can individual scientists and technologists do?

- Read more and think more about fields and problems outside your normal area of specialization.
- Improve your communication skills for conveying the relevant essence of your understandings to members of the public and to policy makers.
- Seek out avenues for doing so.
- “Tithe” ten percent of your professional time and effort to working to increase the benefits of S&T for the human condition and decrease the liabilities.

- For more about the work of the AAAS, please see

  http://www.aaas.org

- For more about work on these issues at Harvard University, please see

  http://bcsia.ksg.harvard.edu/?program=STPP

- For more about work on these issues at the Woods Hole Research Center, please see

  http://www.whrc.org